ESE

Mechanical Engineering

(Previous Years Solved Papers 1995-1999)

Objectives (Volume-II)

Contents

MADE EASY PUBLICATIONS

UNIT

I

Strength of Materials and Engineering Mechanics

Syllabus

Analysis of System of Forces, Friction, Centroid and Centre of Gravity, Dynamics; Stresses and Strains-Compound Stresses and Strains, Bending Moment and Shear Force Diagrams, Theory of Bending Stresses-Slope and deflection-Torsion, Thin and thick Cylinders, Spheres.

Contents

1 Stress and Strain

1.1 The stretch in a steel rod of circular section, having a length L subjected to a tensile load P and tapering uniformly from a diameter d_1 at one end to a diameter d_2 at the other end, is given by

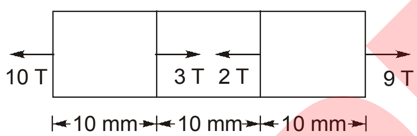
(a) $\frac{PL}{4Ed_1d_2}$ (b) $\frac{PL\pi}{Ed_1d_2}$

(c) $\frac{PL\pi}{4Ed_1d_2}$ (d) $\frac{4PL}{\pi Ed_1d_2}$ **[ESE : 1995]**

1.2 The total extension of the bar loaded as shown in the figure is

A = area of cross-section

E = modulus of elasticity

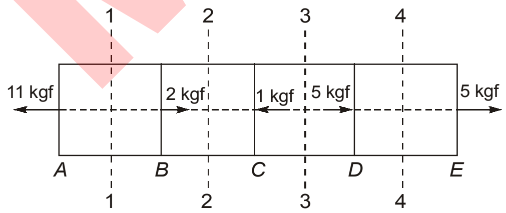


(a) $10 \times 30/AE$ (b) $26 \times 10/AE$

(c) $9 \times 30/AE$ (d) $30 \times 22/AE$

[ESE : 1995]

1.3 A bar of uniform cross-section of one sq. cm is subjected to a set of five forces as shown in the given figure, resulting in its equilibrium. That maximum tensile stress (in kgf/cm^2) produced in the bar is



(a) 1 (b) 2

(c) 10 (d) 11

[ESE : 1997]

1.4 For a composite bar consisting of a bar enclosed inside a tube of another material and when compressed under a load W as a whole through rigid plates at the end of the bar. The equation of compatibility is given by (suffixes 1 and 2 refer to bar and tube respectively)

(a) $W_1 + W_2 = W$

(b) $W_1 + W_2 =$ Constant

(c) $\frac{W_1}{A_1E_1} = \frac{W_2}{A_2E_2}$

(d) $\frac{W_1}{A_1E_2} = \frac{W_2}{A_2E_1}$

[ESE : 1998]

1.5 A tapering bar (diameter of end sections being, d_1 and d_2) and a bar of uniform cross-section 'd' have the same length and are subjected the same axial pull. Both the bars will have the same extension if 'd' is equal to

(a) $\frac{d_1 + d_2}{2}$ (b) $\sqrt{d_1d_2}$

(c) $\sqrt{\frac{d_1 + d_2}{2}}$ (d) $\sqrt{\frac{d_1 - d_2}{2}}$

[ESE : 1998]

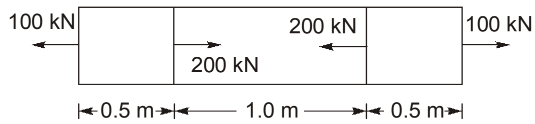
1.6 The deformation of a bar under its own weight as compared to that when subjected to a direct axial load equal to its own weight will be

(a) the same (b) one fourth

(c) half (d) double

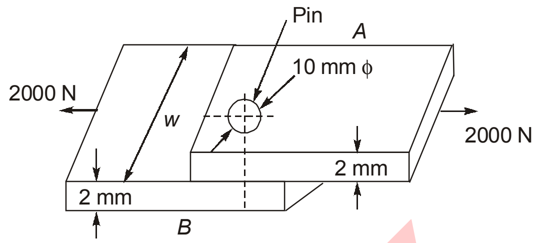
[ESE : 1998]

1.7 A slender bar of 100 mm^2 cross-section is subjected to loading as shown in the figure below. If the modulus of elasticity is taken as 200×10^9 Pa, then the elongation produced in the bar will be



(a) 10 mm (b) 5 mm
(c) 1 mm (d) nil [ESE : 1998]

1.8 If permissible stress in plates of joint through a pin as shown in the figure is 200 MPa, then the width *w* will be



(a) 15 mm (b) 20 mm
(c) 18 mm (d) 25 mm [ESE : 1999]

Answers Stress and Strain

1.1 (d) 1.2 (b) 1.3 (d) 1.4 (c) 1.5 (b) 1.6 (c) 1.7 (d) 1.8 (a)

Explanations Stress and Strain

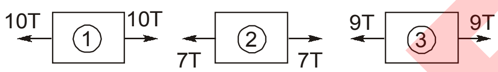
1.1 (d)

Deflection of circular tapering rod subjected to tensile load *P*. is

$$\delta L = \frac{4PL}{\pi d_1 d_2 E}$$

1.2 (b)

F.B.D



$$(\delta l)_{total} = (\delta l)_1 + (\delta l)_2 + (\delta l)_3$$

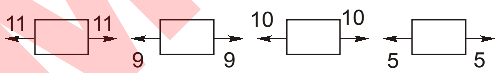
$$= \frac{P_1L_1}{AE} + \frac{P_2L_2}{AE} + \frac{P_3L_3}{AE}$$

$$= \frac{10\times 10}{AE} + \frac{7\times 10}{AE} + \frac{9\times 10}{AE}$$

$$= \frac{26\times 10}{AE}$$

1.3 (d)

F.B.D



Maximum tensile force = 11 kg.f

$$\text{Maximum tensile stress} = \frac{11}{1\times 1} = 11 \text{ kgf/cm}^2$$

1.4 (c)

$(\text{Strain})_1 = (\text{Strain})_2$

$$\therefore \frac{W_1}{A_1E_1} = \frac{W_2}{A_2E_2}$$

1.5 (b)

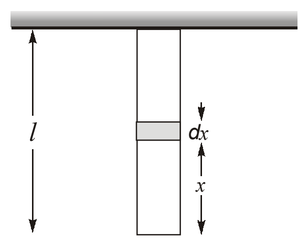
$$\Delta l = \frac{4Pl}{E\pi d_1 d_2} = \frac{Pl}{E\left(\frac{\pi d_1 d_2}{4}\right)} = \frac{Pl}{E\times \text{Area}}$$

$$\therefore \text{Area} = \frac{\pi}{4}(d_{eq})^2 = \frac{\pi}{4}d_1 d_2$$

$$\therefore \boxed{d_{eq} = \sqrt{d_1 d_2}}$$

1.6 (c)

Deformation under own weight



consider a small strip '*dx*' at a distance '*x*' as shown in figure. We shall find change in length for '*dx*' and then integrate for whole length. Force exerted by weight below strip '*dx*'

Force (*P*) = Volume below '*dx*' × specific weight

$= A\,x\,\gamma$ (*A* = cross – sectional area)

Elongation of the strip

$$(\delta l)_{dx} = \frac{(Ax\gamma)dx}{A\times E} \quad \begin{bmatrix}\text{Load} = Ax\rho \\ \text{Length} = dx\end{bmatrix}$$

$$(\delta l)_{dx} = \frac{\gamma x\,dx}{E}$$

For total elongation integrate and take limits

$$\delta l = \int_0^l \frac{\gamma}{E} x\,dx = \frac{\gamma}{E}\left(\frac{x^2}{2}\right)_0^l$$

$$\delta l = \frac{\gamma l^2}{2E} \quad \text{...(i)}$$

Now elongation due to load (W)

$$\delta l = \frac{Wl}{AE}$$

Load = Own weight (given)

$$W = \gamma l A$$

$$\therefore \quad A = \frac{W}{\gamma l}$$

$$\therefore \quad (\delta l)_2 = \frac{\gamma l^2}{E} \quad \text{...(ii)}$$

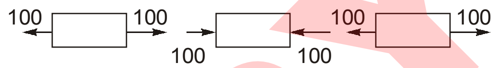
Now from Equation (i) and (ii)

$$\frac{\delta l}{\delta l_2} = \frac{1}{2}$$

$$\therefore \quad \boxed{\delta l = \delta l_2 / 2}$$

1.7 (d)

F.B.D.



$$\text{Total elongation } \delta = \frac{PL}{AE}$$

$$= \frac{1}{AE}(100 \times 0.5 - 100 \times 1 + 100 \times 0.5) = 0$$

1.8 (a)

$$A \times \sigma = F$$

$$(W - 10) \times 2 \times 200 = 2000$$

$$\therefore \quad W - 10 = 5$$

$$\therefore \quad W = 15 \text{ mm}$$

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2 Stress-strain Relationship and Elastic Constants

2.1 If Poisson's ratio of a material is 0.5, then the elastic modulus for the material is
(a) three times its shear modulus
(b) four times its shear modulus
(c) equal to its shear modulus
(d) indeterminate **[ESE : 1995]**

2.2 The relationship between the Lame's constant λ, Young's modulus E and the Poisson's ratio μ is

(a) $\lambda = \dfrac{E\mu}{(1+\mu)(1-2\mu)}$ (b) $\lambda = \dfrac{E\mu}{(1+2\mu)(1-\mu)}$

(c) $\lambda = \dfrac{E\mu}{(1+\mu)}$ (d) $\lambda = \dfrac{E\mu}{(1-\mu)}$

[ESE : 1997]

2.3 The number of independent elastic constants required to express the stress-strain relationship for a linearly elastic isotropic material is
(a) one (b) two
(c) three (d) four **[ESE : 1998]**

2.4 The number of elastic constants for a completely anisotropic elastic material is
(a) 3 (b) 4
(c) 21 (d) 25 **[ESE : 1999]**

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Answers Stress-strain Relationship and Elastic Constants

2.1 (a) **2.2** (a) **2.3** (b) **2.4** (c)

Explanations Stress-strain Relationship and Elastic Constants

2.1 (a)

$E = 2G(1+\mu)$

put $\mu = 0.5$

$\therefore$ $E = 2G(1 + 0.5) = 3G$

2.3 (b)

By Hooke's law

E and μ, Young's modulus and Poisson's ratio

2.4 (c)

Type of Material	Number of Independent elastic constant
1. Isotropic and homogeneous	2 (E, ν)
2. Orthotropic	9
3. Anistropic	21

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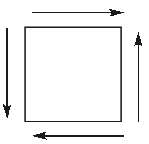
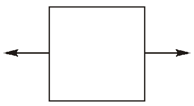
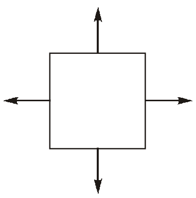
3 Principal Stresses and Strains and Mohr's Circle

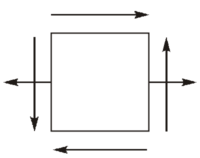
3.1 Match **List-I** (State of stress) with **List-II** (Kind of loading) and select the correct answer using the codes given below the lists:

List-I

A. 

B. 

C. 

D. 

List-II

1. Combined bending and torsion of circular shaft.
2. Torsion of circular shaft.
3. Thin cylinder subjected to internal pressure.
4. Tie bar subjected to tensile force.

Codes:

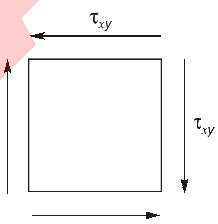
	A	B	C	D
(a)	1	2	3	4
(b)	2	3	4	1
(c)	2	4	3	1
(d)	3	4	1	2

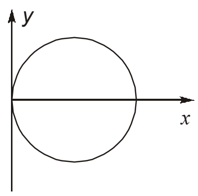
[ESE : 1995]

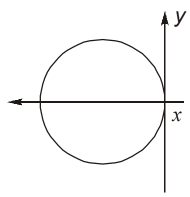
3.2 Consider the following statements.
State of stress at a point when completely specified, enables one to determine the
1. Principal stresses at the point
2. Maximum shearing stress at the point
3. Stress components on any arbitrary place containing the point

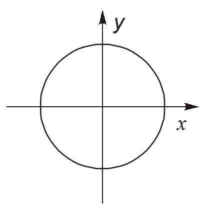
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 3
(c) 2 and 3 (d) 1 and 2 **[ESE : 1996]**

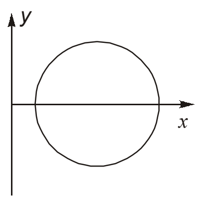
3.3 State of stress at a point in a strained body is shown in figure. Which one of the figure given below represents correctly the Mohr's circle for the state of stress?



(a) 

(b) 

(c) 

(d) 

[ESE : 1996]

3.4 Consider the following statements:
State of stress in two dimensions at a point in a loaded component can be completely specified by indicating the normal and shear stresses on
1. a plane containing the point
2. any two planes passing through the point
3. two mutually perpendicular planes passing through the point

Which of these statements is/are correct?
(a) 1 and 3 (b) 2 only
(c) 1 only (d) 3 only **[ESE : 1998]**

Answers Principal Stresses and Strains and Mohr's Circle

3.1 (c) **3.2** (a) **3.3** (c) **3.4** (d)

Explanations Principal Stresses and Strains and Mohr's Circle

3.1 (c)

Diagram $A \rightarrow$ Only shear stress is acting i.e. circular shaft subjected to torsion.

Diagram $B \rightarrow$ Only tensile stress is acting i.e. tie bar is subjected to tensile force.

Diagram $C \rightarrow$ Hoop stress and longitudinal stress are acting.

Diagram $D \rightarrow$ Shear stress as well as normal stress is acting therefore circular shaft is subjected to combined bending and torsion.

3.2 (a)

State of stress at a point when completely specified, enables one to determine the principal stresses at the point, maximum shearing stress at the point and stress components on any arbitrary plane containing the point.

3.3 (c)

Since neither tensile nor compressive stress exists, the Mohr's diagram is simply a circle of radius τ_{xy} and centre at the intersection of the two axis. It can also be verified by transformation of plane formula.

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4 Thin Cylinder and Thick Cylinder

4.1 Hoop stress and longitudinal stress in a boiler shell under internal pressure are 100 MN/m^2 and 50 MN/m^2 respectively. Young's modulus of elasticity and Poisson's ratio of the shell material are 200 GN/m^2 and 0.3 respectively. The hoop strain in boiler shell is

(a) 0.425×10^{-3} (b) 0.5×10^{-3}
(c) 0.585×10^{-3} (d) 0.75×10^{-3}

[ESE : 1995]

4.2 In a thick cylinder, subjected to internal and external pressures, let r_1 and r_2 be the internal and external radii respectively. Let u be the radial displacement of a material element at radius r_1, $r_2 \geq r \geq r_1$. Identifying the cylinder axis as z axis, the radial strain component e_{rr} is

(a) u/r (b) u/θ
(c) du/dr (d) $du/d\theta$

[ESE : 1996]

4.3 Auto frettage is the method of

(a) joining thick cylinders
(b) calculating stresses in thick cylinders
(c) prestressing thick cylinders
(d) increasing the life of thick cylinders

[ESE : 1996]

4.4 From design point of view, spherical pressure vessels are preferred over cylindrical pressure vessels because they

(a) are cost effective in fabrication
(b) have uniform higher circumferential stress
(c) uniform lower circumferential stress
(d) have a larger volume for the same quantity of material used

[ESE : 1997]

4.5 When a thin cylinder of diameter 'd' and thickness 't' is pressurized with an internal pressure of 'p' (1/m is the Poisson's ratio and E is the modulus of elasticity), then out of the following, which statement is correct

(a) The circumferential strain will be equal to $\dfrac{pd}{2tE}\left(\dfrac{1}{2}-\dfrac{1}{m}\right)$

(b) The longitudinal stress will be equal to $\dfrac{pd}{2tE}\left(1-\dfrac{1}{2m}\right)$

(c) The longitudinal stress will be equal to $\dfrac{pd}{2t}$

(d) The ratio of the longitudinal strain to circumferential strain will be equal to $\dfrac{m-2}{2m-1}$

[ESE : 1998]

4.6 A thick-walled hollow cylinder having outside and inside radii of 90 mm and 40 mm respectively is subjected to an external pressure of 800 MNm^2. The maximum circumferential stress in the cylinder will occur at a radius of

(a) 40 mm (b) 60 mm
(c) 65 mm (d) 90 mm **[ESE : 1998]**

4.7 In a thick cylinder pressurized from inside, the hoop stress is maximum at

(a) The centre of the wall thickness
(b) The outer radius
(c) The inner radius
(d) Both the inner and the outer radii

[ESE : 1998]

4.8 Circumferential stress in a cylindrical steel boiler shell under internal pressure is 80 MPa. Young's modulus of elasticity and Poisson's ratio are respectively 2×10^5 MPa and 0.28. The magnitude of circumferential strain in the boiler shall be

(a) 3.44×10^{-4} (b) 3.84×10^{-4}
(c) 4×10^{-4} (d) 4.56×10^{-4}

[ESE : 1999]

4.9 A thin cylinder with closed lids is subjected to internal pressure and supported at the ends as shown in figure-I.

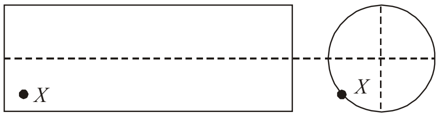
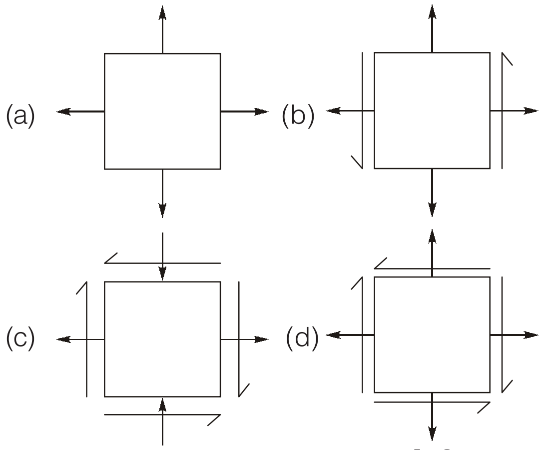


Figure-I

The state of stress at point X is as represented as



[ESE : 1999]

4.10 A thin cylinder with both ends closed is subjected to internal pressure p. The longitudinal stress at the surface has been calculated as σ_o. Maximum shear stress at the surface will be equal to

(a) $2\sigma_0$ (b) $1.5\sigma_0$
(c) σ_0 (d) None of these

[ESE : 1999]

4.11 If a thick cylindrical shell is subjected to internal pressure, then hoop stress, radial stress and longitudinal stress at point in the thickness will be

(a) Tensile, compressive and compressive respectively
(b) All compressive
(c) All tensile
(d) Tensile, compressive and tensile respectively

[ESE : 1999]

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Answers Thin Cylinder and Thick Cylinder

4.1 (a) 4.2 (c) 4.3 (c) 4.4 (c) 4.5 (d) 4.6 (a) 4.7 (c) 4.8 (a) 4.9 (a)
4.10 (c) 4.11 (d)

Explanations Thin Cylinder and Thick Cylinder

4.1 (a)

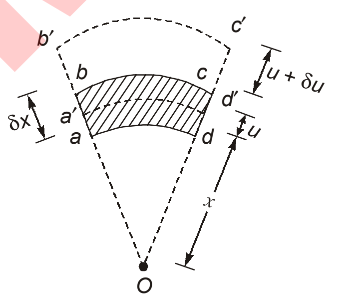
$$\sigma_1 = \frac{pd}{2t} = 100\text{N/mm}^2$$

$$\sigma_2 = \frac{pd}{4t} = 50\text{N/mm}^2$$

$$\text{Hoop strain} = \frac{pd}{4tE}(2-\mu)$$

$$= \frac{50}{200\times1000}\times(2-0.3) = \mathbf{0.425 \times 10^{-3}}$$

4.2 (c)



Change in displacement = $u + \delta u - u = \delta u$

$$\therefore \text{ Radial strain, } \epsilon_r = \underset{\delta x \to 0}{Lt}\frac{\delta u}{\delta x} = \frac{du}{dr}$$

4.3 (c)

Autofrettage: Autofrettage is one of the oldest methods of prestressing (method of increasing pressure capacity) the cylinders. It is overloading the cylinder before it is put into service. In this method, a forged cylinder is subjected to a large internal pressure, so as to expand the internal diameter, causing overstrain. The internal pressure is applied is such a way that a portion of the cylinder at the inner surface is subjected to stresses in the plastic range, while the outer surface is still in the elastic range.

When the pressure is released, the portion of the cylinder at the outer surface contracts exerting the pressure on the portion at the inner surface which has undergone permanent deformation. As a result, **residual compressive stresses** are induced at the inner surface and tensile stresses at the outer surface.

It is commonly used is gun barrels. It not only increases the pressure capacity of the cylinder, but also improves the endurance strength.

4.4 (c)

In spherical vessel, the circumferential stress and longitudinal stress is equal and less than circumferential stress of cylinder vessel.

$$\sigma_h = \frac{pd}{2t} \text{ (for cylinder)}$$

$$\sigma_h = \frac{pd}{4t} \text{ (for sphere)}$$

4.5 (d)

Circumferential stress $(\sigma_1) = \dfrac{pd}{2t}$

Longitudinal stress $(\sigma_2) = \dfrac{pd}{4t}$

Circumferential strain

$$e_1 = \frac{\delta d}{d} = \frac{\sigma_1}{E} - \frac{1}{m}\cdot\frac{pd}{4tE} = \frac{pd}{2tE} - \frac{1}{m}\cdot\frac{pd}{4tE}$$

$$e_1 = \frac{pd}{2tE}\left(1 - \frac{1}{2m}\right)$$

Longitudinal strain

$$e_2 = \frac{\delta l}{l} = \frac{\sigma_2}{E} - \frac{1}{m},\frac{\sigma_1}{E} = \frac{pd}{4tE} - \frac{1}{m},\frac{pd}{2tE}$$

$$e_2 = \frac{pd}{2tE}\left(\frac{1}{2} - \frac{1}{m}\right)$$

$$\frac{\text{Longitudinal Strain}}{\text{Circumfential Strain}} = \frac{\frac{1}{2} - \frac{1}{m}}{1 - \frac{1}{2m}} = \frac{m-2}{2m-1}$$

4.6 (a)

The maximum hoop stress will always occurs at inner most radii irrespective of the location of pressure

4.7 (c)

Hoop stress: $\sigma_x = \dfrac{A}{r^2} + B$

Hence hoop stress will be maximum at inner radius

4.8 (a)

Circumferential stress, $\sigma_1 = \dfrac{pd}{2t} = 80\ \text{N/mm}^2$

Circumferential strain $= \dfrac{pd}{2Et}\left(1 - \dfrac{\mu}{2}\right)$

$$= \frac{80}{2\times 10^5}\left(1 - \frac{0.28}{2}\right) = 3.44 \times 10^{-4}$$

4.9 (a)

Point '*x*' is subjected to circumferential and longitudinal stress. i.e. tension in all faces, but there is no shear stress.

4.10 (c)

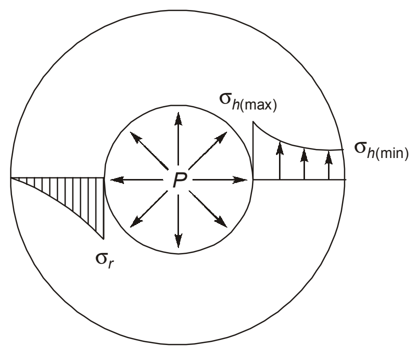
Longitudinal stress $(\sigma_2) = \dfrac{pd}{4t} = \sigma_0$

Hoop stress $(\sigma_1) = \dfrac{pd}{2t} = 2\sigma_O$

Principal stresses $2\sigma_0$, σ_0

Shear stress $= \dfrac{2\sigma_0}{2} = \sigma_0$

4.11 (d)



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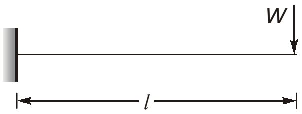
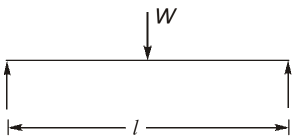
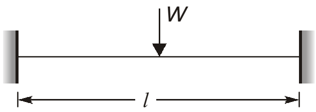
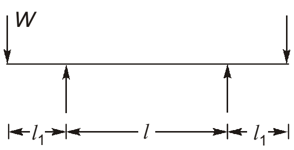
5 Shear Force and Bending Moment Diagrams

5.1 Constant bending moment over span 'l' will occur in

(a) 

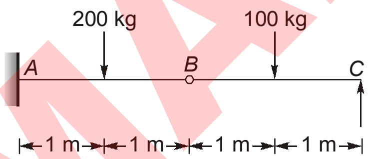
(b) 

(c) 

(d) 

[ESE : 1995]

5.2 The given figure shows a beam *BC* simply supported at *C* and hinged at *B* (free end) a cantilever *AB*. The beam and the cantilever carry forces of 100 kg) and 200 kg respectively. The bending moment at *B* is



(a) Zero (b) 100 kg-m
(c) 150 kg-m (d) 200 kg-m

[ESE : 1995]

5.3 Consider the following statements:
If at a section distant from one of the ends of the beam, *M* represents the bending moment *V* the shear force and *w* the intensity of loading, then

1. $dM/dx = V$
2. $dV/dx = w$
3. $dw/dx = y$

y - the deflection of the beam at the section

Which of these statements are correct?
(a) 1 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1995]

5.4 A cantilever beam having 5 m length is so loaded that it develops a shearing force of 20 T and a bending moment of 20 T-m at a section 2 m from the free end. Maximum shearing force and maximum bending moment developed in the beam under this load, are respectively 50 T and 125 T-m. The load on the beam is
(a) 25 T concentrated load at free end
(b) 20 T concentrated load at free end
(c) 5 T concentrated load at free end 2 T/m load over entire length
(d) 10 T/m udl over entire length [ESE : 1995]

5.5 The bending moment (*M*) is constant over a length segment (*l*) of a beam the shearing force will also be constant over this length and is given by
(a) M/l (b) $M/2l$
(c) $M/4l$ (d) None of the above

[ESE : 1996]

5.6 If the shear force acting at every section of a beam is of the same magnitude and of the same direction then it represents a
(a) simply supported beam with a concentrated load at the centre
(b) overhung beam having equal overhung at both supports and carrying equal concentrated loads acting in the same direction at the free ends
(c) cantilever subjected to concentrated load at the free end
(d) simply supported beam having concentrated loads of equal magnitude and in the same direction acting at equal distances from the supports

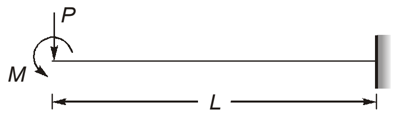
[ESE : 1996]

5.7 A cantilever beam carries a load W uniformly distributed over its entire length. If the same load is placed at the free end of the same cantilever, then the ratio of maximum deflection in the first case to that in the second case will be

(a) 3/8 (b) 8/3

(c) 5/8 (d) 8/5 [ESE : 1996]

5.8 The given figure shows a cantilever of span L subjected to a concentrated load P and a moment M at the free end. Deflection at the free end is given by



(a) $\frac{PL^2}{2EI}+\frac{ML^2}{3EI}$ (b) $\frac{ML^2}{2EI}+\frac{PL^3}{3EI}$

(c) $\frac{ML^2}{3EI}+\frac{PL^3}{2EI}$ (d) $\frac{ML^2}{2EI}+\frac{PL^3}{48EI}$

[ESE : 1996]

5.9 For a cantilever beam of length 'L' flexural rigidity EI and loaded at its free end by a concentrated load W, match **List-I** with **List-II** and select the correct answer using the codes below the lists:

List-I	List-II
A. Maximum bending moment	1. WL
B. Strain energy	2. $WL^2/2EI$
C. Maximum slope	3. $WL^3/3EI$
D. Maximum deflection	4. $W^2L^3/6EI$

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	1	4	2	3
(c)	4	2	1	3
(d)	4	3	1	2

[ESE : 1996]

5.10 The given figure shows the shear force diagram for the beam $ABCD$ bending moment in the portion BC of the beam

(a) is a non zero constant

(b) is zero

(c) varies linearly form B to C

(d) varies parabolically from B to C

[ESE : 1996]

5.11 The maximum bending moment in a simply supported beam of length L loaded by a concentrated load W at the midpoint is given by

(a) WL (b) $\frac{WL}{2}$

(c) $\frac{WL}{4}$ (d) $\frac{WL}{8}$

[ESE : 1996]

5.12 A beam, built in both ends, carries a uniformly distributed load over its entire span as shown in figure-I. Which one of the diagrams given below represents bending moment distribution along the length of the beam?

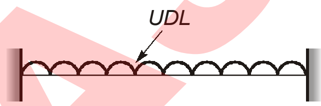
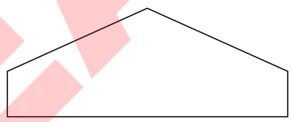
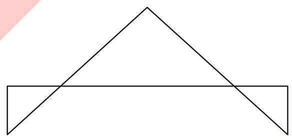
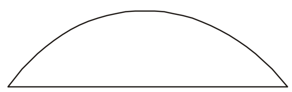
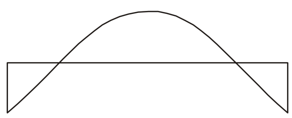


Figure-I

(a)


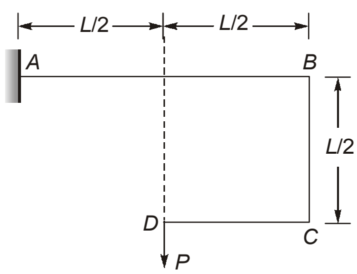
(b)


(c)


(d)


[ESE : 1996]

5.13 A beam subjected to a load P is shown in the figure below.

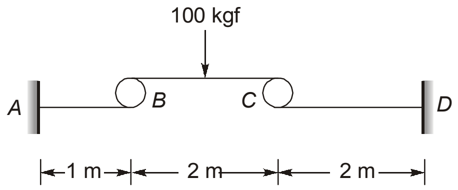


The bending moment at the support A of the beam will be

(a) PL (b) $PL/2$

(c) $2PL$ (d) Zero [ESE : 1997]

5.14 A 2 m long beam *BC* carries a single concentrated load at its mid-span and is simply supported at ends by two cantilevers *AB*, 1 m long and *CD*, 2 m long as shown in the figure.



The shear force at end *A* of the cantilever *AB* will be

(a) zero (b) 40 kgf
(c) 50 kgf (d) 60 kgf **[ESE : 1997]**

5.15 If a beam is subject to a constant bending moment along its length then the shear force will

(a) also have a constant value everywhere along its length
(b) be zero at all sections along the beam
(c) be maximum at the centre and zero at the ends
(d) zero at the centre and maximum at the ends

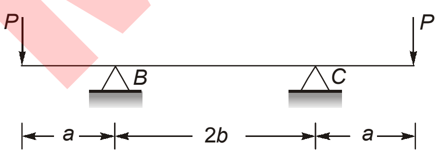
[ESE : 1997]

5.16 A simply supported beam with width '*b*' and depth '*d*' carries a central load *W* and undergoes deflection δ at the centre. If the width and depth and interchanged, the deflection at the centre of the beam would attain the value

(a) $\left(\frac{d}{b}\right)\delta$ (b) $\left(\frac{d}{b}\right)^2\delta$
(c) $\left(\frac{d}{b}\right)^3\delta$ (d) $\left(\frac{d}{b}\right)^{3/2}\delta$

[ESE : 1997]

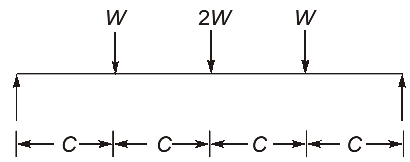
5.17 For the beam shown in the figure below, the elastic curve between the supports *B* and *C* will be



(a) circular (b) parabolic
(c) elliptic (d) a straight line

[ESE : 1998]

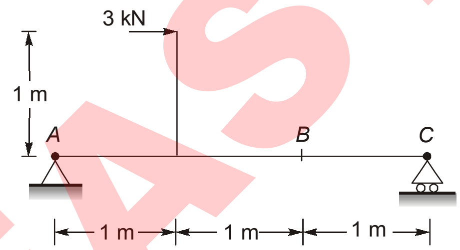
5.18 A simply supported beam is loaded as shown in the figure below.



The maximum shear force in the beam will be

(a) Zero (b) *W*
(c) 2*W* (d) 4 *W* **[ESE : 1998]**

5.19 A lever is supported on two hinges at *A* and *C*. It carries a force of 3 kN as shown in the figure below. The bending moment at *B* will be



(a) 3 kN-m (b) 2 kN-m
(c) 1 kN-m (d) Zero **[ESE : 1998]**

5.20 The bending moment diagram shown in figure-I corresponds to the shear force diagram in

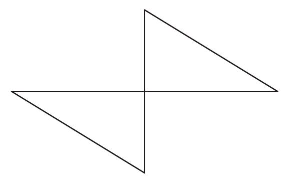
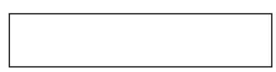
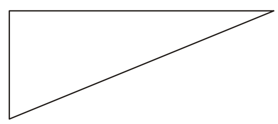
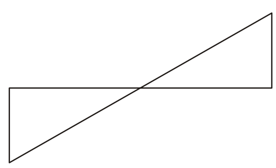


Figure-I

(a)

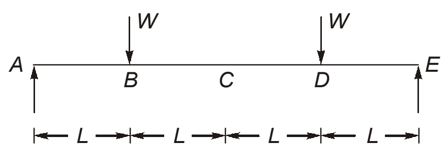

(b)


(c)


(d)


[ESE : 1999]

5.21 Which one of the following portions of the loaded beam shown in the given figure is subjected to pure bending?



(a) *AB* (b) *DE*
(c) *AE* (d) *BD*

[ESE : 1999]

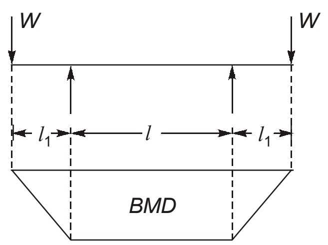
Answers Shear Force and Bending Moment Diagrams

5.1 (d)	5.2 (a)	5.3 (b)	5.4 (d)	5.5 (d)	5.6 (c)	5.7 (a)	5.8 (b)	5.9 (b)
5.10 (a)	5.11 (c)	5.12 (d)	5.13 (b)	5.14 (c)	5.15 (b)	5.16 (b)	5.17 (a)	5.18 (c)
5.19 (c)	5.20 (b)	5.21 (d)						

Explanations Shear Force and Bending Moment Diagrams

5.1 (d)

Bending moment diagram for loading given in option (d)



5.2 (a)

Bending moment at internal hinge is always zero.

5.3 (b)

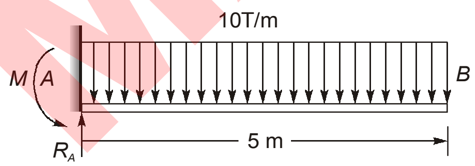
Rate of change of bending moment is equal to the shear force at that section i.e

$$\frac{dM}{dx} = V$$

Rate of change of shear force is equal to the intensity of loading

$$\frac{dV}{dx} = -W$$

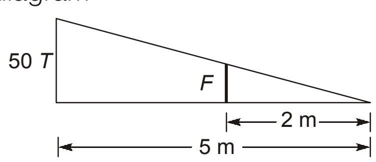
5.4 (d)



$$R_A = 10 \times 5 = 50\text{T}$$

$$M = 10 \times 5 \times \frac{5}{2} = 125\text{T}.m$$

S.F diagram



For similar triangle

$$\frac{50T}{5} = \frac{F}{x} = \frac{F}{2}$$

$\therefore F = 20\text{T}$

M at 2 m from free end.

$= 10\text{T} \times 2 \times 1 = 20\text{T}\ m$

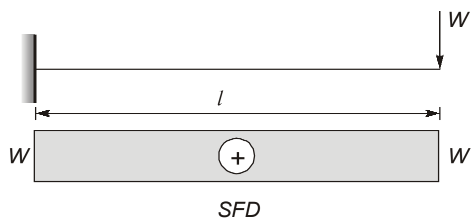
10T m udl over whole span of beam

5.5 (d)

$$\frac{dM}{dx} = S_x$$

When bending moment is constant then shearing force in that section is zero.

5.6 (c)



5.7 (a)

In first case $\delta_1 = \dfrac{WL^3}{8EI}$

In second case $\delta_2 = \dfrac{WL^3}{3EI}$

$$\therefore \frac{\delta_1}{\delta_2} = \frac{3}{8}$$

5.8 (b)

Deflection can be found by using super imposition method. Deflection due to point load (cantilever) $\delta_1 = \dfrac{Pl^3}{3EI}$ Deflection due to moment at end in cantilever $\delta_2 = \dfrac{Ml^2}{2EI}$. Summation of δ_1 and δ_2 will give the total deflection of the cantilever.

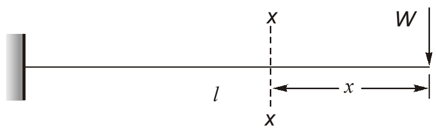
5.9 (b)

Strain energy stored in cantilever under concentrated load at free end.

$$U = \int_0^l \frac{M^2 dx}{2EI} = \int_0^l \frac{(Wx)^2 dx}{2EI}$$

$$U = \frac{W^2 l^3}{6EI}$$

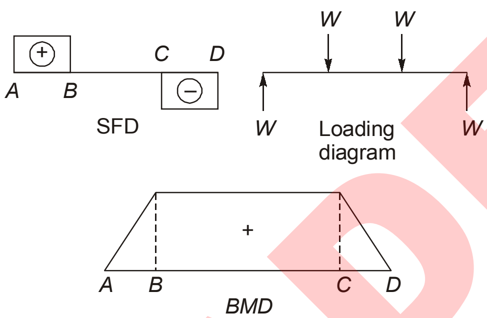
Maximum bending moment at fixed end = WL



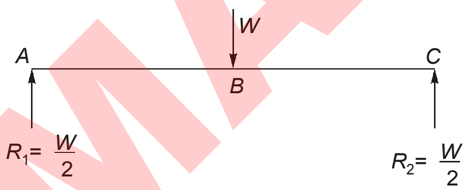
Maximum slope = $\dfrac{Wl^2}{2EI}$

Maximum deflection = $\dfrac{Wl^3}{3EI}$

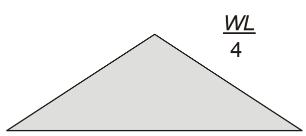
5.10 (a)



5.11 (c)

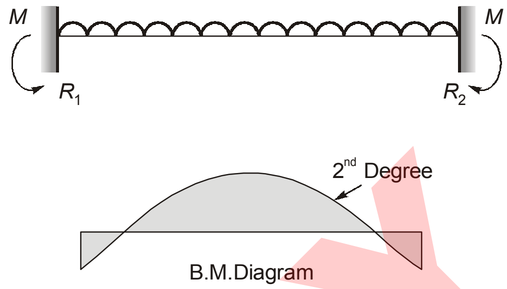


Bending moment at $B = \dfrac{W}{2} \times \dfrac{L}{2} = \dfrac{WL}{4}$

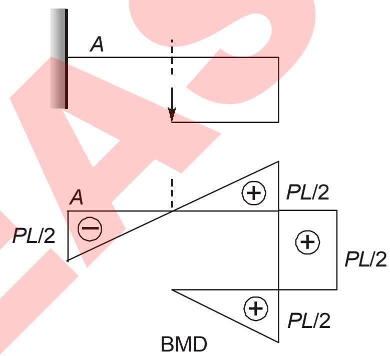


B.M. Diagram

5.12 (d)

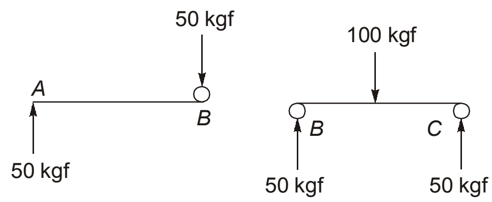


5.13 (b)



5.14 (c)

F.B.D.



5.15 (b)

$$\frac{dM}{dx} = S$$

Whenever Bending moment is constant then shear force will be zero.

5.16 (b)

For simple supported beam

deflection: $\delta = \dfrac{WL^3}{48EI}$

for same load; $\boxed{\delta \propto \dfrac{1}{I}}$, $\dfrac{\delta_1}{\delta} = \dfrac{I}{I_1}$

$$\delta = \frac{bd^3}{db^3} \cdot \delta_1$$

$$\therefore \quad \delta \times \frac{1}{12} b d^3 = \delta_1 \times \frac{1}{12} b^3 d$$

$$\therefore \quad \boxed{\delta_1 = \left(\frac{d}{b}\right)^2 \delta}$$

5.17 (a)

From symmetry,

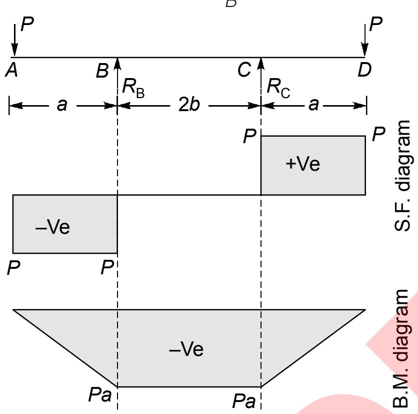
Reaction at support B and C will be same and equal to P (upward).

Taking moment about B,

$$P \times a + R_C \times 2b = P \times (a + 2b)$$

$$R_C = \frac{P \times 2b}{2b} = P$$

$$R_B = 2P - P$$

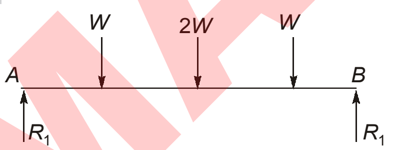


$\because$ $SF = 0 \Rightarrow BM =$ constant

Elastic curve will be circular.

$$\left[R = \frac{EI}{M} = \text{constant}\right]$$

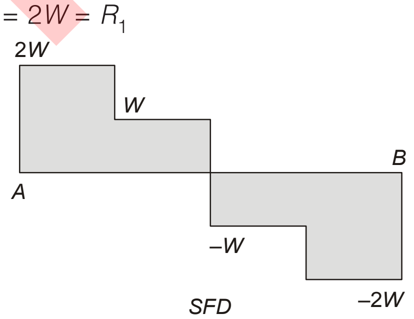
5.18 (c)



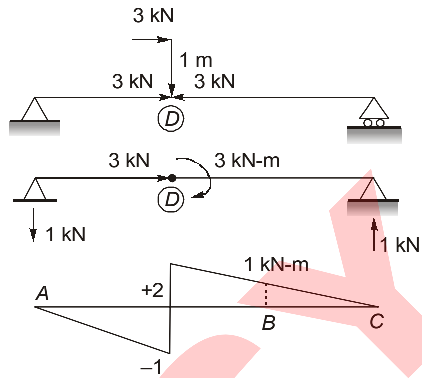
Moment about $A = 0$

$$W \times c + 2W \times 2c + W \times 3c - R_2 \times 4c = 0$$

$$R_2 = 2W = R_1$$

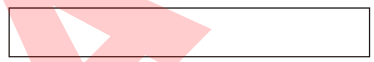


5.19 (c)



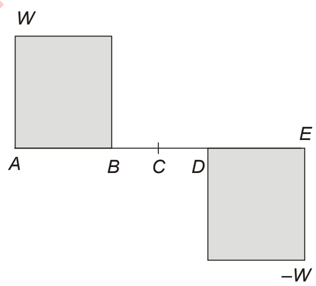
5.20 (b)

Since B.M.D. is of first degree thus corresponding S.F.D will be of zeroth degree.



5.21 (d)

Shear force diagram.



In section BD, shear force is zero. As we know that $s = \frac{dM}{dX}$

$$\therefore \quad M = \text{Constant}$$

Hence this section subjected to pure bending.

■■■■

6 Bending of Beams, Shear Stress Distribution

6.1 A rectangular section beam subjected to a bending moment M varying along its length is required to develop same maximum bending stress at any cross-section. If the depth of the section is constant, then its width will vary as

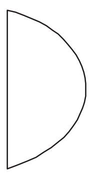
(a) M (b) $\sqrt{M}$

(c) M^2 (d) $1/M$

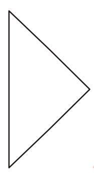
[ESE : 1995]

6.2 In a beam of circular cross-section, the shear stress variation across a cross-section is

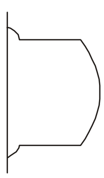
(a)



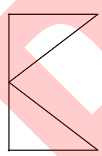
(b)



(c)



(d)



[ESE : 1995]

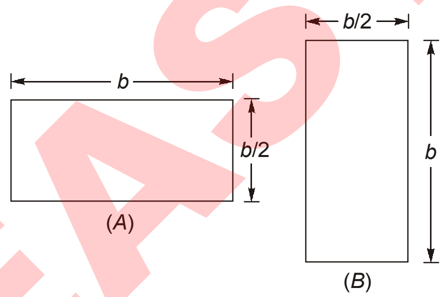
6.3 A wooden beam of rectangular cross-section 10 cm deep by 5 cm wide carries maximum shear force of 2000 kgf. Shear stress at neutral axis of the beam section is

(a) zero (b) 40 kgf/cm^2

(c) 60 kgf/cm^2 (d) 80 kgf/cm^2

[ESE : 1997]

6.4 A beam cross-section is used in two different orientations as shown in the figure given below:



Bending moments applied to the beam in both cases are same. The maximum bending stresses induced in cases (A) and (B) are related as

(a) $\sigma_A = \sigma_B$ (b) $\sigma_A = 2\sigma_B$

(c) $\sigma_A = \frac{\sigma_B}{2}$ (d) $\sigma_A = \frac{\sigma_B}{4}$

[ESE : 1997]

6.5 Two beams of equal cross-section area are subjected to equal bending moment. If one beam has square cross-section and the other has circular section, then

(a) both beams will be equally strong

(b) circular section beam will be stronger

(c) square section beam will be stronger

(d) the strength of the beam will depend on the nature of loading

[ESE : 1999]

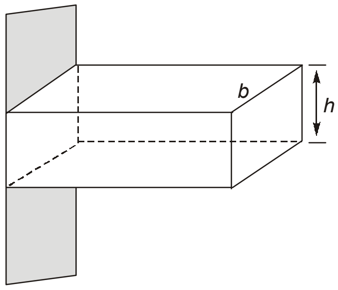
■■■■

Answers **Bending of Beams, Shear Stress Distribution**

6.1 (a) 6.2 (a) 6.3 (c) 6.4 (b) 6.5 (c)

Explanations Bending of Beams, Shear Stress Distribution

6.1 (a)



$$\frac{M}{I} = \frac{\sigma_b}{y_{max}}$$

$$\frac{M}{\frac{1}{12}bh^3} = \frac{\sigma_b}{\frac{h}{2}}$$

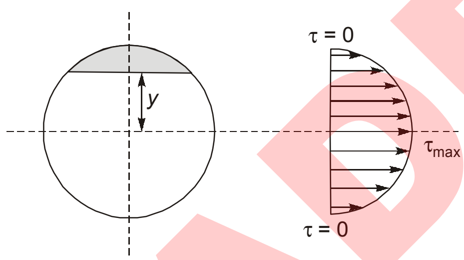
$$\therefore \quad M = \sigma_b \times \frac{1}{6}bh^2$$

Width (b) $\propto M$

6.2 (a)

Shear stress in circular cross-section

$$\tau = \frac{F}{3I}(r^2 - y^2)$$



6.3 (c)

$$\tau_{max} = \tau_{NA} = 1.5\,\tau_{avg} = \frac{3}{2}\cdot\frac{S}{bd}$$

$$\tau_{max} = \frac{3}{2}\times\frac{2000}{10\times 5} = 60 \text{ kg.f/cm}^2$$

6.4 (b)

For first case

$$I_A = \frac{1}{12}\times b\times\left(\frac{b}{2}\right)^3 = \frac{b^4}{12\times 8}$$

$$\frac{M}{I_A} = \frac{\sigma}{y} \Rightarrow \frac{M\times 12\times 8}{b^4} = \frac{\sigma_A}{b/4}$$

$$\therefore \quad \sigma_A = \frac{24M}{b^3}$$

For second case

$$I_B = \frac{1}{12}\times\left(\frac{b}{2}\right)\times(b)^3 = \frac{b^4}{12\times 2}$$

$$\therefore \quad \frac{M}{\frac{b^4}{12\times 2}} = \frac{\sigma_B}{\frac{b}{2}}$$

$$\therefore \quad \sigma_B = \frac{12M}{b^3}$$

$$\therefore \quad \boxed{\sigma_A = 2\sigma_B}$$

6.5 (c)

If 'd' is diameter of circular section and 'a' be the side of square section and cross-section area of sqaure is equal to cross area of circle.

$$\therefore \quad a^2 = \frac{\pi}{4}d^2$$

$$\therefore \quad a = \sqrt{\frac{\pi}{4}}d$$

Section modulus:

$$Z_s = \frac{a^3}{6},\ Z_c = \frac{\pi}{32}d^3$$

$$\frac{Z_s}{Z_c} = \frac{a^3}{d^3}\times\frac{32}{\pi\times 6} = \frac{\pi}{4}\times\sqrt{\frac{\pi}{4}}\times\frac{32}{\pi\times 6}$$

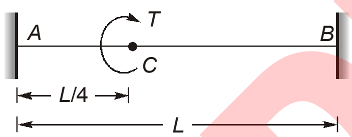
$$= 1.18$$

Hence square section beam will be stronger than circular beam.

7 Torsion of Shafts

7.1 A 3-meter long steel cylindrical shaft is rigidly held at its two ends. A pulley is mounted on the shaft at 1 meter from one end; the shaft is twisted by applying torque on the pulley.
The maximum shearing stresses developed in 1 m and 2 m lengths are respectively τ_1 and τ_2. The ratio $\tau_2 : \tau_1$ is
(a) 1/2 (b) 1
(c) 2 (d) 4
[ESE : 1995]

7.2 A round shaft of diameter '*d*' and length '*l*' fixed at both ends '*A*' and '*B*', is subjected to a twisting moment '*T*' at '*C*' at a distance of 1/4 from *A* (see figure). The torsional stresses in the parts *AC* and *CB* will be



(a) equal
(b) in the ratio of 1 : 3
(c) in the ratio of 3 : 1
(d) indeterminate
[ESE : 1997]

7.3 Maximum shear stress in a solid shaft of diameter *D* and length *L* twisted through an angle θ is τ. A hollow shaft of same material and length having outside and inside diameters of *D* and *D*/2 respectively is also twisted through the same angle of twist θ. The value of maximum shear in the hollow shaft will be
(a) $\frac{16}{15}\tau$ (b) $\frac{8}{7}\tau$
(c) $\frac{4}{3}\tau$ (d) τ
[ESE : 1997]

7.4 Two hollow shafts of the same material have the same length and outside diameter. Shaft 1 has internal diameter equal to one third of the outer diameter and shaft 2 has internal diameter equal to half of the outer diameter. If both the shafts are subjected to the same torque, the ratio of their twists θ_1/θ_2 will be equal to
(a) 16/81 (b) 8/27
(c) 19/27 (d) 243/256
[ESE : 1998]

7.5 A solid shaft of diameter 100 mm, length 1000 mm is subjected to a twisting moment '*T*', the maximum shear stress developed in the shaft is 60 N/mm^2. A hole of 50 mm diameter is now drilled throughout the length of the shaft. To develop a maximum shear stress of 60 N/mm^2 in the hollow shaft, the torque '*T*' must be reduced by
(a) *T*/4 (b) *T*/8
(c) *T*/12 (d) *T*/16 **[ESE : 1998]**

■■■■

Answers **Torsion of Shafts**

7.1 (a) 7.2 (c) 7.3 (d) 7.4 (d) 7.5 (d)

Explanations Torsion of Shafts

7.1 (a)

Angle of twist is same

$$\frac{\tau}{R} = \frac{G\theta}{L} \text{ (torsion formula)}$$

$$\therefore \quad \tau \times L = \text{constant}$$

$$\tau_1 \times 1 = \tau_2 \times 2$$

$$\frac{\tau_2}{\tau_1} = \frac{1}{2}$$

7.2 (c)

$$\frac{\tau}{\frac{d}{2}} = \frac{G\theta}{L}$$

for same angle of twist

$$\boxed{\tau \propto \frac{1}{L}}$$

$$\therefore \quad \tau_1 \times \frac{l}{4} = \tau_2 \times \frac{3l}{4}$$

$$\therefore \quad \frac{\tau_1}{\tau_2} = \frac{3}{1}$$

7.3 (d)

For solid shaft

$$\frac{\tau}{D/2} = \frac{G\theta}{L} \qquad \therefore \; \tau = \frac{G\theta}{L} \cdot \frac{D}{2}$$

for hollow shaft

$$\frac{\tau_2}{D/2} = \frac{G\theta}{L} \qquad \therefore \; \tau_2 = \frac{G\theta}{L} \cdot \frac{D}{2} = \tau$$

7.4 (d)

We know that

$$\frac{T}{J} = \frac{G\theta}{L}$$

for same torque, and identical shaft

$$\boxed{\theta \propto 1/J}$$

For first shaft.

$$J_1 = \frac{\pi}{32} \times \left[D^4 - \left(D/3\right)^4\right] = \frac{80}{81} \times \frac{\pi}{32} D^4$$

for second shaft

$$J_2 = \frac{\pi}{32} \times \left[D^4 - \left(D/2\right)^4\right] = \frac{15}{16} \times \frac{\pi}{32} D^4$$

$$\therefore \quad \theta_1 J_1 = \theta_2 J_2$$

$$\frac{\theta_1}{\theta_2} = \frac{15}{16} \times \frac{81}{80} = \frac{243}{256}$$

7.5 (d)

For solid shaft

$$\tau = \frac{16T}{\pi d^3} \qquad \text{...(i)}$$

For hollow shaft

$$\tau = \frac{16}{15} \times \frac{16T}{\pi d^3} \qquad \text{...(ii)}$$

From eq (i) and eq (ii),

$$T' = \frac{15}{16} T$$

Hence reduced torque $= T - \frac{15}{16} T = \frac{T}{16}$

■■■■

8 Euler's Theory of Column

8.1 Match **List-I** (End conditions of columns) with **List-II** (Lowest critical load) and select the correct answer using the codes given below the lists:

List-I

A. Column with both ends hinged
B. Column with both ends fixed
C. Column with one ends fixed and the other end hinged
D. Column with one ends fixed and the other end free

List-II

1. $\pi^2 EI/L^2$
2. $2\pi^2 EI/L^2$
3. $4\pi^2 EI/L^2$
4. $\pi^2 EI/4L^2$

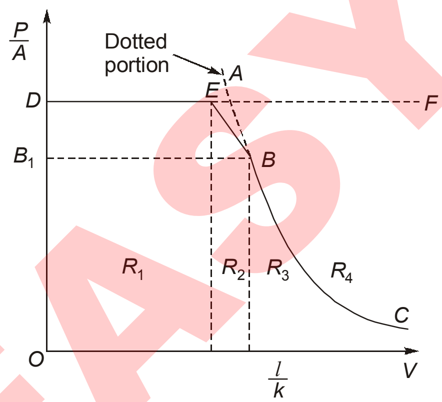
(E is the Young's modulus of elasticity of column material, L is the length and I is the second moment of area of cross-section of the column.)

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	2	1	4
(c)	1	3	2	4
(d)	2	4	3	1

[ESE : 1995]

8.2 The curve *ABC* is the Euler's curve for stability of column. The horizontal line *DEF* is the strength limit. With reference to this figure match **List-I** (Regions) with **List-II** (Column specifications) and select the correct answer using the codes given below the lists:



List-I	**List-II**
A. R_1	1. Long, stable
B. R_2	2. Short
C. R_3	3. Medium
D. R_4	4. Long, unstable

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	2	3	1	4
(c)	1	2	4	3
(d)	2	1	3	4

[ESE : 1997]

8.3 The ratio of the compressive critical load for a long column fixed at both the ends and a column with one end fixed and the other end free is

(a) 1 : 2 (b) 1 : 4
(c) 1 : 8 (d) 1 : 16

[ESE : 1997]

8.4 The Euler's crippling load for a 2 m long slender steel rod of uniform cross-section hinged at both the ends is 1 kN. The Euler's crippling load for a 1 m long steel rod of the same cross-section and hinged at both ends will be

(a) 0.25 kN (b) 0.5 kN
(c) 2 kN (d) 4 kN **[ESE : 1998]**

8.5 Euler's formula gives 5 to 10% error in crippling load as compared to experimental results in practice because
(a) effect of direct stress is neglected
(b) pin joints are not free from friction
(c) the assumptions made in using the formula are not met in practice
(d) the material does not behave in an ideal elastic way in tension and compression
[ESE : 1998]

8.6 A short column of external diameter D and internal diameter d carries an eccentric load W. The greatest eccentricity which the load can be applied without producing tension on the cross-section of the column would be

(a) $\frac{D+d}{8}$ (b) $\frac{D^2+d^2}{8d}$

(c) $\frac{D^2+d^2}{8D}$ (d) $\sqrt{\frac{D^2+d^2}{8}}$

[ESE : 1999]

Answers Euler's Theory of Column

8.1 (c) 8.2 (b) 8.3 (d) 8.4 (d) 8.5 (c) 8.6 (c)

Explanations Euler's Theory of Column

8.1 (c)

Critical load $P_E = \frac{\pi^2 EI}{L_{eq}^2}$

Column with both ends pinned, $l_{eq} = l$

$\therefore P_E = \frac{\pi^2 EI}{l^2}$

Column with both ends fixed; $l_{eq} = l/2$

$\therefore P_E = \frac{4\pi^2 EI}{l^2}$

Column with one end fixed and other end hinged

$l_{eq} = \frac{l}{\sqrt{2}}$

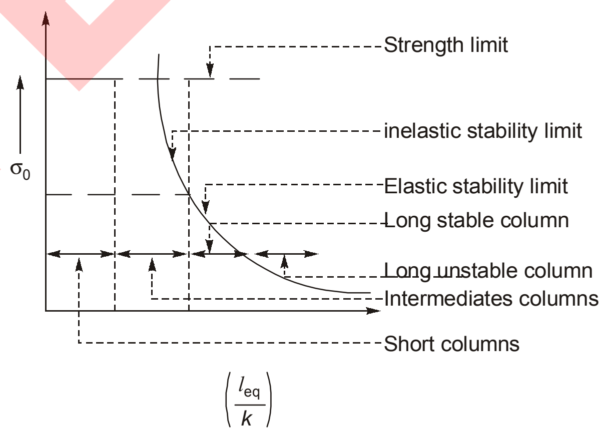
$\therefore P_E = \frac{2\pi^2 EI}{l^2}$

Column with one end fixed and other end free

$l_{eq} = 2l$

$\therefore P_E = \frac{\pi^2 EI}{4l^2}$

8.2 (b)



8.3 (d)

$P_E = \frac{\pi^2 EI}{L_{eq}^2}$

$P_1 = \frac{4\pi^2 EI}{l^2} \rightarrow$ both end fixed

$P_2 = \frac{\pi^2 EI}{4l^2} \rightarrow$ one end fixed and other free

$\therefore \frac{P_1}{P_2} = 16 : 1$

So, best possible answer is (d).

8.4 (d)

$$P_E = \frac{\pi^2 EI}{l^2} \text{ for both ends hinged}$$

$$\therefore \quad 1000 = \frac{\pi^2 EI}{4} \quad \text{...(i)}$$

$$P_E = \frac{\pi^2 EI}{1} (at\ l = 1m)$$

$$\therefore \quad P_E = 4 \text{ kN}$$

8.6 (c)

To avoid tension on cross-section column

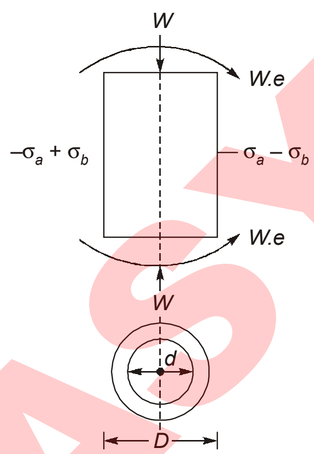
$\therefore \sigma_a + \sigma_b \le 0$

$$\Rightarrow \quad -\frac{W}{A} + \frac{We}{Z} = 0 \quad \text{...(i)}$$

$$\Rightarrow \quad A = \frac{\pi}{4}(D^2 - d^2)$$

and $$Z = \frac{\pi}{32} D^3 (1 - K^4)$$

where $$K = \frac{d}{D}$$



But these value in equation (i)

We have, $$e \le \frac{D^2 + d^2}{8D}$$

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9 Strain Energy & Thermal Stresses

9.1 A 10 cm long and 5 cm diameter steel rod fits snugly between two rigid walls 10 cm apart at room temperature. Young's modulus of elasticity and coefficient of linear expansion of steel are 2×10^6 kgf/cm^2 and 12×10^{-6}/°C respectively. The stress developed in the rod due to a 100°C rise in temperature will be

(a) 6×10^{-10} kgf/cm^2 (b) 6×10^{-9} kgf/cm^2

(c) 2.4×10^3 kgf/cm^2 (d) 2.4×10^4 kgf/cm^2

[ESE : 1997]

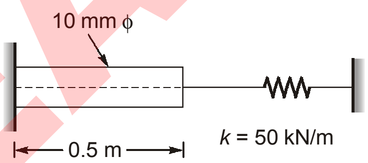
9.2 For the state of stress of pure shear τ, the shear strain energy stored per unit volume in the elastic, homogenous isotropic material having elastic constants E and ν will be

(a) $\frac{\tau^2}{E}(1+\nu)$ (b) $\frac{\tau^2}{2E}(1+\nu)$

(c) $\frac{2\tau^2}{E}(1+\nu)$ (d) $\frac{\tau^2}{2E}(2+\nu)$

[ESE : 1998]

9.3 If the rigid rod fitted snugly between the supports as shown in the figure below, is heated, the stress induced in it due to 20°C rise in temperature will be ($\alpha = 12.5 \times 10^{-6}$/°C and $E = 200$ GPa)



(a) 0.07945 MPa (b) –0.07945 MPa

(c) –0.03972 MPa (d) 0.03972 MPa

[ESE : 1999]

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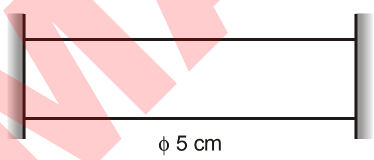
Answers Strain Energy & Thermal Stresses

9.1 (c) **9.2** (a) **9.3** (b)

Explanations Strain Energy & Thermal Stresses

9.1 (c)



$l = 10$ cm

$$E = 2 \times 10^6 \text{ kgf / cm}^2$$

$$\alpha = 12 \times 10^{-6} /°\text{C}; \quad \Delta T = 100°\text{C}$$

It is statically indeterminate. So we used one equation of compatibility.

$$L\,\alpha\,\Delta T = \frac{PL}{AE}$$

$$\sigma = E\,\alpha\,\Delta T = 12 \times 10^{-6} \times 2 \times 10^6 \times 100$$

$$= 2.4 \times 10^3 \text{ kgf/cm}^2$$

9.2 (a)

Strain energy due to pure shear

$$(U) = \frac{1}{2}\phi \times \tau = \frac{1}{2} \times \frac{\tau^2}{G} = \frac{\tau^2}{2G}$$

$$U = \frac{\tau^2}{E}(1+\mu) \qquad [E = 2G(1+\mu)]$$

9.3 (b)

$$\sigma = \frac{\alpha TE}{1 + \frac{AE}{kL}} = 0.07945$$

■■■■

10 Deflection of Beams

10.1 A beam having uniform cross-section carries a uniformly distributed load of intensity 'q' per unit length over its entire span, and its mid-span deflection is δ.
The value of mid-span deflection of the same beam when the same load is distributed with intensity varying from $2q$ per unit length at one end to zero at the other end is

(a) $\frac{\delta}{3}$ (b) $\frac{\delta}{2}$
(c) $\frac{2\delta}{3}$ (d) δ [ESE : 1995]

10.2 A simply supported beam carrying a concentrated load W at mid-span deflects δ_1 under the load. If the same beam carries the load W such that it is distributed uniformly over entire length and undergoes a deflection δ_2 at the mid span. The ratio $\delta_1 : \delta_2$ is

(a) 2 : 1 (b) $\sqrt{2} : 1$
(c) 1 : 1 (d) 1 : 2 [ESE : 1995]

10.3 Two identical cantilevers are loaded as shown in the respective figures. If slope at the free end of the cantilever in figure E is θ, the slope at free end of the cantilever in figure F will be

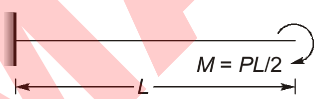


Figure-E

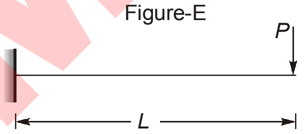


Figure-F

(a) $\frac{1}{3}\theta$ (b) $\frac{1}{2}\theta$
(c) $\frac{2}{3}\theta$ (d) θ
[ESE : 1997]

10.4 A simply supported beam of constant flexural rigidity and length $2L$ carries a concentrated load P at its mid-span and the deflection under the load is δ. If a cantilever beam of the same flexural rigidity and length L is subjected to a load P at its free end, then the deflection at the free end will be

(a) $\delta/2$ (b) δ
(c) 2δ (d) 4δ [ESE : 1998]

10.5 A cantilever beam of rectangular cross-section is subjected to a load W at its free end. If the depth of the beam is doubled and the load is halved, the deflection of the free end as compared to original deflection will be

(a) half (b) one-eighth
(c) one-sixteenth (d) double
[ESE : 1999]

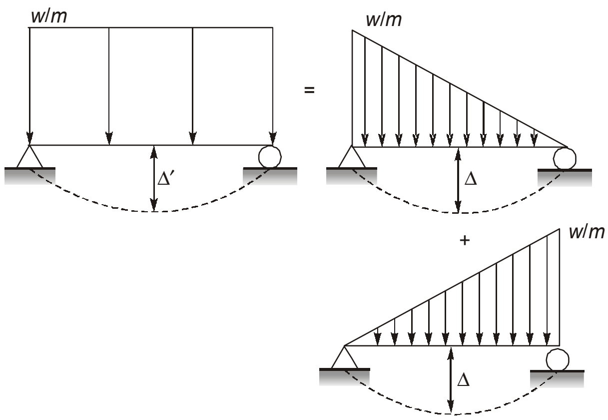
■■■■

Answers **Deflection of Beams**

10.1 (d) 10.2 (*) 10.3 (d) 10.4 (c) 10.5 (c)

Explanations Deflection of Beams

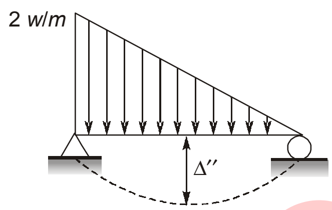
10.1 (d)



$$\Delta' = \Delta + \Delta$$

$$\Delta = \frac{\Delta'}{2} = \frac{1}{2} \times \frac{5wL^4}{384EI}$$

Now,



$$\Delta'' = 2\Delta = \frac{5wL^4}{384EI}$$

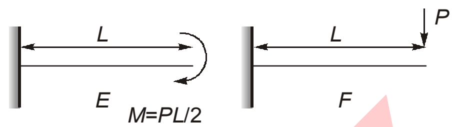
10.2 (*)

$$\delta_1 = \frac{WL^3}{48EI};\ \delta_2 = \frac{5WL^3}{384EI}$$

$$\therefore \quad \frac{\delta_1}{\delta_2} = 1.6$$

Nearest answer is (b)

10.3 (d)



For concentrated load $\theta_F = \dfrac{PL^2}{2EI}$

For moment at end $\theta_E = \dfrac{M \times L}{EI} = \dfrac{PL^2}{2EI}$

$\therefore\ \theta_E = \theta_F$

10.4 (c)

For simple supported beam

$$\delta = \frac{P(2L)^3}{48EI} = \frac{8PL^3}{48EI} = \frac{PL^3}{6EI}$$

for cantilever:

$$\delta_2 = \frac{PL^3}{3EI}$$

$$\therefore \quad \boxed{\delta_2 = 2\delta}$$

10.5 (c)

Deflection in cantilever

$$\delta = \frac{WL^3}{3EI} = \frac{WL^3}{3E \times \frac{1}{12}bd^3} = \frac{4WL^3}{Ebd^3}$$

Now $\delta' = \dfrac{4 \times \frac{W}{2} \times L^3}{E \times b \times (2d)^3} = \left(\dfrac{1}{16}\right)\dfrac{4WL^3}{Ebd^3}$

$$\delta' = \frac{\delta}{16}$$

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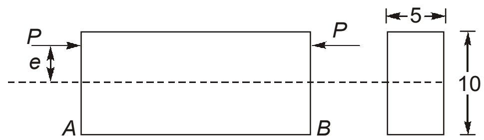
11 Combined Stresses

11.1 For the configuration of loading shown in the given figure, the stress in fibre *AB* is given by



(a) $\frac{P}{A}$ (tensile)

(b) $\left(\frac{P}{A} - \frac{P.e.5}{I_{xx}}\right)$compressive)

(c) $\left(\frac{P}{A} + \frac{P.e.5}{I_{xx}}\right)$compressive)

(d) *P*/*A* (compressive)

[ESE : 1995]

11.2 The equivalent bending moment under combined action of bending moment *M* and torque T is

(a) $\sqrt{M^2 + T^2}$
(b) $\frac{1}{2}\sqrt{M^2 + T^2}$
(c) $M + \sqrt{M^2 + T^2}$
(d) $\frac{1}{2}\left(M + \sqrt{M^2 + T^2}\right)$

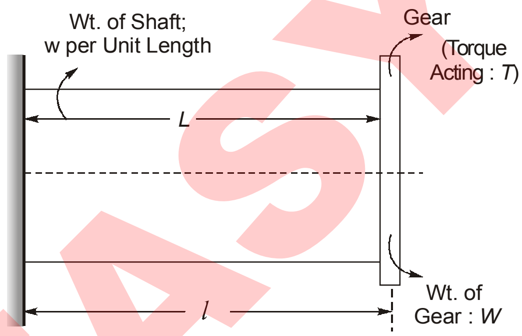
[ESE : 1996]

11.3 A circular shaft is subjected to the combined action of bending, twisting and direct axial loading. The maximum bending stress σ, maximum shearing stress $\sqrt{3}\sigma$ and a uniform axial stress σ (compressive) are produced. The maximum compressive normal stress produced in the shaft will be

(a) 3σ
(b) 2σ
(c) σ
(d) Zero

[ESE : 1998]

11.4 For obtaining the maximum shear stress induced in the shaft shown in the given figure, the torque should be equal to



(a) T

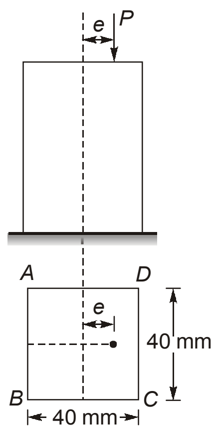
(b) $Wl + T$

(c) $\left[(Wl)^2 + \left(\frac{wL}{2}\right)^2\right]^{\frac{1}{2}}$

(d) $\left[\left\{Wl + \frac{wL^2}{2}\right\}^2 + T^2\right]^{\frac{1}{2}}$

[ESE : 1999]

11.5 A column of square section 40 mm × 40 mm, fixed to the ground carries an eccentric load *P* of 1600 N as shown in the figure.



If the stress developed along the edge *CD* is –1.2 N/mm^2, the stress along the edge *AB* will be

(a) –1.2 N/mm^2
(b) +1 N/mm^2
(c) +0.8 N/mm^2
(d) –0.8 N/mm^2

[ESE : 1999]

Answers Combined Stresses

11.1 (b) 11.2 (d) 11.3 (a) 11.4 (d) 11.5 (d)

Explanations Combined Stresses

11.1 (b)

For *AB* section

Direct stress $(\sigma_1) = \frac{P}{A}$ (Compressive)

Bending stress $(\sigma_2) = \frac{P.e.5}{I_{xx}}$(tensile)

total stress in fibre *AB* = $(\sigma_1 - \sigma_2)$

$$= \left(\frac{P}{A} - \frac{P.e.5}{I_{xx}}\right) \text{ (compressive)}$$

11.2 (d)

Bending stress $(\sigma) = \frac{32M}{\pi d^3}$

Shear stress $(\tau) = \frac{16T}{\pi d^3}$

Maximum normal stress

$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\Rightarrow \frac{32M_{eq}}{\pi d^3} = \frac{32M}{2\pi d^3} + \left[\sqrt{\left(\frac{32M}{2\pi d^3}\right)^2 + \left(\frac{16T}{\pi d^3}\right)^2}\right]$$

$$\therefore \quad M_{eq} = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

11.3 (a)

Normal stress = -2σ, 0

Shear stress = $\sqrt{3}\sigma$

$$\sigma_1, \sigma_2 = \frac{-2\sigma}{2} \pm \sqrt{\left(\frac{-2\sigma}{2}\right)^2 + \left(\sqrt{3}\sigma\right)^2}$$

$$= -\sigma \pm \sqrt{\sigma^2 + 3\sigma^2} = -\sigma \pm 2\sigma$$

$$= -3\sigma, +\sigma$$

Maximum compressive stress = **3 σ**

11.4 (d)

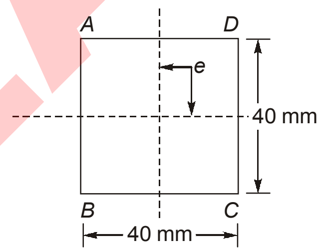
Total bending moment

$$M = Wl + wL\frac{L}{2} = Wl + \frac{wL^2}{2}$$

$\therefore$ Equivalent torque = $\sqrt{M^2 + T^2}$

$$= \left[\left(Wl + \frac{wL^2}{2}\right)^2 + T^2\right]^{\frac{1}{2}}$$

11.5 (d)



Direct stress,

$$(\sigma_1) = \frac{P}{A} = \frac{1600}{40 \times 40} = 1\,\text{N/mm}^2 \text{ (compressive)}$$

Bending stress,

$$(\sigma_2) = \frac{Pe}{z} = \frac{6 \times 1600 \times e}{(40)^3} = 0.15\,e$$

For edge *CD*.

$(-\sigma_1 - \sigma_2) = -1.2$ MPa $\Rightarrow 1 + 0.15e = 1.2$

$\therefore e = 1.333$ mm ; For edge *AB*,

Total stress = $-\sigma_1 + \sigma_2 = -1 + 0.15e$

$= -1 + 0.15 \times 1.33 =$ **– 0.8N/mm²**

UNIT

II

Engineering Materials

Syllabus

Basic Crystallography, Alloys and Phase diagrams, Heat Treatment, Ferrous and Non Ferrous Metals, Non metallic materials, Basics of Nano-materials, Mechanical Properties and Testing, Corrosion prevention and control.

Contents

1 Crystal Systems

1.1 In metals subjected to cold working, strain hardening effect is due to
(a) slip mechanism
(b) twining mechanism
(c) dislocation mechanism
(d) fracture mechanism

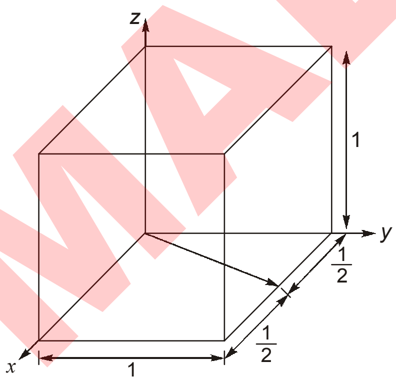
[ESE : 1997]

1.2 Which of the following properties of a solid are dependent on crystal imperfections?
1. Yield stress
2. Melting point
3. Semiconductivity
4. Ductility

Select the correct answer using the codes given below:
(a) 1 and 3
(b) 1, 3 and 4
(c) 2, 3 and 4
(d) 2 and 4

[ESE : 1997]

1.3 A unit cell of a crystal is shown in given figure. The miller indices of the direction (arrow) shown in the figure is



(a) [0 1 2]
(b) [0 2 1]
(c) [1 2 0]
(d) [2 0 1]

[ESE : 1998]

1.4 Match **List-I** (Material) with **List-II** (Structure) and select the correct answer using the codes given below the lists:

	List-I		List-II
A.	Charcoal	**1.**	F.C.C.
B.	Graphite	**2.**	H.C.P.
C.	Chromium	**3.**	Amorphous
D.	Copper	**4.**	B.C.C.

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	3	2	4	1
(c)	2	3	4	1
(d)	2	3	1	4

[ESE : 1998]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

1.5 **Assertion (A):** Refining the grain size of polycrystalline material renders it harder and stronger.
Reason (R): Grain boundaries provide easy paths to dislocation motion.

[ESE : 1998]

1.6 **Assertion (A):** Plastic deformation in metals and alloys is a permanent deformation under load. This property is useful in obtaining products by cold rolling.
Reason (R): Plastic or permanent deformation in metal or alloy is caused by movement of dislocations.

[ESE : 1998]

1.7 Match **List-I** (Crystal structure) with **List-II** (Atomic packing factor) and select the correct answer using the codes given below the lists:

	List-I		List-II
A.	Simple cubic	1.	74%
B.	Body-Centred cubic	2.	74%
C.	Face-Centred cubic	3.	52%
D.	Hexagonal close packed	4.	68%

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	2	1
(c)	3	4	1	2
(d)	4	3	1	2

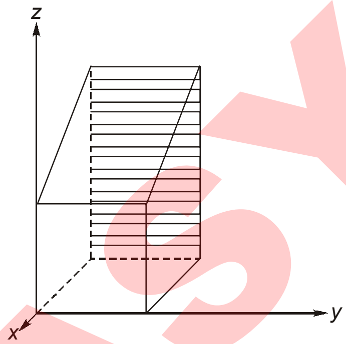
[ESE : 1999]

1.8 Gibb's phase rule is given by
(F = number of degree of freedom
C = number of components
P = number of phases)

(a) $F = C + P$
(b) $F = C + P - 2$
(c) $F = C - P - 2$
(d) $F = C - P + 2$

[ESE : 1999]

1.9 The set of Miller indices of the plane shown in the given figure is



(a) (1 0 0)
(b) $(\bar{1}00)$
(c) (1 0 1)
(d) (1 1 0)

[ESE : 1999]

Answers Crystal Systems

1.1 (c) 1.2 (b) 1.3 (c) 1.4 (b) 1.5 (c) 1.6 (a) 1.7 (a, c) 1.8 (d) 1.9 (b)

Explanations Crystal Systems

1.1 (c)

Dislocation mechanism is responsible for strain hardening.

1.2 (b)

Melting point is not affected by crystal imperfection semiconductivity is affected by point defect.

1.4 (b)

BCC : Li, Na, K, Rb, Cs, Fr, Cr, Fe (α iron and δ iron), Mo, Nob, Ta, W, V, Zr, Ti

FCC : Ac, Al, Ca, Ce, Cu, Au, Ir, Pb, Ni, Pd, Pt, Fe (γ iron), Rn, Rh, Ag, Sr, Th, Yb

HCP : Be, Cd, Co, Mg, Os, Re, Ti, Zn, Zr and He

Amporphous : Glass, Charcoal

1.5 (c)

Refining of grain size means having small grain which don't permit movement of dislocation easily so strength increases

1.7 (a & c)

Both (a) & (c) are correct.

Crystal structure :		APF
Simple cubic	:	0.52
BCC	:	0.68
FCC	:	0.74
HCP	:	0.74

1.8 (d)

$P + F = C + 2$ Gibb's phase rule

1.9 (b)

Intercept on y and z axis is ∞. So taking reciprocal it will be 0, 0 on both x and y-axis. Intercept on x axis is on the negative side of x-axis $(\bar{1}00)$.

2 Alloy and Binary Phase Diagrams

2.1 Consider the following statements:
Addition of silicon to cast iron
1. Promotes graphite module formation
2. Promotes graphite flake formation
3. Increases the fluidity of the molten metal
4. Improves the ductility of cast iron

Which of these statements are correct?
(a) 1 and 4 (b) 2 and 3
(c) 1 and 3 (d) 3 and 4

[ESE : 1995]

2.2 Eutectoid reaction occurs at
(a) 600°C (b) 723°C
(c) 114°C (d) 1493°

[ESE : 1995]

2.3 Match **List-I** (Name of material) with **List-II** (% Carbon range) and select the correct answer using the codes give below the lists:

List-I
A. Hypo-eutectoid steel
B. Hyper-eutectoid steel
C. Hypo-eutectic cast iron
D. Hyper-eutectic cast iron

List-II
1. 4.3 – 6.67
2. 2.0 – 4.3
3. 0.8 – 2.0
4. 0.008 – 0.8

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	1	3	4	2
(c)	4	1	2	3
(d)	1	2	3	4

[ESE : 1995]

2.4 Which one of the following sets of constituents is expected in equilibrium cooling of a hypereutectoid steel from austenitic state?
(a) Ferrite and pearlite
(b) Cementite and pearlite
(c) Ferrite and bainite
(d) Cementite and martensite

[ESE : 1995]

2.5 Addition of magnesium to cast iron increases its
(a) hardness
(b) ductility and strength in tension
(c) Corrosion resistance
(d) creep strength

[ESE : 1995]

2.6 A given steel test specimen is studied under metallurgical microscope. Magnification used is 100 X. In that different phases are observed. One of them is Fe_3C.
The observed phase Fe_3C is also known as
(a) ferrite (b) cementite
(c) austenite (d) martensite

[ESE : 1997]

2.7 **Assertion (A):** Carbon would form an interstitial solid solution with iron.
Reason (R): The atomic radius of iron is smaller than that of carbon.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

2.8 Heating the hypoeutectoid steels to 30°C above the upper critical temperature line, soaking at the temperature and then cooling slowly to room temperature to form a pearlite and ferrite structure, is known as
(a) Hardening (b) Normalising
(c) Tempering (d) Annealing

[ESE : 1999]

2.9 In a eutectic system, two elements are completely
(a) Insoluble in solid and liquid state
(b) Soluble liquid state
(c) Soluble in solid state
(d) Insoluble in liquid state
[ESE : 1999]

2.10 **Assertion (A) :** Carbon forms interstitial solid solution when added to iron.

Reason (R) : The atomic radius of carbon atom is much smaller than that of iron.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1999]

Answers Alloy and Binary Phase Diagrams

2.1 (b) **2.2** (b) **2.3** (a) **2.4** (b) **2.5** (b) **2.6** (b) **2.7** (c) **2.8** (d) **2.9** (b)
2.10 (a)

Explanations Alloy and Binary Phase Diagrams

2.1 (b)
Silicon is strong graphitizer and promotes graphitization (i.e. decomposition of cementite to iron and graphite Graphitizer improves the fluidity of iron).

2.2 (b)
Eutectoid reaction is at 0.76% of carbon at 727°C in iron carbon diagram in which austenite transforms to pearlite. (% of carbon)

2.3 (a)

Hypoeutectoid steel	0.008 – 0.76%C
Hypereutectoid steel	0.76 – 2.1%C
Hypoeutectic steel	2.1 – 4.3%C
Hypereutectic steel	4.3 – 6.64%C

2.4 (b)
Hypereutectoid steel when cooled in equilibrium will result in pro-eutectoid cementite and pearlite whereas hypoeutectoid steel when cooled in equilibrium will result in pro-eutectoid ferrite and pearlite.

2.6 (b)
Cementite has Fe_3C composition, inter metallic compound.

2.7 (c)
Carbon in present as interstitial impurity in iron matrix. The size of iron atom is larger than that of carbon.

2.8 (d)
Slow cooling signifies cooling in furnace so it refer annealing process.

2.9 (b)
Eutectic system implies two solid completely soluble in liquid system and insoluble in solid state

$$\text{Liquid } A \rightleftharpoons \text{Solid } B + \text{solid } C$$

3 Heat Treatment of Steels

3.1 Match **List-I** (Heat treatment) with **List-II** (Effect on the properties) and select the correct answer using the codes given below the lists:

List-I

A. Annealing
B. Nitriding
C. Martempering
D. Normalising

List-II

1. Refined grain structure
2. Improves the hardness of the whole mass
3. Increases surface hardness
4. Improves ductility

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	1	3	4	2
(c)	4	2	1	3
(d)	2	1	3	4

[ESE : 1995]

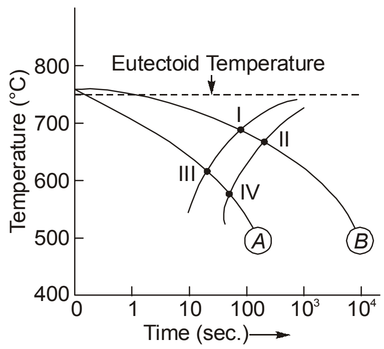
3.2 Consider the following statements
When a metal or alloy is cold worked
1. It is worked below room temperature
2. It is worked below recrystallization temperature
3. Its hardness and strength increases
4. Its hardness increases but strength does not increase

Which of these statements are correct?
(a) 1 and 3 (b) 1 and 3
(c) 2 and 3 (d) 2 and 4
[ESE : 1996]

3.3 Machines tool guideways are usually hardened by
(a) vacuum hardening
(b) martempering
(c) induction hardening
(d) flame hardening **[ESE : 1996]**

3.4 Guideways of lathe beds are hardened by
(a) carburizing (b) cyaniding
(c) nitriding (d) flame hardening
[ESE : 1997]

3.5 Two cooling curves *A* and *B* for eutectoid iron-carbon alloy are superimposed on a continuous cooling transformation diagram as shown in the given figure. Fine pearlite microstructure is represented by the points labelled



(a) I and III (b) II
(c) IV (d) I**[ESE : 1998]**

■■■■

Answers Heat Treatment of Steels

3.1 (a) **3.2** (c) **3.3** (d) **3.4** (d) **3.5** (c)

Explanations Heat Treatment of Steels

3.1 (a)

Annealing is softening process which improves ductility. Normalizing is cooling of material in air so it refines grain structures (due to faster cooling than annealing) Nitriding is employed with alloy steel in which different alloys forms their respective nitrides so surface hardness improves.

Martempering is two stage cooling process avoiding the nose of TTT diagram to from martensite. The two stage cooling minimizes distortion and quench crack.

3.2 (c)

When metal is cold worked (below recrystalization) then strain hardening takes place due to which hardness and strength both increases.

3.3 (d)

Flame hardening is done to increase the hardness at surface and have tough core.

3.5 (c)

Slow cooling above nose of TTT diagram will have fine pearlite. Point IV will correspond 100% completion line.

■■■■

4 Mechanical Testing & Mechanical Properties of Materials

4.1 In low carbon steels, presence of small quantities sulphur improves

(a) weldability (b) formability
(c) machinability (d) hardenability

[ESE : 1995]

4.2 During tensile-testing of a specimen using Universal Testing Machine, the parameters actually measured include

(a) True stress and true strain
(b) Poisson's ratio and Young's modulus
(c) Engineering stress and engineering strain
(d) load and elongation

[ESE : 1996]

4.3 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Toughness
B. Endurance strength
C. Resistance to abrasion
D. Deflection in beam

List-II

1. Moment area method
2. Hardness
3. Energy absorbed before fracture in a tension test
4. Fatigue loading

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	4	3	2	1
(c)	3	4	2	1
(d)	3	4	1	2

[ESE : 1997]

4.4 Match **List-I** (Elastic properties of an isotropic elastic material) with **List-II** (Nature of strain produced) and select the correct answer using the codes given below the lists:

List-I

A. Young's modulus
B. Modulus of rigidity
C. Bulk modulus
D. Poisson's ratio

List-II

1. Shear strain
2. Normal strain
3. Transverse strain
4. Volumetric strain

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	1	3	4
(c)	2	1	4	3
(d)	1	2	4	3

[ESE : 1997]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.5 **Assertion (A) :** The notch sensitivity of cast iron component is zero.

Reason (R) : Cast iron does not have yield point.

[ESE : 1997]

4.6 **Assertion (A) :** Specimens for impact testing are never notched.

Reason (R) : A notch introduces tri-axial tensile stresses which cause brittle fracture.

[ESE : 1999]

Answers Mechanicals Testing & Mechanical Properties of Materials

4.1 (c) 4.2 (d) 4.3 (c) 4.4 (c) 4.5 (b) 4.6 (d)

Explanations Mechanicals Testing & Mechanical Properties of Materials

4.1 (c)

Sulphur forms MnS when manganese is added which increases machinability. Its amount is controlled because formation of FeS leads to hot shortness as FeS is low melting eutectic.

4.2 (d)

Load and elongation is measured in tensile test.

4.3 (c)

Endurance strength is used in fatigue loading. Deflection in beam in related to moment area method.

4.4 (c)

$$\text{Young's modulus } (E) = \frac{\text{Normal stress}}{\text{Normal strain}}$$

$$\text{Modulus of rigidity } (G) = \frac{\text{Shear stress}}{\text{Shear strain}}$$

$$\text{Bulk modulus} = \frac{\text{Change in pressure}}{\text{Volumetric strain}}$$

$$\text{Poisson's ratio} = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

4.5 (b)

Notch sensitivity of gray cast iron is zero because of presence of graphite flakes which have itself many notches so practically insensitive for stress concentration.

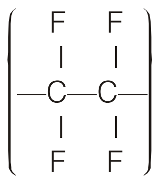
4.6 (d)

Specimen of impact testing are notched (45°) to test the behaviour of ductile material for failure as brittle material when tri-axial stress induced in it. This test is also used to check the susceptibility of material for ductile to brittle transition.

■■■■

5 Plastic, Ceramic and Composite Materials

5.1 The structure of a polymer is shown in the given figure. This polymer finds special application in



(a) packaging (b) adhesives
(c) bearings (d) fertilizer

[ESE : 1995]

5.2 Consider the following statements:
Thermosetting plastic are
1. Formed by addition polymerization
2. Formed by condensation polymerization
3. Softened on heating and hardened on cooling for any number of times
4. modulated by heating and cooling

Which of these statements are correct?
(a) 1 and 3 (b) 2 and 4
(c) 1 and 4 (d) 2 and 3

[ESE : 1996]

5.3 Match **List-I** and **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Polyethylene	**1.** Adhesive
B. Polyurethane	**2.** Film
C. Cyanoacrylate	**3.** Wire
D. Nylon	**4.** Foam

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	4	2	3	1
(c)	2	4	1	3
(d)	4	2	1	3

[ESE : 1996]

5.4 Consider the following statements
Fibre Reinforced plastic are:
1. Made of thermosetting resins and glass fibre
2. Made of thermoplastic resins and glass fibre.
3. Anisotropic
4. Isotropic

Which of these statements are correct?
(a) 1 and 4 (b) 1 and 3
(c) 2 and 3 (d) 2 and 4

[ESE : 1996]

5.5 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Neoprene
B. Bakelite
C. Foamed poly-urethane
D. Araldite

List-II
1. Electric switches
2. Adhesive
3. Thermal insulator
4. Oil seal

Codes:

	A	B	C	D
(a)	4	1	2	3
(b)	1	4	2	3
(c)	4	1	3	2
(d)	1	4	3	2

[ESE : 1997]

5.6 Which one of the following materials is used for car tyres as a standard material?
(a) Styrene-butadiene Rubber (SBR)
(b) Butyl rubber
(c) Nitrile rubber
(d) Any one of the above depending upon the need

[ESE : 1997]

5.7 Consider the following statements:

The strength of the fibre reinforced plastic product

1. Depends upon the strength of the fibre alone
2. Depends upon the fibre and plastic
3. Is isotropic
4. Is anisotropic

Which of these statements are correct?

(a) 1 and 3 (b) 1 and 4
(c) 2 and 3 (d) 2 and 4 **[ESE : 1999]**

5.8 Consider the following pairs of plastics and their distinct characteristics:

1. Acrylics...Very good transparency to light
2. Polycarbonate...Poor impact resistance
3. PTFE...Low coefficient of friction
4. Polypropylene...Excellent fatigue strength

Which of these statements are correct?

(a) 2 and 3 (b) 1 and 3
(c) 1 and 4 (d) 2 and 4 **[ESE : 1999]**

Answers Plastic, Ceramic and Composite Materials

5.1 (c) 5.2 (b) 5.3 (c) 5.4 (b) 5.5 (c) 5.6 (a) 5.7 (d) 5.8 (b, c)

Explanations Plastic, Ceramic and Composite Materials

5.1 (c)

It is monomer of Poly-Tetra-Fluro-Ethene (PTFE). It is chemically inert in almost all environment, excellent electrical properties, low coefficient of friction. It is used as anti-corrosive seals, chemical pipes and valves, bearings, anti adhesive coating, high temperature electronic parts.

5.2 (b)

Thermosetting plastic become soft during their first heating and become very hard during cooling. They do not soften during subsequent heating and rather become harder during cooling.

5.5 (c)

(i) Neoprenes are used as wire and cable, chemical tank linings, belts, hoses, seals and gaskets. It has excellent ozone, heat and weathering resistance and also good oil resistance.

(ii) Bakelite has excellent thermal stability to over 150°C and may be compounded with a large number of resins, fillers. It is used in motor housing, telephones, auto distributor and electrical fixtures.

(iii) Foamed Polyurethane are commonly used as cushions in auto mobiles and furniture as well as in packaging and thermal insulation.

(iv) Araldite has excellent combination of mechanical properties and corrosion resistance, dimensionally stable, good adhesion, relatively inexpensive and good electrical properties.

5.8 (b, c)

Poly-tetra-fluoro-ethylene has very low coefficient of friction and it does not stick to other materials. Poly propylene has the capability to be bent repeatedly and no crack will develop in it.

6 Properties & Application of Various Ferrous & Non-ferrous Metals and Their Alloys

6.1 Match **List-I** (Alloy)with **List-II** (Use) and select the correct answer using the codes give below the lists:

List-I
- **A.** Low carbon steel
- **B.** Hadfield manganese steel
- **C.** Constantan
- **D.** Babbitt alloy

List-II
1. Bearing
2. Thermocouple
3. Wire nails
4. Bulldozer blades

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	4	1	2
(c)	3	2	1	4
(d)	3	4	2	1

[ESE : 1995]

6.2 18/8 stainless steel contains
(a) 18% stainless, 8% chromium
(b) 18% chromium, 8% nickel
(c) 18% tungsten, 8% nickel
(d) 18% tungsten, 8% chromium

[ESE : 1996]

6.3 Tin base white metals are used where the bearings are subjected to
(a) large surface wear
(b) elevated temperature
(c) light load and pressure
(d) high pressure and load,

[ESE : 1996]

6.4 Alloy steel which is work hardenable and which is used to make the blades of bulldozers, bucket wheel excavators and other earth moving equipment contain iron, carbon and
(a) Chromium (b) Silicon
(c) Manganese (d) Magnesium

[ESE : 1996]

6.5 Which of the following pairs regarding the effect of alloying elements in steel are correctly matched?
1. Molybdenum : Forms abrasion resisting particles
2. Phosphorous : Improves mechanability in free cutting steels
3. Cobalt : Contributes to red hardness by hardening ferrite
4. Silicon Reduces oxidation resistance

Which of these statements are correct?
(a) 2, 3 and 4 (b) 1, 3 and 4
(c) 1, 2 and 3 (d) 1, 2 and 4

[ESE : 1996]

6.6 **Assertion (A) :** Austenitic stainless steel contains 18% chromium and 8% nickel. Since it retains its austenitic structure at room temperature, it is called austenitic stainless steel.
Reason (R) : Chromium present in the steel improves its corrosion resistance by forming a thin film of chromium oxide on the surface.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

6.7 Match **List-I** (Alloying element in steel) with **List-II** (Property conferred on steel by the element) and select the correct answer using the codes given below the lists:

	List-I		List-II
A.	Nickel	1.	Corrosion resistance
B.	Chromium	2.	Magnetic permeability
C.	Tungsten	3.	Heat resistance
D.	Silicon	4.	Hardenability

Codes:

	A	B	C	D
(a)	4	1	3	2
(b)	4	1	2	3
(c)	1	4	3	2
(d)	1	4	2	3

[ESE : 1998]

6.8 Match **List-I** (Alloys) with **List-II** (Applications) and select the correct answer using the codes given below the lists:

List-I
A. Chromel B. Babbit alloy
C. Nimonic alloy D. High speed steel

List-II
1. Journal bearing
2. Milling cutter
3. Thermocouple wire
4. Gas turbine blades

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	3	4	1	2
(c)	2	4	1	3
(d)	2	1	4	3

[ESE : 1998]

6.9 **Assertion (A) :** Cast iron is generally hard, brittle and wear resistant.
Reason (R) : Cast iron contains more than 20% carbon and as such the percentage cementite in it is higher.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1998]

6.10 Match **List-I** (Material) with **List-II** (Applications) and select the correct answer using the codes given below the Lists:

List-I
A. Tungsten carbide B. Silicon nitride
C. Aluminium oxide D. Silicon carbide

List-II
1. Abrasive wheels
2. Heating elements
3. Pipes for conveying liquid metals
4. Drawing dies

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	4	3	2	1
(c)	3	4	2	1
(d)	4	3	1	2

[ESE : 1999]

Answers Properties & Application of Various Ferrous and Non-ferrous Metals and Their Alloys

6.1 (d) **6.2** (b) **6.3** (a) **6.4** (c) **6.5** (c) **6.6** (b) **6.7** (a) **6.8** (a) **6.9** (c) **6.10** (d)

Explanations Properties & Application of Various Ferrous and Non-ferrous Metals and Their Alloys

6.1 (d)

- Hadfield manganese steel has high surface hardness and tough core so used as bulldozer blades.
- Constantan is nickel based alloy used as Thermocouple.
- Babbit alloy are copper based alloy having tin, zinc, lead or arsenic. It is used as bearing material.
- Low carbon steel is used in wire nails.

6.2 (b)

18/8 signifies 18% Chromium and 8% nickel. It is also called austenitic stainless steel, non-magnetic in nature, Titanium & niobium added to stabilize the carbon.

6.3 (a)

Tin based babbits have better corrosion and wear resistance as compared to lead based babbits.

Lead is added to these babbits to reduce their cost however lead decreases the load bearing ability of these bearing.

6.4 (c)

Hadfield manganese steel has high surface hardness and tough core so used as bulldozer blades.

6.5 (c)

Silicon are strong oxidizer.

6.7 (a)

Nickel	:	Increases hardenability
Chromium	:	Corrosion resistance
Tungsten	:	Heat resistance
Silicon	:	Improves magnetic permeability

6.9 (c)

Percentage of carbon is 6.67% (limited) in Fe–C alloys

6.10 (d)

Aluminium oxide	:	Abrasive wheel
Tungsten carbide	:	Drawing dies

UNIT III

Mechanisms and Machines

Syllabus

Types of Kinematics Pair, Mobility, Inversions, Kinematic Analysis, Velocity and Acceleration Analysis of Planar Mechanisms, CAMs with uniform acceleration and retardation, cycloidal motion, oscillating followers; Vibrations – Free and forced vibration of undamped and damped SDOF systems, Transmissibility Ratio, Vibration Isolation, Critical Speed of Shafts. Gears – Geometry of tooth profiles, Law of gearing, Involute profile, Interference, Helical, Spiral and Worm Gears, Gear Trains- Simple, compound and Epicyclic; Dynamic Analysis – Slider – crank mechanisms, turning moment computations, balancing of Revolving & Reciprocating masses, Gyroscopes –Effect of Gyroscopic couple on automobiles, ships and aircrafts, Governors, Flywheel.

Contents

1 Displacement, Velocity and Acceleration

1.1 The instantaneous centre of rotation of a rigid thin disc rolling on a plane rigid surface is located at
(a) the centre of the disc
(b) an infinite distance on the plane surface
(c) the point of contact
(d) the point on the circumference situated vertically opposite to the contact point
[ESE : 1995]

1.2 The directions of Coriolis component of acceleration, $2\omega V$, of the slider A with respect to the coincident point B is shown in figure 1, 2, 3 and 4. Directions shown by figures

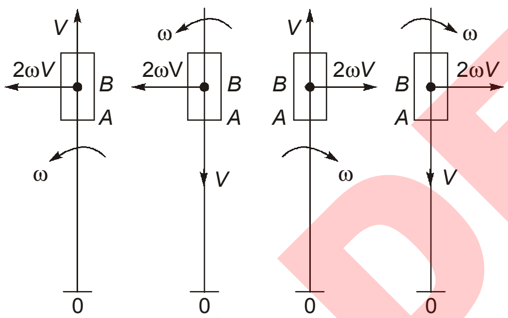
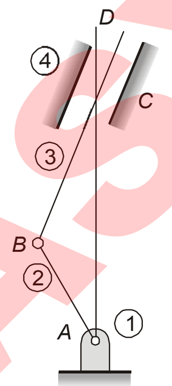


Fig. 1 Fig. 2 Fig. 3 Fig. 4

(a) 2 and 4 are wrong
(b) 1 and 2 are wrong
(c) 1 and 3 are wrong
(d) 2 and 3 are wrong
[ESE : 1995]

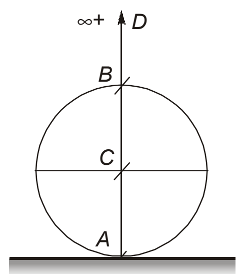
1.3 The centre of gravity of the coupler link in a 4-bar mechanism would experience
(a) no acceleration
(b) only linear acceleration
(c) only angular acceleration
(d) both linear and angular accelerations
[ESE : 1996]

1.4 In the Mechanism *ABCD* shown in the given figure, the fixed link is denoted as (1), Crank *AB* as (2) rocker *BD* (3), Swivel trunnion at *C* as (4) The instantaneous centre I_{41} is at



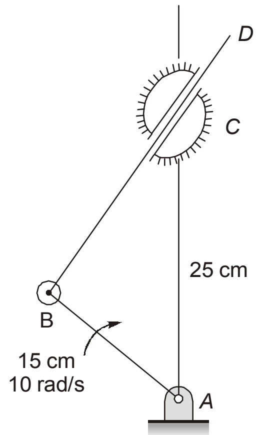
(a) the centre of swivel trunnion
(b) the intersection of line *AB* and a perpendicular to *BD* to
(c) infinity along *AC*
(d) infinity perpendicular to *BD*
[ESE : 1996]

1.5 The instantaneous centre of motion of rigid thin disc wheel rolling on plane rigid surface shown in the figure, is located at the point



(a) *A* (b) *B*
(c) *C* (d) *D*
[ESE : 1996]

1.6 In the figure shown, crank *AB* is 15 cm long and is rotating at 10 rad/s *C* is vertically above *A*. *CA* equals 25 cm. *C* is a swivel trunnion through which *BD* (40 cm.) Slides. If *ABCD* becomes a vertical line during its motion, the angular velocity of the swivel trunnion at that instant will be



(a) (150/10) rad/s (b) (100/25) rad/s
(c) (100/15) rad/s (d) (100/10) rad/s

[ESE : 1997]

1.7 In order to draw the acceleration diagram, it is necessary to determine the Coriolis component of acceleration in the case of
(a) crank and slotted lever quick return mechanism
(b) slider-crank mechanism
(c) four bar mechanism
(d) pantograph

[ESE : 1997]

1.8 Two links *OA* and *OB* are connected by a pin joint at '*O*'. The link *OA* turns with angular velocity ω_1 radians per second in the clockwise direction and the link *OB* turns with angular velocity ω_2 radians per second in the anticlockwise direction. If the radius of the pin at '*O*' is '*r*', then the rubbing velocity at the pin joint '*O*' will be
(a) $\omega_1.\omega_2.r$ (b) $(\omega_1 - \omega_2)r$
(c) $(\omega_1 + \omega_2)r$ (d) $(\omega_1 - \omega_2)2r$

[ESE : 1998]

1.9 When a slider moves with a velocity '*V*' on a link rotating at an angular speed of ω the Coriolis component of acceleration is given by
(a) $\sqrt{2V\omega}$ (b) $V\omega$
(c) $V\omega/2$ (d) $2V\omega$ [ESE : 1998]

1.10 The total number of instantaneous centres for a mechanism consisting of '*n*' links is
(a) $n/2$ (b) n
(c) $\frac{n-1}{2}$ (d) $\frac{n(n-1)}{2}$

[ESE : 1998]

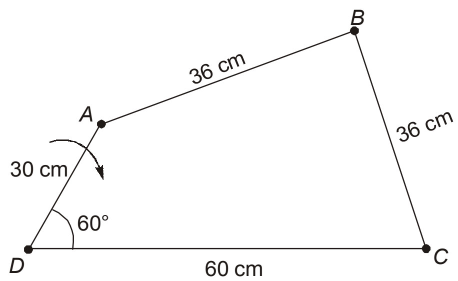
1.11 In SHM, with respect to the displacement vector, the positions of velocity vector and acceleration vector will be respectively
(a) 180° and 90° (b) 90° and 180°
(c) 0° and 90° (d) 90° and 0°

[ESE : 1998]

1.12 The relative acceleration of two points which are at variable distance apart on a moving link can be determined by using the
(a) three centres in line theorem
(b) instantaneous centre of rotation
(c) Coriolis component of acceleration method
(d) Klein's construction

[ESE : 1999]

1.13 Consider a four-bar mechanism shown in the given figure. The driving link *DA* is rotating uniformly at a speed of 100 r.p.m clockwise.



The velocity of *A* will be
(a) 300 cm/s (b) 314 cm/s
(c) 325 cm/s (d) 400 cm/s

[ESE : 1999]

Answers	Displacement, Velocity and Acceleration

1.1 (c) 1.2 (a) 1.3 (d) 1.4 (a) 1.5 (a) 1.6 (a) 1.7 (a) 1.8 (c) 1.9 (d)
1.10 (d) 1.11 (b) 1.12 (c) 1.13 (b)

Explanations — Displacement, Velocity and Acceleration

1.1 (c)

If the two links form a higher kinematic pair with pure rolling. Than their instantaneous centre lies at the point of contact it self.

1.2 (a)

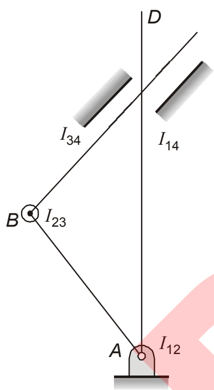
$a_{coriolis} = 2\omega v$

Along a line rotated 90° from the sliding velocity vector in a direction same as that of the angular velocity of the slotted lever.

1.3 (d)

The centre of gravity of the link in a 4-bar mechanism would experience both linear and angular acceleration.

1.4 (a)



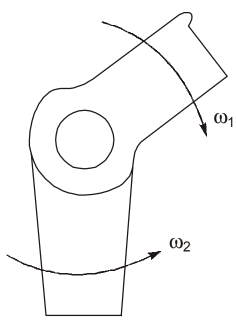
1.5 (a)

If the two links form a higher kinematic pair with pure rolling. Than their instantaneous centre lies at the point of contact itself.

1.7 (a)

In crank and slotted lever quick return mechanism there exists coincident points in two kinematic links and hence, the sliding pair revolve which give Coriolis components of acceleration

1.8 (c)



$$V_{rubbing} = r_b(\vec{\omega_1} - \vec{\omega_2}) = (\omega_1 + \omega_2)\, r_b$$

1.9 (d)

$$\text{Coriolis components} = 2\vec{\omega} \times \vec{V}$$

1.10 (d)

$$\text{Total number of } I.C. = \frac{n(n-1)}{2}$$

1.11 (b)

Let $x = A \sin\omega t$

$V = A\omega \cos \omega t = A\omega \sin(\omega t + 90°)$

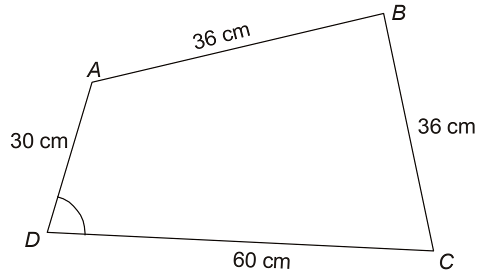
$F = -A\omega^2 \sin\omega t = A\omega^2 \sin(\omega t + 180°)$

1.12 (c)

The correct option is (c) i.e., Coriolis component of acceleration method.

- Instantaneous centre of rotation method is used for the analysis of velocity only and not for acceleration.
- Klein's construction is used for only slides and crank mechanism.
- Therefore the relative acceleration of two point (like in withworth quick return mechanism) which are at variable distance apart on a moving link can be determined by Coriolis component of acceleration method.

1.13 (b)

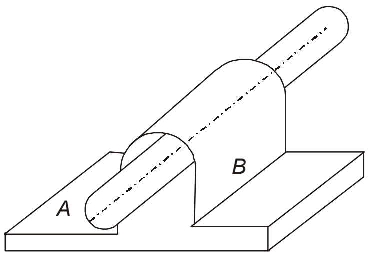


$$V = r\omega = 30 \times \frac{2\pi \times 100}{60} = 314 \text{ cm/s}$$

■■■■

2 Planar Mechanism

2.1 A round bar *A* passes through the cylindrical hole in *B* as shown in the given figure. Which one of the following statements is correct in this regard?



(a) The two links shown form a kinematic pair
(b) The pair is completely constrained
(c) The pair has incomplete constraint
(d) The pair is successfully constrained

[ESE : 1995]

Directions: The following items consists of two statements; one labelled as **'Assertion'** and the other as **'Reason'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

2.2 **Assertion (A):** The elements of higher pairs must be force closed.
Reason (R): This is required in order to provide completely constrained motion.

[ESE : 1995]

2.3 **Assertion (A):** Hydraulic fluid is one form of link.
Reason (R): A link need not necessarily be a rigid body but it must be a resistant body.

[ESE : 1996]

2.4 **Assertion (A):** The Ackermann steering gear is commonly used in all automobiles.
Reason (R): It has the correct inner turning angle θ for all positions.

[ESE : 1996]

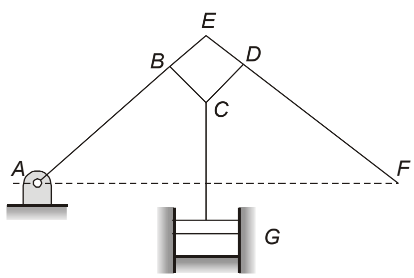
2.5 Which of the following statements regarding laws governing the friction between dry surface are correct?

1. The friction force is dependent on the velocity of sliding.
2. The friction force is directly proportional to the normal force.
3. The friction force is dependent on the materials of the contact surfaces.
4. The Friction force is independent of the area of contact surfaces.

(a) 2, 3 and 4 (b) 1 and 3
(c) 2 and 4 (d) 1, 2,3 and 4

[ESE : 1996]

2.6 **Assertion (A)**: The given line diagram of Watt's indicator mechanism is a type of crank and lever mechanism.



Reason (R): BCD acts as a lever.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

2.7 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Quadric cycle chain
B. Single slider crank chain
C. Double slider crank chain
D. Crossed slider crank chain

List-II
1. Rapson's slide
2. Oscillating cylinder engine mechanism
3. Ackermann steering mechanism
4. Oldham coupling

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	4	3	1	2
(c)	3	2	4	1
(d)	3	4	2	1

[ESE : 1997]

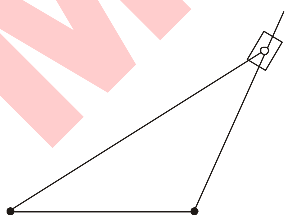
2.8 Which of the following pair(s) is /are correctly matched?

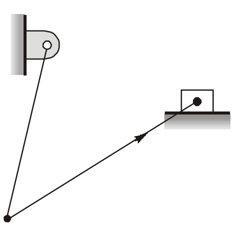
I. Four bar chain : Oscillating- oscillating converter
II. Inertia governor : Rate of change of engine speed
III. Hammer blow : Reciprocating unbalanced mass

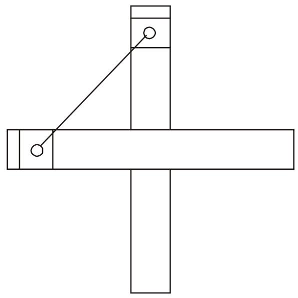
Select the correct answer using the codes given below :
(a) I alone (b) I, II and III
(c) II and III (d) I and III

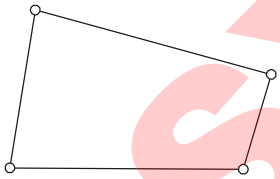
[ESE : 1998]

2.9 Which of the following are examples of a kinematic chain?

1. 

2. 

3. 

4. 

Select the correct answer using the codes given below :
(a) 1, 3 and 4 (b) 2 and 4
(c) 1, 2 and 3 (d) 1, 2, 3 and 4

[ESE : 1998]

2.10 Which of the following pairs are correctly matched? Select the correct answer using the codes given below the pairs.

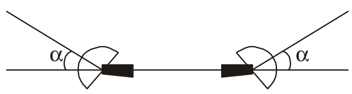
Mechanism
1. Whitworth quick return motion
2. Oldham's coupling
3. Scotch yoke

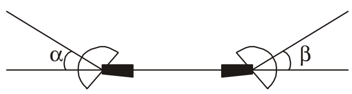
Chain from which derived
1. Single slider crank chain
2. Four bar chain
3. Double Slider crank chain

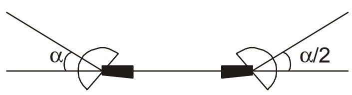
Code:
(a) 1 and 2 (b) 1, 2 and 3
(c) 1 and 3 (d) 2 and 3

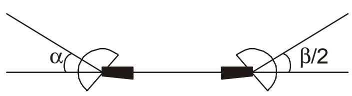
[ESE : 1998]

2.11 Which one of the following figures representing Hooke's jointed inclined shaft system will result in a velocity ratio of unity?

(a) 

(b) 

(c) 

(d) 

[ESE : 1998]

2.12 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. 4 links, 4 turning pairs
B. 3 links, 3 turning pairs
C. 5 links, 5 turning pairs
D. footstep bearing

List-II

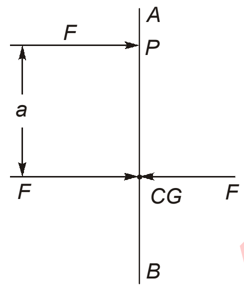
1. Complete constraint
2. Successful constraint
3. Rigid frame
4. Incomplete constraint

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	1	3	2	4
(c)	3	1	2	4
(d)	1	3	4	2

[ESE : 1999]

2.13 A link AB is subjected to a force F (→) at a point P perpendicular to the link at a distance a from the CG as shown in the figure



This will result in

(a) an inertia force F(→) through the CG and no inertia torque
(b) an inertia torque F.a (↺) and no inertia force
(c) both inertia force F(→) through the CG and inertia torque F.a (↺)
(d) both inertia force F(←) through the CG and inertia torque F.a (↻) [ESE : 1999]

2.14 In a single slider four-bar linkage when the slider is fixed, it form a mechanism of

(a) hand pump
(b) reciprocating engine
(c) quick return
(d) oscillating cylinder [ESE : 1999]

■■■■

Answers Planar Mechanism

2.1 (c)	2.2 (a)	2.3 (a)	2.4 (c)	2.5 (a)	2.6 (d)	2.7 (c)	2.8 (b)	2.9 (d)
2.10 (c)	2.11 (a)	2.12 (d)	2.13 (c)	2.14 (a)				

Explanations Planar Mechanism

2.1 (c)

A round bar in a cylindrical hole can revolve as well as reciprocate. Therefore, the pair is incompletely constrained i.e. relative motion is possible in more than one direction.

A rectangular bar in a rectangular hole can only reciprocate. Therefore, the pair is completely constrained i.e. relative motion is possible in only one direction.

Foot step bearing in a shaft is an example of successfully constrained motion. i.e. the motion is made constrained with some external forces.

2.2 (a)

Elements of higher pair like follower in cam is under the action of gravity or spring force.

2.3 (a)

Link need not necessarily be a rigid body but it must be a resistant body so that it is capable of transmitting motion from one member to another without appreciable deformation in it. For eg: in hydraulic lifts it transmits motion.

2.4 (c)

Ackermann steering gear fulfils fundamental equation for gearing at middle and two extreme positions not in all positions.

2.5 (a)

Laws of friction:

The force of solid friction

1. is directly proportional to normal force between the two surfaces
2. opposes the motion between the surfaces
3. depends upon the material of the two surfaces
4. is independent of the area of contact
5. is independent of the velocity of sliding

The last of these laws (i.e. point 5) is not true in the strict sense as it has been found that the friction force decreases slightly with the increase in velocity.

Only option (2) and (3) is correct.

2.6 (d)

A Watt's indicator diagram, also known as Watt's straight line mechanism or double lever mechanism, consists four link (as shown in figure). Link *BCD* and *EF* acts as lever. The displacement of link *BFD* is directly proportional to the pressure of gas or steam which acts on the plunger.

2.7 (c)

4-Bar Mechanism:

(1) Quadric cycle chain → Ackermann steering

(2) Single slider crank chain → oscillating cylinder engine mechanism

(3) Double slider crank chain → Oldham coupling

(4) Crossed slider crank chain → Rapson's slide

2.8 (b)

Four bar chain: Oscillating-oscillating converter.

Inertia governor: Rate of change of engine speed.

Hammer blow: Reciprocating unbalanced mass.

2.9 (d)

For kinematic chain

$$3l = 2p - 4$$

where, l = number of link; p = number of pair

here $p = 4$ $\therefore l = 4$

2.10 (c)

Oldham's coupling → Double slider crank chain

2.11 (a)

For double Hooke's joint θ_A and θ_B are equal for all the time and hence, speed ratio, $\frac{\omega_B}{\omega_A}$ is always unity.

2.12 (d)

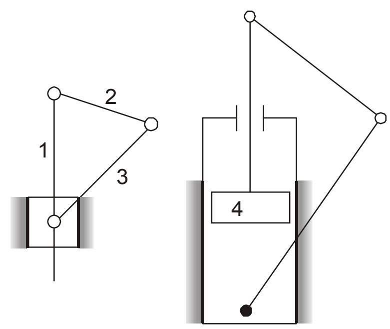
If $l = (2p - 4)$ → Complete constraint

$l > (2p - 4)$ → Rigid frame

$l < (2p - 4)$ → Incomplete constraints

2.14 (a)

If is the fourth inversion of slider crank chain when slider is fixed



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3 Cams

3.1 In a cam drive with uniform velocity follower, the slope of the displacement must be as shown in Fig. I. But in actual practice it is as shown in Fig. II (i.e. rounded at the corners).

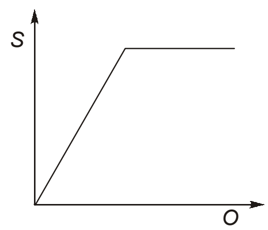


Fig. I

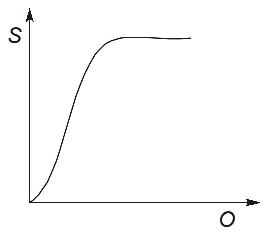


Fig. II

This is because of

(a) the difficulty in manufacturing cam profile
(b) loose contact of follower with cam surface
(c) The acceleration in the beginning and retardation at the end of stroke would require to be infinitely high
(d) uniform velocity motion is a partial parabolic motion [ESE : 1996]

3.2 In a cam drive, it is essential to offset the axis of a follower to

(a) decrease the side thrust between the follower and guide
(b) decrease the wear between follower and cam surface
(c) take care of space limitation
(d) reduce the cost [ESE : 1998]

3.3 For a given lift of the follower in a given angular motion of the cam, the acceleration/ retardation of the follower will be the least when the profile of the cam during the rise portion is

(a) such that the follower motion is simple harmonic
(b) such that the follower motion has a constant velocity from start to end
(c) a straight line, it being a tangent cam
(d) such that the follower velocity increases linearly for half the rise portion and then decreases linearly for remaining half of the rise portion [ESE : 1999]

■■■■

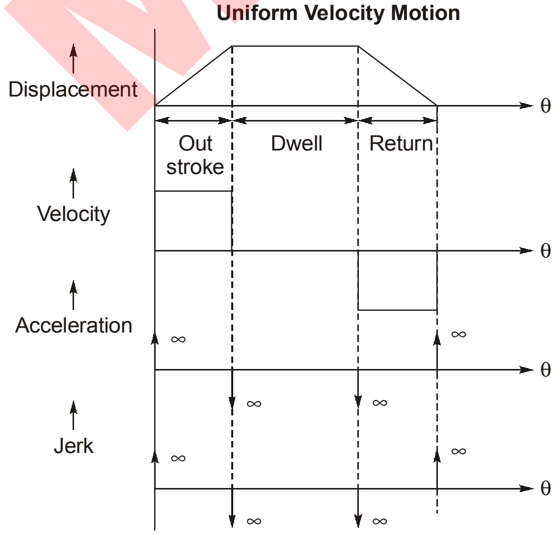
Answers Cams

3.1 (c) 3.2 (b) 3.3 (b)

Explanations Cams

3.1 (c)

Uniform Velocity Motion



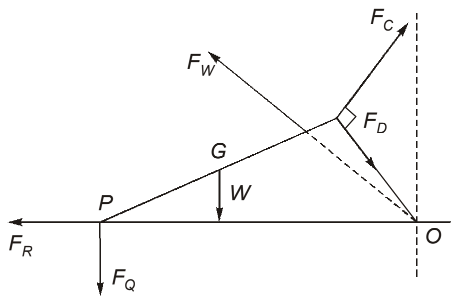
3.2 (b)

If the follower movement is displacement from the cam centre then the follower is called as an offset follower, offsetting results in reduced forces and stresses. The offsetting eccentricity should be in the direction to improve force components tending to jam the translating follower in its bearing guide and decrease the wear between follower and cam surface.

■■■■

4 Dynamic Analysis of Slider-crank

4.1 With reference to the engine mechanism shown in the given figure, match **List-I** with **List-II** and select the correct answer using the codes given below the lists:



List-I	List-II
A. F_Q	1. Inertia force of reciprocating mass
B. F_R	2. Inertia force of connecting rod
C. F_W	3. Crank effort
D. F_C	4. Piston side thrust

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	1	2	3	4
(c)	4	1	2	3
(d)	4	1	3	2

[ESE : 1996]

4.2 What is the correct sequence of the following steps in engine analysis?
1. Vibration analysis.
2. Inertia force analysis.
3. Balancing analysis.
4. Velocity and Acceleration analysis.

Select the correct answer using the codes given below :

(a) 2, 4, 1, 3 (b) 2, 4, 3, 1
(c) 4, 2, 1, 3 (d) 4, 2, 3, 1

[ESE : 1997]

4.3 Which one of the following pairs is correctly matched?
(a) Governor : Interference
(b) Gears : Hunting
(c) Klein's construction : acceleration of piston
(d) Cam : Pinion [ESE : 1999]

■■■■

Answers Dynamic Analysis of Slider-crank

4.1 (c) **4.2** (d) **4.3** (c)

Explanations Dynamic Analysis of Slider-crank

4.1 (c)

F_Q : Piston side thrust
F_R : Inertia force of reciprocating mass
F_W : Inertia force of connecting rod
F_c : Crank effort

4.2 (d)

The correct option is (d) i.e., the correct sequence is velocity and acceleration analysis → Inertial force analysis → Balancing analysis → Vibration analysis.

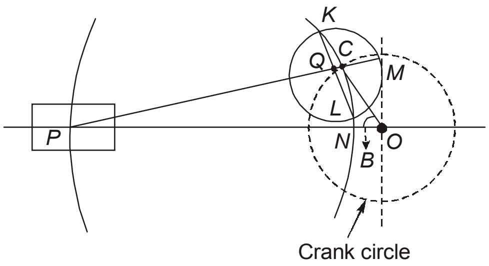
4.3 (c)

Governor	Hunting
Gear	Interference
Klein's construction	acceleration of piston
Cam	Follower

■■■■

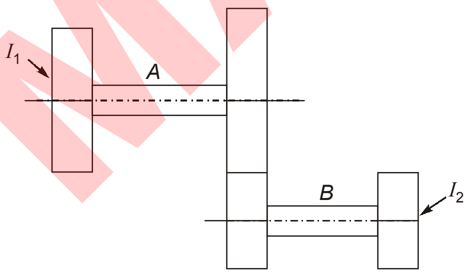
5 Gear and Gear Train

5.1 Klein's construction for determining the acceleration of piston *P* is shown in the given figure. When *N* coincides with *O*



(a) acceleration of piston is zero and its velocity is zero
(b) acceleration is maximum and velocity is maximum
(c) acceleration is maximum and velocity is zero
(d) acceleration is zero and velocity is maximum [ESE : 1995]

5.2 A torsional system with discs of moment of inertia I_1 and I_2, shown in the given figure, is gear driven such that the ratio of the speed of shaft *B* to shaft *A* is '*n*'. Neglecting the inertia of gears, the equivalent inertia of disc of *B* at the speed of shaft *A* is equal to



(a) nI_2 (b) n^2I_2
(c) I_2/n^2 (d) I_2/n [ESE : 1995]

5.3 Which one of the following pairs is not correctly matched?
(a) Positive drive .... Belt drive
(b) High velocity ratio .... Worm gearing
(c) To connect non-parallel and non-intersecting shafts .... Spiral gearing
(d) Diminished noise and smooth operation .... Helical gears [ESE : 1995]

5.4 Which one of the following is true for involute gears?
(a) Interference is inherently absent
(b) Variation in centre distance of shaft increases radial force
(c) A convex flank is always in contact with concave flank
(d) Pressure angle is constant through the teeth engagement

[ESE : 1995]

5.5 The gear train usually employed in clocks is a
(a) reverted gear train
(b) simple gear train
(c) sun and planet gear
(d) differential gear [ESE : 1995]

5.6 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Interference
B. Dynamic load on tooth
C. Static load
D. Contact ratio

List-II
1. Arc of approach, arc of recess, circular pitch
2. Lewis equation
3. Minimum number of teeth on pinion
4. Inaccuracies in tooth profile

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	1	2	3	4
(c)	4	3	2	1
(d)	3	4	2	1

[ESE : 1995]

5.7 A fixed gear having 200 teeth is in mesh with another gear having 50 teeth. The two gears are connected by an arm. The number of turns made by the smaller gear for one revolution of arm about the centre of the bigger gear is

(a) $\frac{2}{4}$ (b) 3
(c) 4 (d) 5

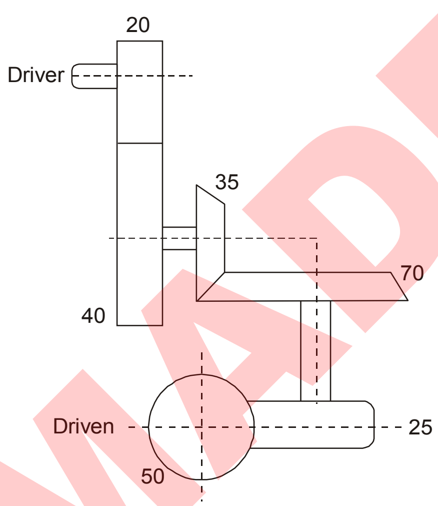
[ESE : 1996]

5.8 An involute pinion and gear are in mesh. If both have the same size of addendum, then there will be an interference between the

(a) tip of the gear tooth and flank of pinion
(b) tip of the pinion and flank of gear
(c) flanks of both gear and pinion
(d) tips of both gear and opinion

[ESE : 1996]

5.9 A compound train consisting of spur, bevel and spiral gears is shown in the given figure along with the teeth numbers marked against the wheels. Overall speed ratio of the train is



(a) 8 (b) 2
(c) $\frac{1}{2}$ (d) None of these

[ESE : 1996]

5.10 Which of the following statements are correct?

1. For constant velocity ratio transmission between two gears, the common normal at the point of contact must always pass through a fixed point on the line joining the centres of rotation of the gears.
2. For involute gears the pressure angle changes with change in centre distance between gear.
3. The velocity ratio of compound gear train depends upon the number of teeth of the input and output gears only.
4. Epicyclic gear trains involve rotation of at least one gear axis about some other gear axis.

(a) 1, 2 and 3 (b) 1 and 3
(c) 1, 2 and 4 (d) 2, 3 and 4

[ESE : 1996]

5.11 Match **List-I** (Positioning of two shafts) with **List-II** (Possible connection) and select the correct answer using the codes given below the lists:

List-I
A. Parallel shafts with slight offset
B. Parallel shafts at a reasonable distance
C. Perpendicular shafts
D. Intersecting shafts

List-II
1. Hooks joint
2. Worm and wheel
3. Oldham coupling
4. Belts and pulley

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	4	3	1	2
(c)	3	4	1	2
(d)	3	4	2	1

[ESE : 1997]

5.12 A reverted gear train is one in which the output shaft and input shaft

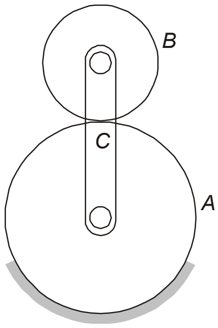
(a) rotate in apposite directions
(b) are coaxial
(c) are at right angles to each other
(d) are at an angle to each other

[ESE : 1997]

5.13 In the case of an involute toothed gear, involute starts from

(a) addendum circle
(b) dedendum circle
(c) pitch circle
(d) base circle [ESE : 1997]

5.14 In the epicyclic gear train shown in the given figure, 'A' is fixed. A has 100 teeth and B has 20 teeth. If the arm C makes three revolutions, the number of revolutions made by B will be



(a) 12 (b) 15
(c) 18 (d) 24 [ESE : 1997]

5.15 Two geared shaft A and B having moments of inertia I_a and I_b and angular acceleration α_a and α_b respectively are meshed together. B rotates at G times the speed of A. If the gearing efficiency of the two shafts in η then in order to accelerate B, the torque which must be applied to A will be

(a) $I_a\alpha_a + G^2 I_b\alpha_b/\eta$ (b) $G^2 I_b\alpha_a\eta$
(c) $G^2 I_a\alpha_a\eta$ (d) $G^2 I_b\alpha_b\eta$ [ESE : 1998]

5.16 The working surface above the pitch surface of the gear tooth is termed as

(a) addendum (b) dedendum
(c) flank (d) face [ESE : 1998]

5.17 Consider the following characteristics:

A. Small interference
B. Strong tooth
C. Low production cost
D. Gear with small number of teeth

These characteristics which are applicable to stub 20° involute system would include

(a) 1 only (b) 2, 3 only 4
(c) 1, 2 and 3 (d) 1, 2, 3 and 4

[ESE : 1998]

5.18 When two shafts are neither parallel nor intersecting, power can be transmitted by using

(a) a pair of spur gears
(b) a pair of helical gears
(c) an Oldham's coupling
(d) a pair of spiral gears [ESE : 1998]

5.19 Consider the following statements:

A pinion of 14½° pressure angle and 48 involute teeth has a pitch circle diameter of 28.8 cm. It has

1. module of 6 mm
2. circular pitch of 18 mm
3. addendum of 6 mm
4. diametral pitch of 11/113

Which of these statements are correct?

(a) 2 and 3 (b) 1 and 3
(c) 1 and 4 (d) 2 and 4 [ESE : 1999]

5.20 Consider the following statements regarding the choice of conjugate teeth for the profiles of mating gears:

1. They will transmit the desired motion.
2. They are difficult to manufacture.
3. Standardization is not possible.
4. The cost of production is low.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 2, 3 and 4 (d) 1, 3 and 4

[ESE : 1999]

■■■■

Answers Gear and Gear Train

5.1	(d)	5.2	(b)	5.3	(a)	5.4	(d)	5.5	(a)	5.6	(d)	5.7	(d)	5.8	(a)
5.9	(a)	5.10	(c)	5.11	(d)	5.12	(b)	5.13	(d)	5.14	(c)	5.15	(a)	5.16	(d)
5.17	(d)	5.18	(d)	5.19	(b)	5.20	(a)								

Explanations Gear and Gear Train

5.1 (d)

When N coincide with O, Then $\theta = 90°$, i.e. acceleration is maximum and velocity is zero.

5.2 (b)

$$I'_B = I_B(\text{on } B) \times \left(\frac{\omega_B}{\omega_A}\right)^2 = n^2 I_2$$

5.3 (a)

Due to slip present, the velocity ratio will not remain constant and hence, belt drive is not a positive drive.

5.4 (d)

For involute gears, pressure angle is always constant. This 14.5° to 22.5°. The general value being 20°.

5.5 (a)

In reverted gear train, first and last gear is on the same axis. Such an arrangement has application on speed reducers, clocks (to connect hour hand to minute hand) and machine tools.

5.6 (d)

To avoid interference certain minimum number of teeth must be provided on the gear.

$$\text{contact ratio} = \frac{\text{Arc of contact}}{\text{Circular pitch}}$$

Lewis equation gives static load on teeth.

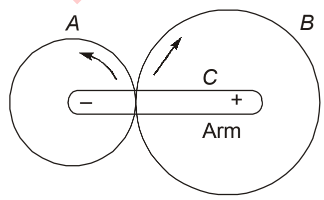
5.7 (d)

	Activities	N_A	N_s	Arm
1.	Fix the Arm C	–	–	0
2.	Give +1 Revolution to gear A	+1	$-\frac{T_A}{T_B}$	0
3.	Give $+x$ Revolution to same gear (A)	$+x$	$-\frac{T_A}{T_B}x$	0
4.	Give $+y$ Revolution to Arm C	$x + y$	$y - \frac{T_A}{T_B}x$	y

Revolution of Arm, $y = 1$

Gear B ($T_B = 200$) fixed,

i.e. $N_B = 0$



$T_A = 50$
$T_B = 200$

$$\Rightarrow \quad y - \frac{T_A}{T_B}x = 0$$

$$\Rightarrow \quad y = \frac{T_A}{B}x$$

$$\Rightarrow \quad 1 = \frac{50}{200}x$$

$$\Rightarrow \quad x = 4$$

Revolution of gear A,

$$N_A = x + y$$
$$= 1 + 4 = \textbf{5 Revolution}$$

5.8 (a)

Interference occurs between tip of the gear tooth and flank of pinion.

5.9 (a)

For compound gear train

$$\text{Speed ratio} = \frac{\text{Product of no. teeth on driven}}{\text{Product of no of teeth on driver}}$$

$$= \frac{40 \times 70 \times 50}{20 \times 35 \times 25} = \mathbf{8}$$

5.10 (c)

Speed ratio of compound gear train

$$= \frac{\text{Product of no. of teeth on driven}}{\text{Product of no. of teeth on driver}}$$

5.11 (d)

(1) Parallel shafts with slight offset → oldham coupling
(2) Parallel shafts at reasonable distance → Belts and pulleys
(3) Perpendicular shafts → worm and wheel
(4) Intersecting shafts → Hooks joint

5.12 (b)

Reverted gear train is a special type of compound gear train in which the first and the last gear have the same axis. i.e. they are coaxial.

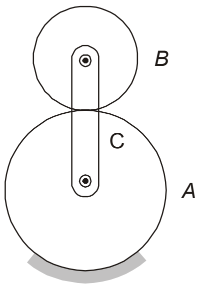
5.13 (d)

Involute starts from base circle.

Two important properties of an involute

(i) A normal to an involute is a tangent to the base circle.
(ii) The radius of curvature of an involute is equal to the length of the tangent to the base circle.

5.14 (c)



Given: T_A = 100, T_B = 20, $N_{arm'c'}$ = 3 rev.

N_A = 0 ($\because$ A is fixed)

To find: N_B = ?

Condition	Arm - C	Gear - A	Gear - B
Suppose arm *C* is fixed and gear *A* is given +1 rev. *CCW*.	0	+1	$-\frac{T_A}{T_B}$
Arm'*C*'is fixed and gear *A* is given $+x$ rev. *CCW*	0	$+x$	$-x\frac{T_A}{T_B}$
Add + *y* rev.	y	$y+x$	$y-x\frac{T_A}{T_B}$

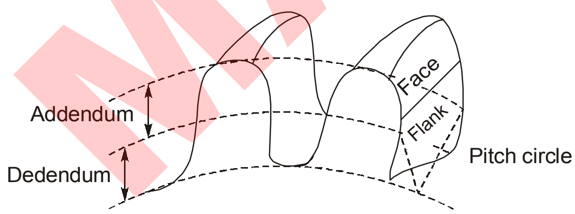
According to the question

$$y = 3$$
$$y + x = 0$$
$$x = -3$$

$$N_B = y - x\frac{T_A}{T_B}$$

$$3 + 3 \times \frac{100}{20} = 18 \text{ revolutions}$$

5.16 (d)



5.17 (d)

Characteristics of stub 20° involute system

1. Small interference
2. Strong tooth
3. Low production cost
4. Gear with smaller number of teeth.

5.18 (d)

Spiral gears are also called as skew gears, screw gears or crossed helical gears. In helical gears, the power is transmitted between two parallel shafts. In spiral gears (cross helical gears) the power is transmitted between two non-parallel and non-intersecting shafts. Spiral gears give a point contact. Due to point contact, spiral gears are not recommended for power transmission. Spiral gears are used in instrumentation, distribution device of automobile engine and other similar application where there are small loads.

The mating gears in helical gearing must have opposite hand of helix, but is case of spiral gearing, the same or opposite hand of helix can be meshed.

5.19 (b)

θ = 14.5°, Z = 48, d = 288 mm

$$\text{Module} = \frac{d}{z} = \frac{288}{48} = 6 \text{ mm}$$

circular pitch = πm = 6π = 18.85 mm

addendum = m = 6 mm

$$\text{diametral pitch} = \frac{1}{m} = \frac{1}{6}$$

5.20 (a)

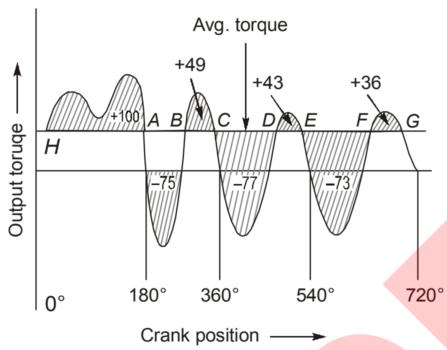
It has been proved that any arbitrary shape of the tooth can be chosen for profile of teeth of one of the two gears in mesh and profile for the other may be determined to satisfy the law of gearing. Such teeth are called conjugate teeth.

Theoretically, such profile teeth will transmit the desired motion but objection to such random profile is the obvious difficulty of manufacture, standard-ization and cost of production. Therefore, conjugate teeth are not in normal use.

■■■■

6 Flywheel

6.1 The given figure shows the output torque plotted against crank positions for a single cylinder four-stroke-cycle engine. The areas lying above the zero-torque line represent positive work and the areas below represent negative work. The engine drives a machine which offers a resisting torque magnitudes of the hatched areas are given by number (in the areas) as shown :



During the cycle, the minimum speed occurs in the engine at

(a) *B* (b) *D*
(c) *H* (d) *F* [ESE : 1995]

6.2 In a 4-stroke IC engine, the turning moment during the compression stroke is

(a) positive throughout
(b) negative throughout
(c) positive during major portion of the stroke
(d) negative during major portion of the stroke

[ESE : 1996]

6.3 In the case of a flywheel, the maximum fluctuation of energy is the

(a) sum of maximum and minimum energies
(b) difference between the maximum and minimum energies
(c) ratio of the maximum and minimum energy
(d) ratio of the minimum and maximum energy

[ESE : 1998]

6.4 Consider the following parameters:

1. Limit of peripheral speed
2. Limit of centrifugal stress
3. Coefficient of fluctuation of speed
4. Weight of the rim

Which of these parameters-are used in the calculation of the diameter of flywheel rim?

(a) 1, 3 and 4 (b) 2, 3 and 4
(c) 1, 2 and 3 (d) 1, 2 and 4

[ESE : 1999]

■■■■

Answers Flywheel

6.1 (d) **6.2** (b) **6.3** (b) **6.4** (d)

Explanations Flywheel

6.1 (d)

Let energy at *H* is *E*

Energy at $A = E + 100$

Energy at $B = E + 100 - 75 = E + 25$

Energy at $C = E + 100 - 75 + 49$
$= E + 74$

Energy at $D = E + 100 - 75 + 49 - 77$
$= E - 3$

Energy at $E = E + 100 - 75 + 49 - 77 + 43$
$= E + 40$

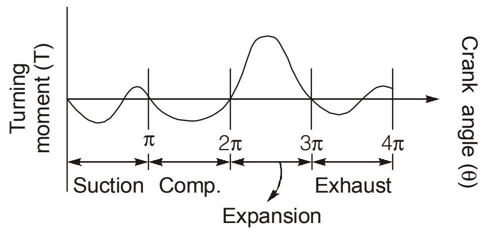
Energy at $F = E + 100 - 75 + 49 - 77 + 43 - 77$
$= E - 33$

Energy at G = Energy at F + 36
$= E - 33 + 36$
$= E + 3$

Minimum energy at *F*. Hence speed at *F* will be minimum

6.2 (b)

4-stroke IC engine



6.3 (b)

$$e_{max} = KE_{max} - KE_{min} = \frac{1}{2} I(\omega_{max}^2 - \omega_{min}^2)$$

6.4 (d)

Linear velocity

For a given 'ω' more the diameter more will be V

$$V = \sqrt{\frac{\text{Centrifugal stress } (\sigma)}{\text{Density of rim } (\rho)}}$$

∴ For calculation of flywheel rim

1. Limit of peripheral speed
2. Limit of centrifugal stress
3. Weight of rim.

■■■■

7 Vibration

7.1 The equation of free vibrations as a system is $\ddot{X} + 36\pi^2 x = 0$. Its natural frequency is

(a) 46 Hz (b) 3π Hz
(c) 3 Hz (d) 6π Hz

[ESE : 1995]

7.2 Which of the following methods can be used to determine the damping of machine element?

1. Logarithmic method
2. Bandwidth method
3. Rayleigh method
4. Holzer method

Select the correct using the codes given below:

(a) 1 and 3 (b) 1 and 2
(c) 3 and 4 (d) 1, 3 and 4

[ESE : 1995]

7.3 If $\omega/\omega_n = \sqrt{2}$, where ω is the frequency of excitation and ω_n is the natural frequency of vibrations, then the transmissibility of vibrations will be

(a) 0.5 (b) 1.0
(c) 1.5 (d) 2.0

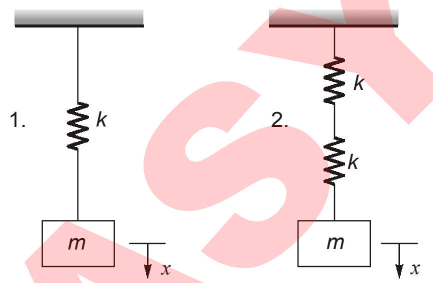
[ESE : 1995]

7.4 A slender shaft supported on two bearing at its ends carries a disc with a eccentricity 'e' from the axis of rotation. The critical speed of the shaft is N. If the disc is replaced by a second one of same weight but mounted with an eccentricity 2e, critical speed of the shaft in the second case is

(a) 1/2 N (b) $1/\sqrt{2}$ N
(c) N (d) 2 N

[ESE : 1995]

7.5 For the spring mass system shown in the figure 1, the frequency of vibration is N. What will be the frequency when one more similar spring added in series, as shown in figure 2?



(a) N/2 (b) $N/\sqrt{2}$
(c) $\sqrt{2}/N$ (d) 2N

[ESE : 1995]

7.6 When shaking force is transmitted through the spring, damping becomes detrimental when the ratio of its frequency to the natural frequency is greater than

(a) 0.25 (b) 0.50
(c) 1.00 (d) $\sqrt{2}$

[ESE : 1996]

7.7 When the mass of a critically damped single degree of freedom system is deflected from its equilibrium position and released, it will

(a) return to equilibrium position without oscillation
(b) oscillate with increasing time period
(c) oscillate with decreasing amplitude
(d) oscillate with constant amplitude

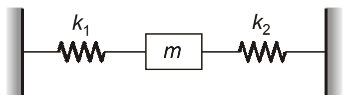
[ESE : 1996]

7.8 The equation of motion for a single degree of freedom system with viscous damping is $4\ddot{X} + 9\dot{X} + 16X = 0$ the damping ratio of the system is

(a) $\frac{9}{128}$ (b) $\frac{9}{16}$
(c) $\frac{9}{8\sqrt{2}}$ (d) $\frac{9}{8}$

[ESE : 1996]

7.9 For the spring mass system shown in the given figure, the frequency of oscillations of the block along the axis of the spring is



(a) $\frac{1}{2\pi}\frac{\sqrt{k_1 - k_2}}{m}$ (b) $\frac{1}{2\pi}\frac{\sqrt{k_1 k_2}}{(k_1 + k_2)m}$

(c) $\frac{1}{2\pi}\sqrt{\frac{k_1 + k_2}{m}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{m}{k_1 + k_2}}$

[ESE : 1996]

7.10 The critical speed of a rotating shaft depends upon

(a) mass
(b) stiffness
(c) mass and stiffness
(d) mass, stiffness and eccentricity

[ESE : 1996]

7.11 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Flywheel
B. Governor
C. Critical speed
D. Inertia Force

List-II
1. Dunkerley method
2. Turning moment
3. D'Alembert's Principle
4. Speed control on par with load

Codes:

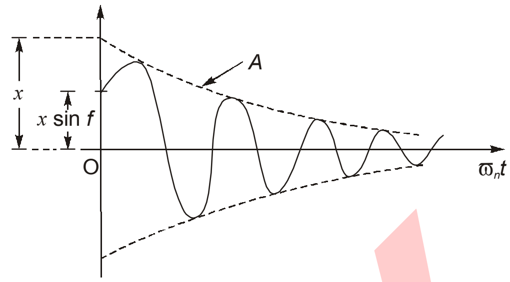
	A	B	C	D
(a)	4	2	3	1
(b)	4	2	1	3
(c)	2	4	3	1
(d)	2	4	1	3

[ESE : 1997]

7.12 A damped free vibration is expressed by the general equation

$$x = Xe^{-(\zeta\omega_n t)}\sin\left(\sqrt{1-\zeta^2}\,\omega_n t + \phi\right)$$

which is shown graphically below :

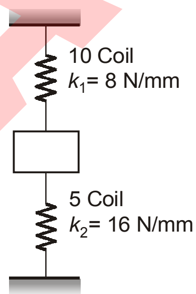


The envelope *A* has the equation :

(a) $X e^{-t}$
(b) $X \sin(\sqrt{1 - \zeta^2})\omega_n t$
(c) $e^{-\zeta\omega_n t}$
(d) $X e^{-\zeta\omega_n t}$

[ESE : 1997]

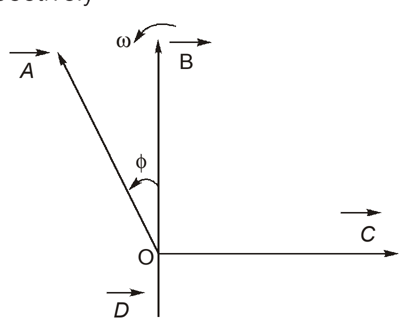
7.13 Which is the equivalent stiffness (i.e. spring constant) the system shown in the given figure?



(a) 24 N/mm (b) 16 N/mm
(c) 4 N/mm (d) 5.3 N/mm

[ESE : 1997]

7.14 The given figure depicts the vector diagram of forces and displacements in the case of Forced Damped Vibration. If vector *A* represents the forcing function $P = P_0 \sin\omega t$, vector *B* the displacement $y = Y\sin\omega t$ and ϕ the phase angle between them, then the vectors *C* and *D* represent respectively



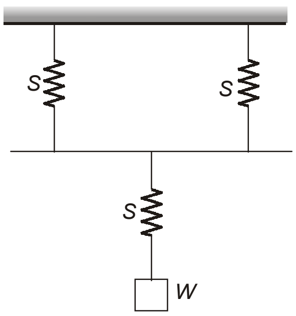
(a) the force of inertia and the force of damping
(b) the elastic force and the damping force
(c) the damping force and the inertia force
(d) the damping force and the elastic force

[ESE : 1997]

7.15 If two identical helical spring are connected in parallel and to these two, another identical spring is connected in series and the system in loaded by a weight W, as shown in the figure, then the resulting deflection will be given by (δ = deflection, S = stiffness, W = load)

(a) $\delta = \dfrac{3W}{2S}$ (b) $\delta = \dfrac{W}{2S}$

(c) $\delta = \dfrac{2W}{3S}$ (d) $\delta = \dfrac{W}{3S}$



[ESE : 1997]

7.16 Two heavy rotating masses are connected by shafts of length l_1, l_2 and l_3 and the corresponding diameters are d_1, d_2, d_3. This system is reduced to a torsionally equivalent system having uniform diameter d_1 of the shaft. The equivalent length of the shaft is equal to

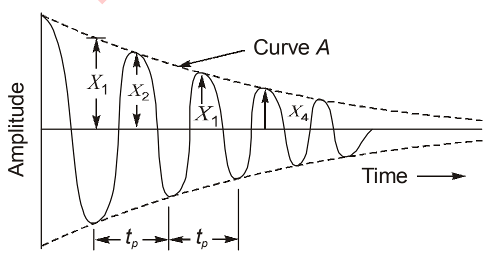
(a) $l_1 + l_2 + l_3$

(b) $\dfrac{l_1 + l_2 + l_3}{3}$

(c) $l_1 + l_2\left(\dfrac{d_1}{d_2}\right)^3 + l_3\left(\dfrac{d_1}{d_3}\right)^3$

(d) $l_1 + l_2\left(\dfrac{d_1}{d_2}\right)^4 + l_3\left(\dfrac{d_1}{d_3}\right)^4$ [ESE : 1997]

7.17 The amplitude versus time curve of as damped-free vibration is shown in the below figure. Curve labelled 'A' is



(a) a logarithmic decrement curve
(b) an exponentially decreasing curve
(c) a hyperbolic curve
(d) a linear curve [ESE : 1998]

7.18 The critical speed of a uniform shaft with a rotor at the centre of the span can be reduced by
(a) Reducing the shaft length
(b) Reducing the rotor mass
(c) Increasing the rotor mass
(d) Increasing the shaft diameter [ESE : 1998]

7.19 If a mass 'm' oscillates on a spring having a mass m_s and stiffness 'k', then the natural frequency of the system is given by

(a) $\sqrt{\dfrac{k}{m + \dfrac{m_s}{3}}}$ (b) $\sqrt{\dfrac{k}{\dfrac{m}{3} + m_s}}$

(c) $\sqrt{\dfrac{3k}{m + m_s}}$ (d) $\sqrt{\dfrac{k}{m + m_s}}$

[ESE : 1998]

7.20 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Node and mode
B. Equivalent inertia
C. Log decrement
D. Resonance

List-II
1. Geared vibration
2. Damped-free vibration
3. Forced vibration
4. Multi-rotor vibration

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	4	1	2	3
(c)	1	4	2	3
(d)	4	1	3	2

[ESE : 1998]

7.21 The critical speed of a uniform shaft with a rotor at the centre of the span can be reduced by
(a) reducing the shaft length
(b) reducing the rotor mass
(c) increasing the rotor mass
(d) increasing the shaft diameter

[ESE : 1998]

7.22 A rotating shaft carries a flywheel which overhangs on the bearing as a cantilever. If this flywheel weight is reduced to half of its original weight, the whirling speed will
(a) be double
(b) increase by $\sqrt{2}$ times
(c) decrease by $\sqrt{2}$ times
(d) be half

[ESE : 1999]

7.23 If a spring-mass-dashpot system is subjected to excitation by a constant harmonic force, then at resonance, its amplitude of vibration will be
(a) infinity
(b) inversely proportion to damping
(c) directly proportional to damping
(d) decreasing exponentially with time

[ESE : 1999]

7.24 In a forced vibration with viscous damping, maximum amplitude occurs when forced frequency is
(a) equal to natural frequency
(b) slightly less than natural frequency
(c) slightly greater than natural frequency
(d) zero

[ESE : 1999]

7.25 The value of the natural frequency obtained by Rayleigh's method
(a) is always greater than the actual fundamental frequency
(b) is always less than the actual fundamental frequency
(c) depends upon the initial deflection curve chosen and may be greater than or less than the actual fundamental frequency
(d) is independent of the initial deflection curve chosen

[ESE : 1999]

7.26 In a multi-rotor system of torsional vibrations, maximum number of nodes that can occur is
(a) two
(b) equal to the number of rotors plus one
(c) equal to the number of rotors
(d) equal to the number of rotors minus one

[ESE : 1999]

■■■■

Answers Vibration

7.1 (c)	7.2 (b)	7.3 (b)	7.4 (c)	7.5 (b)	7.6 (d)	7.7 (a)	7.8 (b)	7.9 (c)
7.10 (c)	7.11 (d)	7.12 (d)	7.13 (a)	7.14 (d)	7.15 (a)	7.16 (d)	7.17 (b)	7.18 (c)
7.19 (a)	7.20 (b)	7.21 (c)	7.22 (b)	7.23 (b)	7.24 (b)	7.25 (a)	7.26 (d)	

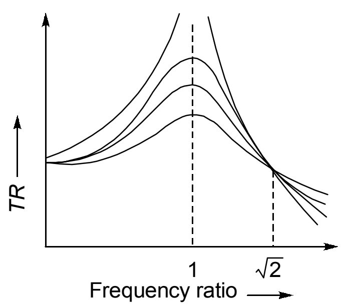
Explanations Vibration

7.1 (c)

$$f = \frac{1}{2\pi}\sqrt{36\pi^2} = 3 \text{ Hz.}$$

7.3 (b)

For $\frac{\omega}{\omega_n} = \sqrt{2}$ transmissibility is 1



7.4 (c)

Critical speed of shaft is independent of the eccentricity.

7.5 (b)

$$W' = \sqrt{\frac{k}{2m}} = \frac{W_n}{\sqrt{2}}$$

$$N' = \frac{N}{\sqrt{2}}$$

7.6 (d)

The damping is detrimental for $\frac{\omega}{\omega_n} < \sqrt{2}$

and advantageous only in the region $\frac{\omega}{\omega_n} > \sqrt{2}$.

7.7 (a)

Critically damped system are of special interest as they regain their equilibrium position, in the shortest possible time, without oscillation. For this reason, large guns are provided with dashports having critical value of damping.

7.8 (b)

$$m\ddot{x} + c\dot{x} + kx = 0$$

$\therefore$ $m = 4$; $c = 9$. $k = 16$

$$\therefore \xi = \frac{C}{2\sqrt{km}} = \frac{9}{2\sqrt{4 \times 16}} = \frac{9}{16}$$

7.9 (c)

Both spring are connected is parallel

$$k_{eq} = k_1 + k_2$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k_1 + k_2}{m}}$$

7.10 (c)

$$\omega = \sqrt{\frac{k}{m}}$$

7.11 (d)

1. Flywheel $\rightarrow$ Turning moment
2. Governor $\rightarrow$ speed control on par with load
3. Critical speed $\rightarrow$ Dunkerley method
4. Inertia force $\rightarrow$ D' Alembert's principal

7.12 (d)

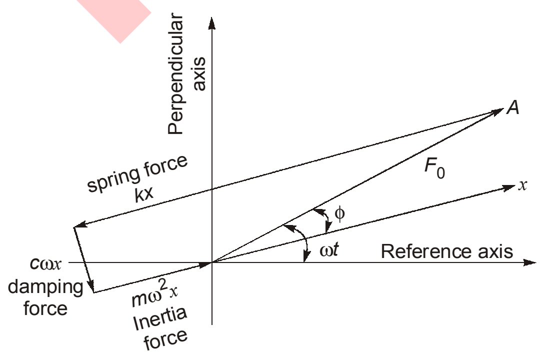
Equation for envelope '*A*' is given as $Xe^{-\xi\omega_n t}$

7.13 (a)

Springs are connected in parallel

$\therefore$ $k_{eq} = K_1 + K_2 = 8 + 16 = $ **24 N/mm**

7.14 (d)



Vector representation of forces on the system having forced vibration

The correct option is (d) i.e., vector (c) and (d) represent the damping force and the elastic force. The following points are observed from the vector diagram:

1. The displacement lags the impressed force an angle ϕ.
2. The spring force is always opposite in direction to the displacement.
3. The damping force lags the displacement by 90°. Since the velocity leads the displacement by 90°, it follows that the damping force is always in direction to the velocity.
4. The inertia force is an phase with the displacement, therefore the inertia is always opposite in direction to the acceleration.

7.15 (a)

$$k_{eq} = \frac{2S \times S}{2S + S} = \frac{2}{3}S$$

$$\therefore W = \frac{2}{3}S \times \delta$$

$$\therefore \delta = \frac{3W}{2S}$$

7.16 (d)

If the two shafts are equivalent, then the stiffness is same and hence, the total angle of twist should be the same (The above analysis can also be done by considering the shaft as springs in series)

$$\theta = \theta_1 + \theta_2 + \theta_3$$

We know that $\dfrac{M_T}{\theta} = \dfrac{GJ}{L}$

$$\therefore \theta = \frac{M_T L}{GJ}$$

$$\frac{M_T L}{GJ} = \frac{M_T L_1}{GJ_1} + \frac{M_T L_2}{GJ_2} + \frac{M_T L_3}{GJ_3}$$

$$\frac{L}{J} = \frac{L_1}{J_1} + \frac{L_2}{J_2} + \frac{L_3}{J_3} \left(J = \frac{\pi}{32}d^2\right)$$

$$L = L_1 + L_2\left(\frac{d_1}{d_2}\right)^4 + L_3\left(\frac{d_1}{d_3}\right)^4$$

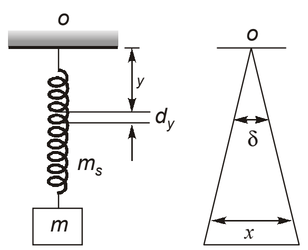
7.17 (b)

The damping factor such that the vibration motion is allowed, however, the amplitude of motion reduce with time in an exponential manner.

7.18 (c)

$$\omega_n = \sqrt{\frac{k}{m}} \quad m\uparrow,\ \omega_n\downarrow$$

7.19 (a)



Let 'L' be the length of the spring and let 'ρ' be the mass of spring per unit length.

Mass of spring $M_s = PL$

Consider a small element 'dy' of the spring at a distance 'y' from the support. The mass of element is dm_s.

$$dm_s = \rho dy$$

Considering that the free end of the spring has moved by 'x'. The displacement at the fixed point will be zero. From similar triangle at any point, at a distance 'y' the displacement is given by 'δ' such that

$$\frac{\delta}{y} = \frac{x}{L}$$

$$\therefore \quad \delta = \frac{xy}{L}$$

Hence velocity of dm_s will be '$\dot{\delta}$'

$$\dot{\delta} = \frac{\dot{x}y}{L}$$

The kinetic energy of the system will be due to mass of the spring 'm_s' and the hanging mass m.

$$KE = KE_{spring} + KE_{mass}$$

$$= \int_0^L \frac{1}{2} dm_s \dot{\delta}^2 + \frac{1}{2} m\dot{x}^2$$

$$= \frac{1}{2} m\dot{x}^2 + \frac{1}{2}\int_0^L \rho dy \times \left(\frac{\dot{x}y}{L}\right)^2$$

$$= \frac{1}{2} m\dot{x}^2 + \frac{1}{2}\int_0^L \rho \frac{\dot{x}^2 y^2}{L^2} dy$$

$$= \frac{1}{2} m\dot{x}^2 + \frac{1}{2}\frac{\rho \dot{x}^2}{L^2}\int_0^L y^2 dy$$

$$= \frac{1}{2} m\dot{x}^2 + \frac{1}{6}\rho L\dot{x}^2 = \frac{1}{2} m\dot{x}^2 + \frac{1}{6} m_s\dot{x}^2$$

$$= \frac{\dot{x}^2}{2}\left(m + \frac{m_s}{3}\right)$$

$$U = PE + KE$$

$$= \frac{1}{2} k\dot{x}^2 + \frac{\dot{x}^2}{2}\left(m + \frac{m_s}{3}\right)$$

Differentiating and using energy method, we get

$$\frac{du}{dt} = \frac{2}{2}\dot{x}\ddot{x}\left(m + \frac{m_s}{3}\right) + \frac{2}{2}kx\dot{x} = 0$$

$$\therefore \quad \ddot{x} + \frac{k}{\left(m + \frac{m_s}{3}\right)} x = 0$$

$$\therefore \quad \omega_n = \sqrt{\frac{k}{\left(m + \frac{m_s}{3}\right)}}$$

7.20 (b)

(1) Node and mode → Multi-rotor vibration

(2) Equivalent Inertia → Geared vibration

(3) Log decrement → Damped free vibration

(4) Resonance → Forced vibration

7.21 (c)

$$\omega_n = \sqrt{\frac{k}{m}}$$

$$\therefore \omega_n \propto \frac{1}{\sqrt{m}}$$

7.22 (b)

Whirling sheed $\propto \sqrt{\frac{1}{I}}$

$$\therefore \quad \frac{\omega_2}{\omega_1} = \sqrt{\frac{2I}{I}}$$

$$\omega_2 = \sqrt{2}\omega_1$$

7.23 (b)

At resonance, amplitude of vibration will be $(F_0/k)/2\xi$ hence inversely proportional to damping.

7.24 (b)

In a forced vibration with viscous damping, maximum amplitude occurs when forced frequency is slightly less than natural frequency.

$$A = \frac{F_0}{\sqrt{(s - m\omega^2) + (c\omega)^2}}$$

$$A = \frac{F_0/s}{\sqrt{\left[1 - \left(\frac{\omega}{\omega_n}\right)^2 + \left[2\varepsilon\frac{\omega}{\omega_n}\right]^2\right]}}$$

7.25 (a)

The correct option is (a)

Rayleigh method is used for finding the first natural frequency of a multi-degree of freedom system

$$\omega_n^2 = \frac{g\Sigma M_i y_i}{\Sigma M_i y_i^2} \quad ...(i)$$

Where M_i and y_i are the mass and the deflection at point i.

In case the deflection curve assumed in (i) above is due to the load considered as dead or static, as is generally done to start with, then the natural frequency obtained from eq. (i) will be somewhat higher than the actual value. The reason is that during the actual vibrations the deflection curve will be due to the inertia load rathers than static loads, and thus the assumed deflection will be different from the actual deflection and wherever assumed deflection is different from the actual one, a higher frequency will result. This is because any change of deflection curve from the actual is associated with the stiffening of system which results in a higher natural frequency.

7.26 (d)

In a multi-rotor system of torsional vibrations, maximum number of nodes that can occur is equal to the number of rotors minus one.

■■■■

8 Governors

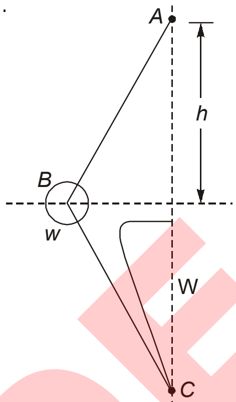
8.1 For a spring controlled governor to be stable, the controlling force (F) is related to the radius (r) by the equation

(a) $F = ar - b$ (b) $F = ar + b$

(c) $F = ar$ (d) $F = a/r + b$

[ESE : 1995]

8.2 Which one of the following equation is valid with reference to the given figure.



(a) $\omega^2 = \left(\frac{W}{w}\right)\left(\frac{g}{h}\right)$

(b) $\omega^2 = \left(\frac{W+w}{w}\right)\left(\frac{g}{h}\right)^{1/2}$

(c) $\omega^2 = \left(\frac{w}{W+w}\right)\left(\frac{g}{h}\right)^{1/2}$

(d) $\omega^2 = \left(\frac{W+w}{w}\right)\left(\frac{g}{h}\right)$

[ESE : 1996]

8.3 Match **List-I** with **List-II** and select the correct answer using the codes below the lists:

List-I

A. Hunting
B. Isochronism
C. Stability
D. Effort

List-II

1. One radius rotation for each speed.
2. Too sensitive.
3. Mean force exerted at the sleeve during change of speed.
4. Constant equilibrium speed for radii of rotation.

Codes:

	A	B	C	D
(a)	2	4	1	3
(b)	3	1	4	2
(c)	2	1	4	3
(d)	1	2	3	4

[ESE : 1996]

8.4 **Assertion (A):** The degree of hunting with an unstable governor will be less than that with an isochronous governor.
Reason (R): With an unstable governor, once the sleeve has moved from one extreme position to the other, a finite change of speed is required to cause it to move back again.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

8.5 The sensitivity of an isochronous governor is

(a) zero (b) one

(c) two (d) infinity **[ESE : 1997]**

8.6 Give that
m = mass of the ball of the governor
ω = angular velocity of the governor and
g = acceleration due to gravity, the height of Watt's governor is given by

(a) $\frac{g}{2\omega^2}$ (b) $\frac{g}{\omega^2}$

(c) $\frac{\sqrt{2}g}{\omega^2}$ (d) $\frac{2g}{\omega^2}$

[ESE : 1998]

8.7 For a given fractional change of speed, if the displacement of the sleeve is high, then the governor is said to be

(a) hunting (b) isochronous

(c) sensitive (d) stable **[ESE : 1998]**

8.8 Consider the following speed governors :

1. Porter governor 2. Hartnell governor
3. Watt governor 4. Proell governor

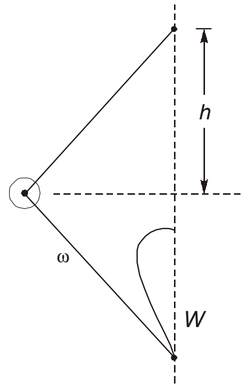
The correct sequence of development of these governors is

(a) 1, 2, 3, 4 (b) 3, 1, 4, 2

(c) 3, 1 2, 4 (d) 1, 3, 4, 2

[ESE : 1999]

8.9 Consider the given figure:



Assertion (A): In order to have the same equilibrium speed for the given values of ω, W and h, the masses of balls used in the Proell governor are less than those of ball used in the Porter governor.

Reason (R): The ball is fixed to an extension link Proell governor.

Of these statements:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

■■■■

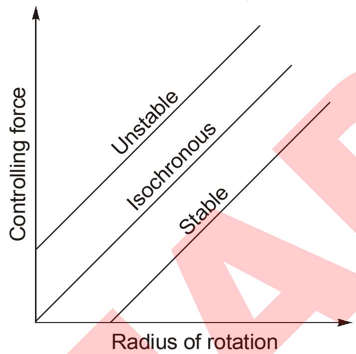
Answers Governors

8.1	(a)	8.2	(d)	8.3	(a)	8.4	(d)	8.5	(d)	8.6	(b)	8.7	(c)	8.8	(b)	8.9	(a)

Explanations Governors

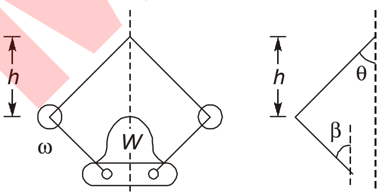
8.1 (a)

$F = ar + b \rightarrow$ unstable governor
$F = ar \rightarrow$ isochronous governor
$F = ar - b \rightarrow$ stable governor



8.2 (d)

Porter governor



$$\omega^2 = \frac{g}{h}\left[\frac{2\omega + W(1+k)}{2\omega}\right]$$

Where $K = \dfrac{\tan\beta}{\tan\theta}$

In this case $\beta = \theta$

$\Rightarrow$ $K = 1$

$$\omega^2 = \frac{g}{h}\left[\frac{\omega + W}{\omega}\right]$$

8.3 (a)

1. Hunting : Too sensitive
2. Isochronism : Constant equilibrium speed for radius of rotation
3. Stability : One radius rotation for each speed
4. Effort : Mean force exerted at the sleeve during change of speed

8.4 (b)

The correct option is (b) i.e., both A and R are true and R is correct explanation of A.

Whenever there is a change in the mean speed, centrifugal governor develop a tendency to oscillate around the derived new mean position. This is because of the fact that when there is a change in the load on the engine, with a consequent change is engine speed, the governor balls and the sleeve seek a new position to restore the original speed. However, due to inertia they overshoot the mark and thereafter again move towards the derived position in the opposite direction with the same result. The process is than repeated and oscillation are set up. If the frequency of fluctuations in engine speed happens to coincide with the natural frequency of oscillations of the governor, then due to resonance, the amplitude of oscillation becomes very high, with the result that the governor tends to intensity the speed variation instead of controlling it. Such a situation is known as hunting.

The problem of hunting becomes more acute when the sensitiveness of a governor is high i.e., when a change in speed causes a large sleeve movement. For example an isochronous governor (i.e., one that is infinitely sensitive) will oscillate between the highest and the lowest position if the speed deviates from the isochoronous speed.

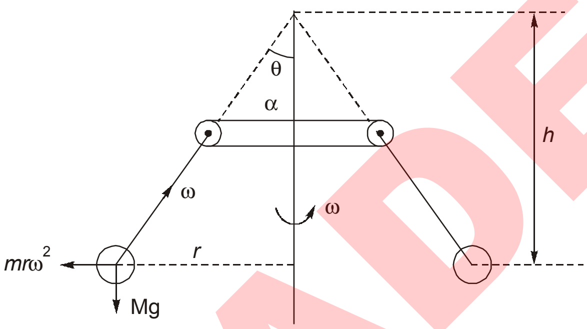
8.5 (d)

$$\text{Sensitivity } (e) = \frac{N_1 + N_2}{2(N_1 - N_2)}$$

For isochronous governor ; $N_1 = N_2$

$\therefore \quad e = \infty$

8.6 (b)



$$\therefore \quad \tan\theta = r/h = \frac{r\omega^2}{g}$$

$$\therefore \quad h = \frac{g}{\omega^2}$$

8.7 (c)

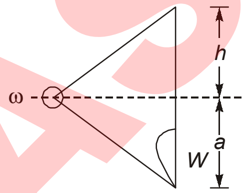
A governor in said to be sensitive if the displacement of the sleeve is high for a given fractional change of speed

$$\text{Sensitivity} = \frac{N_1 + N_2}{2(N_1 - N_2)}$$

8.8 (b)

Correct sequence of development of governors.
1. Watt 2. Porter 3. Proell 4. Hartnel

8.9 (a)

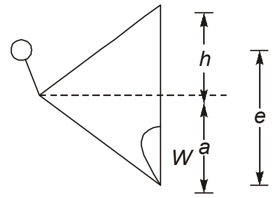


w — weight of ball
W — weight of sleeve
ω — angular speed

Porter governor

$$\omega^2 = \frac{g}{h}\left[\frac{w+W}{w}\right]$$

Proell



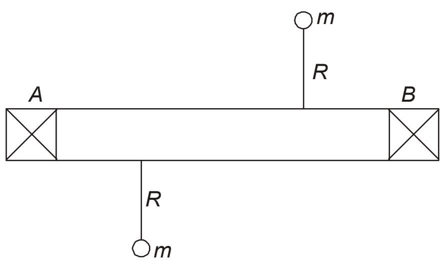
$$\omega^2 = \frac{g}{h}\left(\frac{a}{e}\right)\left[\frac{w+W}{w}\right]$$

For the given values of ω, W and h the masses of balls used in proell generator are less than those of ball used is porter generator.

■■■■

9 Balancing and Gyroscope

9.1 A rotor supported at *A* and *B*, carries two masses as shown in the given figure. The rotor is



(a) dynamically balanced
(b) statically balanced
(c) statically and dynamically balanced
(d) not balanced

[ESE : 1995]

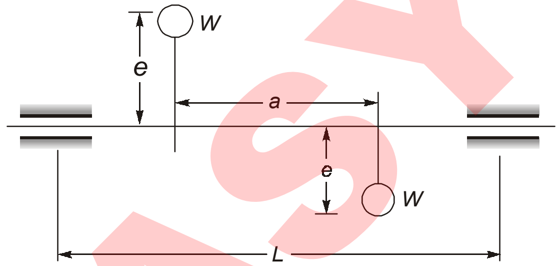
9.2 A system of masses rotating in different parallel planes is in dynamic balance if the resultant
(a) force is equal to zero
(b) couple is equal to zero
(c) force and the resultant couple are both equal to zero
(d) force is numerically equal to the resultant couple, but neither of them need necessarily be zero

[ESE : 1996]

9.3 When the primary direct crank of a reciprocating engine positioned at 30° clockwise, the secondary reverse crank for balancing will be at
(a) 30° anticlockwise
(b) 60° anticlockwise
(c) 30° clockwise
(d) 60° clockwise

[ESE : 1997]

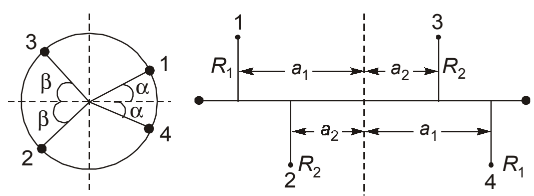
9.4 A statically-balanced system is shown in the given figure. Two equal weights *W*, each with an eccentricity *e*, are placed on opposite sides of the axis in the same axial plane. The total dynamic reactions at the supports will be



(a) Zero
(b) $\frac{W}{g}\omega^2 e\frac{a}{L}$
(c) $2\frac{W}{g}\omega^2 e\frac{a}{L}$
(d) $\frac{W}{g}\omega^2 e\frac{L}{a}$

[ESE : 1997]

9.5 A four-cylinder symmetrical in-line engine is shown in the below figure, Reciprocating weights per cylinder are R_1 and R_2, and the corresponding angular disposition of the crank are α and β. Which one of the following equations should be satisfied for its primary force balance?



(a) $a_1 \tan\alpha = a_2 \tan\beta$
(b) $\cos\alpha = 1/2 \sec\beta$
(c) $R_1 a_1 \sin 2\alpha = -R_2 a_2 \sin 2\beta$
(d) $R_1 \cos\alpha = R_2 \cos\beta$

[ESE : 1998]

9.6 The primary disturbing force due to inertia of reciprocating parts of mass *m* at radius *r*, revolving with an angular velocity ω is given by
(a) $m\omega^2 r\sin\theta$
(b) $m\omega^2 r\cos\theta$
(c) $m\omega^2 r\sin(2\theta/n)$
(d) $m\omega^2 r\cos(2\theta/n)$

[ESE : 1999]

9.7 If a two-mass system is dynamically equivalent to a rigid body, then the system will NOT satisfy the condition that the
(a) sum of the two masses must be equal to that of the rigid body
(b) polar moment of inertia of the system should be equal to that of the rigid body
(c) Centre of Gravity (CG) of the system should coincide with that of the rigid body
(d) total moment of inertia about the axis through CG. Must be equal to that of the rigid body

[ESE : 1999]

9.8 If the ratio of the length of connecting rod to the crank radius increases, then
(a) primary unbalanced forces will increase
(b) primary unbalanced forces will decrease
(c) secondary unbalanced forces will increase
(d) secondary unbalanced forces will decrease

[ESE : 1999]

9.9 **Assertion (A):** In locomotive engines, the reciprocating masses are only partially balanced.
Reason R): Full balancing might lead to lifting the locomotive engine off the rails.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

■■■■

Answers Balancing and Gyroscope

9.1 (b) 9.2 (c) 9.3 (b) 9.4 (a) 9.5 (d) 9.6 (b) 9.7 (b) 9.8 (d) 9.9 (a)

Explanations Balancing and Gyroscope

9.1 (b)

For statically balanced rotor

$$\Sigma \vec{F} = 0$$

For dynamically balanced rotor

$$\Sigma \vec{F} = 0, \quad \Sigma M = 0$$

But in this case $\Sigma M \neq 0$ only $\Sigma F = 0$ therefore the rotor is statically balanced.

9.2 (c)

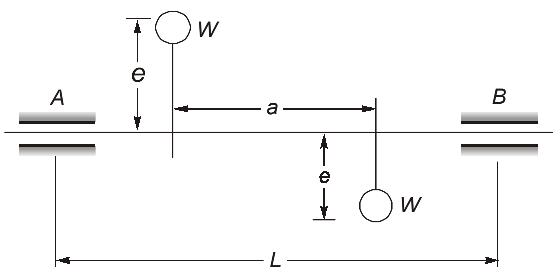
For dynamic balance, resultant force and resultant couple are equal to zero.

$$\Sigma F = 0$$
$$\Sigma M = 0$$

9.3 (b)

When the primary direct crank of a reciprocating engine positioned at 30° clockwise, the secondary reverse crank for balancening will be at 60° anticlockwise.

9.4 (a)



Moment about A

$$\Rightarrow \frac{W}{g}e\omega^2 \times \frac{(L-a)}{2} - \frac{W}{g}e\omega^2 \frac{(L+a)}{2} + R_B \times L = 0$$

$$L \times R_B = \frac{W}{g}\frac{e\omega^2}{2}[L + a - (L - a)]$$

$$R_B = \frac{W}{g}e\omega^2 \frac{a}{L} = me\omega^2 \times \frac{a}{L}$$

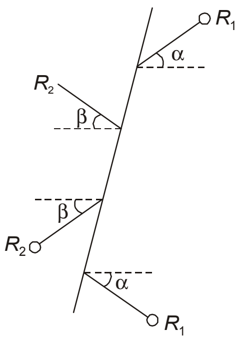
$$R_A = \frac{W}{g}e\omega^2 \frac{a}{L}$$

Total dynamic force (magnitude)

$$= R_A + R_B$$

$$= \frac{2W}{g}e\omega^2 \frac{a}{L}$$

9.5 (d)



The correct option is (d)

Balancing horizontal force let radius be x

$$R_1x\cos\alpha + R_1x\cos\alpha - R_2x\cos\beta - R_2x\cos\beta = 0$$

$$2R_1x\cos\alpha - 2R_2x\cos\beta = 0$$

$$\therefore\ R_1\cos\alpha = R_2\cos\beta$$

9.6 (b)

$$F_{\text{unbalanced force}} = mr\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

$$= \underbrace{mr\omega^2\cos\theta}_{\text{Primary unbalanced force}} + \underbrace{\frac{mr\omega^2\cos 2\theta}{n}}_{\text{Secondary unbalanced force}}$$

9.7 (b)

Following condition must be satisfied by two mass system for dynamic equilibrium

(i) The mass of two system has to be the same.

(ii) The centre of gravity of the two system has to fall at the same position.

(iii) The moment of inertia of the two system must be the same.

Then the three condition stated above lead to the following mathematical equation

$$m_1 + m_2 = m$$

$$m_1a = m_2b$$

$$m_1a^2 + m_2b^2 = mk^2$$

9.8 (d)

F_P = Primary unbalanced force = $mr\omega^2\cos\theta$

F_s = Secondary unbalanced force

$$= \frac{mr\omega^2}{n}\cos 2\theta \qquad \left(n = \frac{l}{r}\right)$$

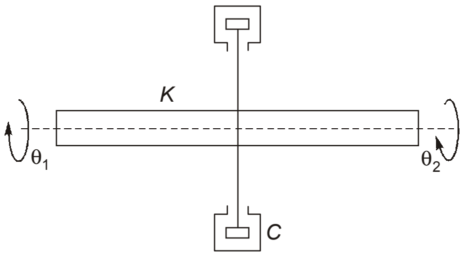
9.9 (a)

In locomotive engines, the reciprocating masses are only partially balanced because full balancing might lead to lifting the locomotive engine off the rails, because of hammer blow.

■■■■

10 Miscellaneous

10.1 Given figure shown a flexible shaft of negligible mass of torsional stiffness k coupled to a viscous damper having a coefficient of viscous damping C. If at any instant the left and right ends of this shaft have angular displacement θ_1 and θ_2 respectively, then the transfer function θ_2/θ_1 of the system is



(a) $\dfrac{K}{K+C}$

(b) $\dfrac{1}{1+\dfrac{C}{K}s}$

(c) $\dfrac{1}{1+\dfrac{K}{C}s}$

(d) $1+\dfrac{K}{C}s$

[ESE : 1995]

■■■■

Answers Miscellaneous

10.1 (b)

UNIT

IV

Design of Machine Elements

Syllabus

Design for static and dynamic loading; failure theories; fatigue strength and the S-N diagram; principles of the design of machine elements such as riveted, welded and bolted joints. Shafts, Spur gears, rolling and sliding contact bearings, Brakes and clutches.

Contents

1 Theories of Failure (Static & Dynamic)

1.1 The design calculations for members subject to fluctuating loads with the same factor of safety yield the most conservative estimates when using
(a) Gerber relation
(b) Soderberg relation
(c) Goodman relation
(d) None of the above

[ESE : 1995]

1.2 Permissible bending moment in a circular shaft under pure bending is M according to maximum principal stress theory of failure the permissible bending moment in the same shaft is
(a) 1/2 M   (b) M
(c) $\sqrt{M}$ (d) 2 M

[ESE : 1995]

1.3 If shaft made from ductile material is subjected to combined bending and twisting moments. Calculations based on which one of the following failure theories would give the most conservative value?
(a) Maximum principal stress theory
(b) Maximum shear stress theory
(c) Maximum strain energy theory
(d) Maximum distortion energy theory

[ESE : 1996]

1.4 If the size of a standard specimen for fatigue testing machine is increased the endurance limit for the material will
(a) have same value as that of standard specimen
(b) increases
(c) decreases
(d) none of these

[ESE : 1996]

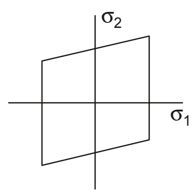
1.5 Stress concentration in a machine component of ductile materials not so harmful as it is in brittle material because
(a) In Ductile material local yielding may distribute stress concentration
(b) Ductile material have large Young's modulus
(c) Poisson's ratio is larger in ductile materials
(d) Modulus of rigidity is larger in ductile material

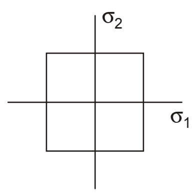
[ESE : 1996]

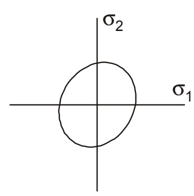
1.6 Match **List-I** (Failure theories) with **List-II** (Figures representing boundaries of these theories) and select the correct answer using codes given below the lists:

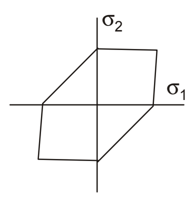
List-I
A. Maximum Principal stress theory
B. Maximum shear stress theory
C. Maximum octahedral shear stress theory
D. Maximum shear strain energy theory

List-II

1. 

2. 

3. 

4. 

Codes:

	A	B	C	D
(a)	2	1	3	4
(b)	2	4	3	1
(c)	4	2	3	1
(d)	2	4	1	3

[ESE : 1997]

1.7 According to the maximum shear stress theory of failure, permissible twisting moment in a circular shaft is T. The permissible twisting moment in the same shaft as per the maximum principal stress theory of failure will be

(a) $T/2$ (b) T

(c) $\sqrt{2T}$ (d) $2T$

[ESE : 1998]

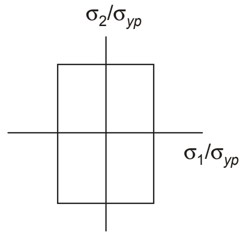
1.8 A solid circular shaft is subjected to pure torsion. The ratio of maximum shear stress to maximum normal stress at any point would be

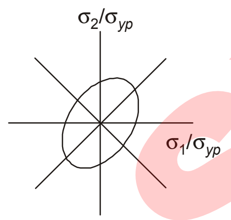
(a) 1 : 1 (b) 1 : 2

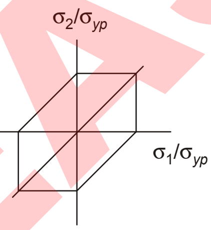
(c) 2 : 1 (d) 2 : 3

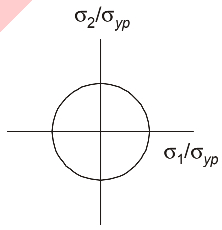
[ESE : 1999]

1.9 Which one of the following figures represents the maximum shear stress Theory or Tresca criterion?

(a)


(b)


(c)


(d)


[ESE : 1999]

■■■■

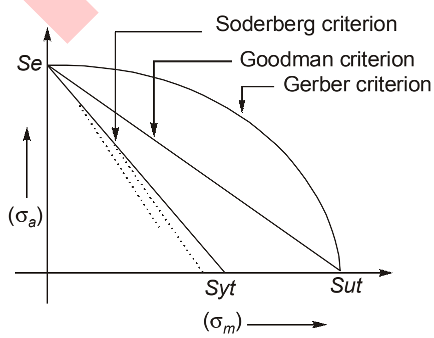
Answers Theories of Failure (Static and Dynamic)

1.1	(b)	1.2	(b)	1.3	(b)	1.4	(c)	1.5	(a)	1.6	(d)	1.7	(d)	1.8	(a)	1.9	(c)

Explanations Theories of Failure (Static and Dynamic)

1.1 (b)

Taking sorderberg criteria the results are more conservative as maximum stress point will be as shown.



1.2 (b)

Maximum bending stress $\sigma_1 = M$

Minimum bending stress $\sigma_2 = O$

$\therefore$ Maximum shear stress $= \dfrac{\sigma_1 - \sigma_2}{2} = \dfrac{M}{2}$

Now, according to maximum shear stress theory

$$\tau_{max} = \frac{\sigma_{per}}{2}$$

$$\sigma_{per} = M$$

1.3 (b)

Most conservative value means safest design i.e largest diameter. For ductile material, maximum shear stresses of theory gives higher value of diameter.

1.4 (c)

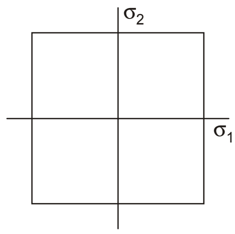
If the diameter or size of the mechanical components is more, the surface area is more hence greater number of surface defect. Hence, endurance limit of component reduced with increase in size.

1.5 (a)

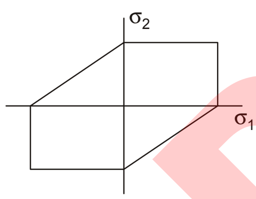
The stress concentration effect in ductile material for static loading has no serious effect because there material undergoes local yielding and distribute the stress where maximum value is reached.

1.6 (d)

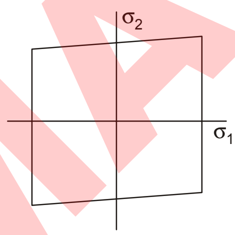
A. Maximum principal stress theory



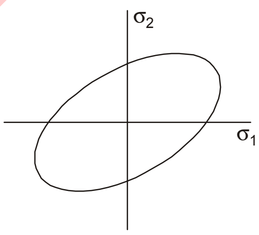
B. Maximum shear stress theory



C. Maximum octahedral shear stress theory.



D. Maximum shear strain energy theory



1.7 (d)

According to maximum shear theory,

$$\frac{S_yt}{2} = \tau = \frac{16T}{\pi d^3}$$

$$\therefore S_yt\left(\frac{\pi d^3}{32}\right) = T \quad \text{...(i)}$$

According to maximum principal stress theory,

$$\frac{16T'}{\pi d^3} = S_yt$$

$$T' = S_yt\frac{\pi d^3}{16} \quad \text{...(ii)}$$

From equation (i) and (ii),

$$T' = 2T$$

1.8 (a)

II[nd] Method

$$T_e = \sqrt{M^2 + T^2}$$

For pure torsion $M = 0$

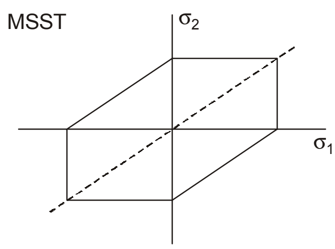
$$T_e = T = \frac{\pi d^3}{16}\cdot\tau_{max}$$

and
$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

$$= \frac{T}{2} = \frac{\pi d^3}{32}\cdot\sigma_{max}$$

$$\therefore \frac{\tau_{max}}{\sigma_{max}} = 1 : 1$$

1.9 (c)



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2 Bolted, Riveted and Welded Joint

2.1 The permissible stress in a fillet weld is 100 N/mm^2. The fillet weld has equal leg lengths of 15 mm each. The allowable shearing load on per cm length of the weld is

(a) 22.5 kN (b) 15.0 kN
(c) 10.6 kN (d) 7.5 kN

[ESE : 1995]

2.2 For bolts of uniform strength, the shank diameter is made equal to

(a) major diameter of threads
(b) pitch diameter of threads
(c) minor diameter of threads
(d) nominal diameter of threads

[ESE : 1995]

2.3 **Assertion (A):** When the coupler of a turn buckle is turned in one direction both the connecting rods either move closer or move away from each other depending upon the direction of rotation of the coupler.

Reason (R): A turn buckle is used to connect two round rods subjected to tensile loading and requiring subsequent adjustment for tightening or loosening.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

2.4 Two rigid plates are clamped by means of bolt and nut with an initial force N. After tightening, a separating force $P (P < N)$ is applied to the lower plate, which in turn acts on nut. The tension in the bolt after this is

(a) $(N + P)$ (b) $(N - P)$
(c) P (d) N

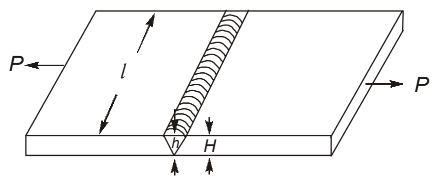
[ESE : 1996]

2.5 A double fillet welded joint with parallel fillet weld of length L and leg B is subjected to a tensile force P. Assuming uniform shear stress distribution, the shear stress in the weld is given by

(a) $\frac{\sqrt{2}P}{BL}$ (b) $\frac{P}{2BL}$
(c) $\frac{P}{\sqrt{2}BL}$ (d) $\frac{2P}{BL}$

[ESE : 1996]

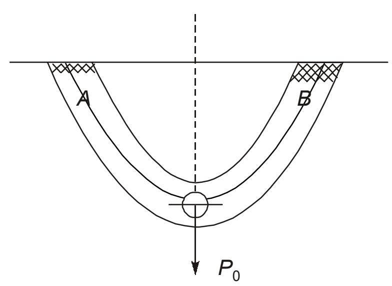
2.6 A butt welded joint, subjected to tensile force P is shown in the given figure, l = length of the weld (in mm) h = throat of the butt weld (in mm) and H is the total height of weld including reinforcement. The average tensile stress σ_t in the weld is given by



(a) $\sigma_t = \frac{P}{Hl}$ (b) $\sigma_t = \frac{P}{hl}$
(c) $\sigma_t = \frac{P}{2hl}$ (d) $\sigma_t = \frac{2P}{hl}$

[ESE : 1997]

2.7 In the welded joint shown in the given figure if the weld at B has thicker fillets than at A then load carrying capacity P_0 of the joint will



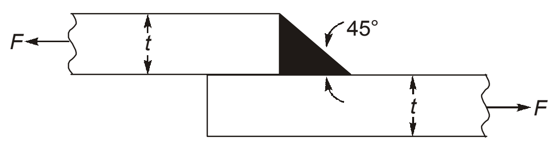
(a) increase (b) decrease
(c) remain unaffected (d) exactly get doubled

[ESE : 1997]

2.8 When a nut is tightened by placing a washer below it the bolt will be subjected to
(a) tensile stress (b) compression stress
(c) shear stress (d) none of these
[ESE : 1998]

2.9 The rivet head used for boiler plate riveting is usually
(a) snap head (b) pan head
(c) counter sink head (d) conical head
[ESE : 1998]

2.10 Two metal plates of thickness 't' and width 'w' are jointed by a fillet weld of 45° as shown in given figure. When subjected to a pulling force 'F', the stress induced in the weld will be



(a) $\frac{F}{wt\sin 45°}$ (b) $\frac{F}{wt}$

(c) $\frac{F\sin 45°}{wt}$ (d) $\frac{2F}{wt}$
[ESE : 1998]

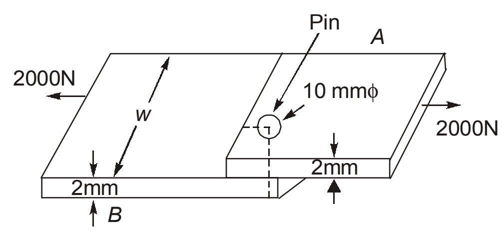
2.11 The piston rod and the crosshead in a steam engine are usually connected by means of
(a) Cotter joint (b) Knuckle joint
(c) Ball joint (d) Universal joint
[ESE : 1998]

2.12 Which of the following stresses are associated with tightening of nut on a bolt
1. Tensile stress due to stretching of bolt.
2. Bending stress due to bending of bolt.
3. Crushing and shear stresses in threads.
4. Torsional shear stress due to frictional resistance between the nut and bolt.

Select the correct answer using the codes given below:
(a) 1, 2 and 4 (b) 1, 2 and 3
(c) 2, 3 and 4 (d) 1, 3 and 4
[ESE : 1998]

2.13 For longitudinal joint in boiler, the type of joint used is
(a) lap joint with one ring one slopping the other
(b) butt joint with single cover plate
(c) butt joint with double cover plate
(d) any one of the above [ESE : 1999]

2.14 If permissible stress in plates of joint through a pin as shown in the given figure is 200 MPa, then the width w will be



(a) 15 mm (b) 18 mm
(c) 20 mm (d) 25 mm [ESE : 1999]

Answers Bolted, Riveted and Welded Joint

2.1 (c)	2.2 (c)	2.3 (a)	2.4 (d)	2.5 (c)	2.6 (b)	2.7 (c)	2.8 (a)	2.9 (a)
2.10 (a)	2.11 (a)	2.12 (d)	2.13 (c)	2.14 (a)				

Explanations Bolted, Riveted and Welded Joint

2.1 (c)

Shear stress is given by $\tau = \frac{\sqrt{2}p}{hl}$

$$\Rightarrow \frac{p}{l} = \frac{\tau h}{\sqrt{2}} = \frac{100\times 15}{\sqrt{2}}$$

∴ Load/cm length = 1060 N/mm = **10.6 kN/cm**

2.2 (c)

Bolt of uniform strength are made to resist shock load by:
1. Making a hole (drilled) i.e., area of shank reduced to root area.
2. Reducing the diameter of shank of bolt corresponding to that of minor diameter.

2.4 (d)

The correct option is (d) i.e., N

Initial load = N

Separating force = P

Since $P < N$ i.e., separating force is less than initial load, therefore tension in the bolt will be N.

If separating force P was larger than N i.e., initial load than the load on the bolt would have been P.

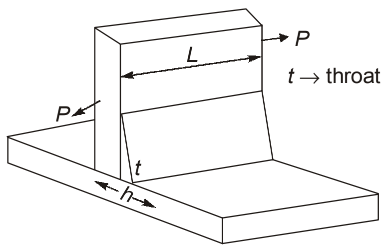
2.5 (c)

The correct option is (c)

For single fillet

$$P = t \times L \times \tau$$

$$= \frac{1}{\sqrt{2}} hL\tau$$



For double fillet

$$P = 2\left(\frac{1}{\sqrt{2}} hL\tau\right) = \sqrt{2}\, hL\tau$$

$$\therefore \quad \tau = \frac{P}{\sqrt{2}\, hL}$$

2.6 (b)

Because throat area is the minimum area and

$A_{throat} = h \times L$

$$\therefore \quad \sigma_t = \frac{P}{hl}$$

2.8 (a)

Bolts are always subjected to tensile stress when nut is tightened. The washer will be in compression.

2.9 (a)

The **Snap Heads** are usually employed for structural work and machine riveting and for boiler shell.

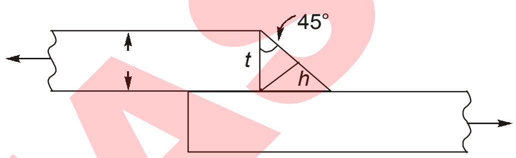
The **Counter sunk heads** are mainly used for ship building where flush surface are necessary.

The **Conical heads** are mainly used in case of hand hammering.

The **Pan head** have maximum strength, but these are difficult to shape.

2.10 (a)

The throat h



$$\sin 45° = \frac{h}{t}$$

$h = t \sin 45°$

Area of minimum throat = $w \times h = wt \sin 45°$

$$\text{Shearing force} = \frac{F}{wt \sin 45°}$$

2.11 (a)

The piston rod and the crosshead in steam engine is connected by cotter joint. It is used when no relative motion between the rods is desirable, cotters are normally driven at right angle to the axis of connected part which are subjected to tensile or compressive stresses.

2.13 (c)

The longitudinal joint in a boiler shell is usually butt joint with two cover plates. This joint is more efficient than lap joint. It is also stiffer and helps to maintain circularity of the shells.

2.14 (a)

It will subjected to single shear as the pin willl be sheared at the junction of two plates. Permissible stress given for the plate

$$2000 = (w - 10) \times 2 \times 10^{-6} \times 200 \times 10^{6}$$

$$\Rightarrow \quad w = 15 \text{ mm}$$

■■■■

3 Bearings, Shafts, Axles & Keys

(Keys out of syllabus from 2016)

3.1 Consider the following design considerations

1. Tensile failure
2. Creep failure
3. Bearing failure
4. Shearing failure
5. Bending failure

The design of the pin of a rocker arm of an I.C. engine is based on

(a) 1, 2 and 4 (b) 1, 3 and 4
(c) 2, 3 and 5 (d) 3, 4 and 5

[ESE : 1995]

3.2 Which one of the following loadings is considered for design of axles?

(a) Bending moment only
(b) Twisting moment only
(c) Combined bending moment and torsion
(d) Combined action of bending moment, twisting moment and axial thrust

[ESE : 1995]

3.3 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Crank shaft
B. Wire shaft
C. Axle
D. Plain shaft

List-II

1. Supports the revolving parts and transmits torque.
2. Transmits motion between shafts where it is not possible to effect a rigid coupling between them.
3. Converts linear motion into rotary motion.
4. Supports only the revolving parts.

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	4	2	3	1
(c)	3	2	4	1
(d)	1	4	2	3

[ESE : 1995]

3.4 **Assertion (A):** In equilibrium position, the journal inside a journal bearing remains floating on the oil film.

Reason (R): In a journal bearing, the load on the bearing is perpendicular to the axis of the journal.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

3.5 In an oil-lubricated journal bearing, coefficient of friction between the journal and the bearing

(a) remains constant at all speeds
(b) is minimum at zero speed and increases monotonically with increases in speed
(c) is maximum at zero speed and decreases monotonically with increase in speed
(d) becomes minimum at an optimum speed and then increases with further increase in speed

[ESE : 1995]

3.6 Removal of metal particles from the raceway of a rolling contact bearing is a kind of failure of bearing known as

(a) pitting (b) wearing
(c) spalling (d) scuffing

[ESE : 1995]

3.7 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. High temperature
B. High load
C. No lubrication
D. Bushings

List-II

1. Teflon bearing
2. Carbon bearing
3. Hydrodynamic bearing
4. Sleeve bearing

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	4	1	2	3
(c)	2	1	3	4
(d)	2	3	1	4

[ESE : 1995]

3.8 Match **List-I** (Machine element) with **List-II** (Cause of failure) and select the correct answer using the codes given below the lists:

List-I
A. Axle
B. Cotter
C. Connecting rod
D. Journal bearing

List-II
1. Shear stress
2. Tensile/compressive stress
3. Wear
4. Bending stress

Codes:

	A	B	C	D
(a)	1	4	2	3
(b)	4	1	2	3
(c)	4	1	3	2
(d)	1	4	3	2

[ESE : 1996]

3.9 A transmission shaft subjected to bending loads must be designed on the basis of
(a) maximum normal stress theory
(b) maximum shear stress theory
(c) maximum normal stress and maximum shear stress theories
(d) fatigue strength

[ESE : 1996]

3.10 Tapered roller bearings can take
(a) radial load only
(b) axial load only
(c) both radial and axial load and the ratio of these being less than unity
(d) both radial and axial load and the ratio of these being greater than unity

[ESE : 1996]

3.11 The bearing characteristic number in a hydrodynamic bearing depends on
(a) it is closer to real life situation
(b) it leads to a safer design
(c) it leads to cost effective design
(d) no other assumption is possible

[ESE : 1996]

3.12 The bearing characteristic number in a hydrodynamic bearing depends upon
(a) length, width and load
(b) Length, width and speed
(c) Viscosity, speed and load
(d) Viscosity, speed and bearing pressure

[ESE : 1996]

3.13 When a shaft transmits power through gears, the shaft experiences
(a) torsional stresses alone
(b) bending stresses alone
(c) constant bending and varying torsional stresses
(d) varying bending and constant torsional stresses [ESE : 1997]

3.14 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Ball bearing
B. Tapered roller bearing
C. Spherical roller bearings
D. Needle roller bearings

List-II
1. Heavy loads with oscillatory motion
2. Light loads
3. Carrying both radial and thrust loads
4. Self-aligning property

Codes:

	A	B	C	D
(a)	4	1	3	2
(b)	2	1	4	3
(c)	2	3	1	4
(d)	2	3	4	1

[ESE : 1997]

3.15 In a journal bearings, the radius of the friction circle increases with the increase in
(a) load
(b) radius of the journal
(c) speed of the journal
(d) viscosity of the lubricant [ESE : 1997]

3.16 Which one of the following statements is NOT true of rolling contact bearing?

(a) The bearing characteristic number is given by ZN/p where Z is the absolute viscosity of the lubricant, N is the shaft speed and p is the bearing pressure.

(b) Inner race of a radial ball bearing has an interference fit with the shaft and rotates along with it.

(c) Outer race of the bearing has an interference fit with bearing housing and does not rotate.

(d) In some cases, the inner race is stationary and outer race rotates.

[ESE : 1997]

3.17 Match **List-I** (Type of keys) with **List-II** (Characteristic) and select the correct answer using the codes given below the lists:

List-I

A. Woodruff key
B. Kennedy key
C. Feather key
D. Flat key

List-II

1. Loose fitting, light duty
2. Heavy duty
3. Self aligning
4. Normal industrial use

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	3	2	1	4
(c)	2	3	4	1
(d)	3	2	4	1

[ESE : 1997]

3.18 Match **List-I** (Machine element) with **List-II** (Cause of failure) and select the correct answer using the codes given below the lists:

List-I

A. Axle
B. Cotter
C. Connecting rod
D. Journal bearing

List-II

1. Shear stress
2. Tensile/compressive stress
3. Wear
4. Bending stress

Codes:

	A	B	C	D
(a)	1	4	2	3
(b)	4	1	2	3
(c)	4	1	3	2
(d)	1	4	3	2

[ESE : 1998]

3.19 Consider the following statements.
A splined shaft is used for

1. Transmitting power
2. Holding a flywheel rigidly in position
3. Moving axially the gear wheels mounted on it
4. Mounting V-belt pulleys on it

Which of these statements are correct?

(a) 2 and 3 (b) 1 and 4
(c) 2 and 4 (d) 1 and 3

[ESE : 1998]

3.20 In the assembly design of shaft, pulley and key, the weakest member is

(a) Pulley (b) Key
(c) Shaft (d) None

[ESE : 1998]

3.21 Assertion (A): Hydrostatic lubrication is more advantageous when compared to hydrodynamic lubrication during starting and stopping the journal in its bearing.

Reason (R): In hydrodynamic lubrication, the fluid film pressure is generated by the rotation of the journal.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

3.22 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. End thrust
B. No cage
C. More accurate centering
D. Can be overloaded

List-II
1. Plain bearing
2. Ball bearing
3. Needle bearing
4. Tapered roller bearing

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	1	2
(c)	3	4	1	2
(d)	4	3	2	1

[ESE : 1998]

3.23 The shearing area of a key of length 'l' breadth 'b' depth 'h' is equal to
(a) $b \times h$
(b) $L \times h$
(c) $L \times b$
(d) $L \times \frac{h}{2}$ [ESE : 1998]

3.24 In a single row deep groove ball bearing, cages are needed to
(a) separate the two races
(b) separate the balls from inner race
(c) separate the outer race from the ball
(d) ensure that the balls do not cluster at one point and maintain proper relative angular portion

[ESE : 1999]

3.25 Which one of the following types of bearings is employed in shafts of gear boxes of automobiles?
(a) Hydrodynamic journal bearings
(b) Multi lobed journal bearings
(c) Antifriction bearings
(d) Hybrid journal bearings [ESE : 1999]

■■■■

Answers Bearings, Shafts, Axles and Keys

3.1 (d)	3.2 (a)	3.3 (c)	3.4 (b)	3.5 (d)	3.6 (a)	3.7 (d)	3.8 (b)
3.9 (c)	3.10 (d)	3.11 (a)	3.12 (d)	3.13 (a)	3.14 (d)	3.15 (b)	3.16 (a)
3.17 (b)	3.18 (b)	3.19 (d)	3.20 (b)	3.21 (a)	3.22 (d)	3.23 (c)	3.24 (d)
3.25 (c)							

Explanations Bearings, Shafts, Axles and Keys

3.1 (d)

Force = Gas force + Inertia force.
This force resisted by bearing pressure between the piston pin and the support length.
Since the force is u.d.l. so bending moment the pin fail is double shear near bosses ovalization is done to (elliptical shape) to take account of non linear distribution of forces. The pin should be checked for induced shear. Rocker arm is generally of I-section, but for low speed engines it can be rectangular section. Due to load on the valve, rocker arm is subjected to bending moment.

3.2 (a)

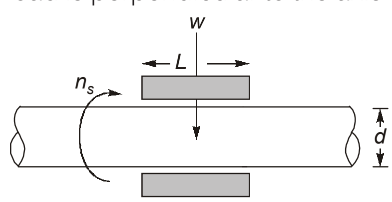
Axle supports rotating member therefore bending stresses but not rotates itself.

3.3 (c)

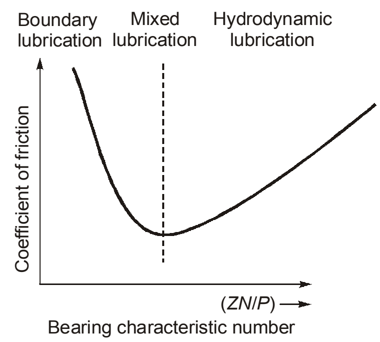
Wire shaft is also called Flexible shaft and it transmit motion between shaft where it is not possible to effect a rigid coupling between them.
Axle supports only revolving parts.
Plain shaft supports the revolving parts and transmits torque.

3.4 (b)

Journal is in floating condition with balanced force created by hydrodynamic pressure.
The load is perpendicular to the axis.



3.5 (d)



3.6 (a)

1. Pitting is a surface fatigue failure that occurs when load on the bearing exceeds the surface endurance strength. This is frequently found in ball bearing.
2. Wearing occurs when surfaces slide against each other and there is insufficient or no lubrication to keep them apart.
3. Spalling: when a progressive failure pitting reaches a certain stage, the metal between adjacent pits tends to be weakended and eventually breaks of this effect is known as spalling.
4. Scuffing is a complex phenomenon of severe adhesive wear generated under particular combinations including contact pressure, lubrication, speed and friction. Scuffing involves the sudden collapse of the lubricant film and is generally regarded as resulting from thermal phenomena.

3.7 (d)

Teflon Bearing	:	No external lubricant like oil
Carbon Bearing	:	High temperature application
Hydrodynamic Bearing	:	High load
Sleeve Bearing	:	Bushing

3.8 (b)

Axle supports rotating member but itself it never rotates. So torque is absent.

∴ Therefore designed only for bending stress.

Connecting rod takes tensile and compressive force arising from piston moment.

Wear is the criteria for Journal bearing.

3.9 (c)

Transmission shafts which is subjected to only bending stress are known as Axle. For pure bending case both theories will give same results.

3.10 (d)

$\frac{F_r}{F_a} > 1$ because majority of load carried is radial and some part axial.

3.12 (d)

Bearing characterstic No.

$$\mu \propto F\left[\frac{3n}{p} \times \frac{D}{c} \times \frac{L}{D}\right]$$

or $\frac{zn}{p}$ = bearing characterstic no.

where = z = viscosity; n = speed

p = bearing pressure

3.13 (a)

$P = T \times \omega$

$$\therefore \quad T = \frac{\pi}{16} \times \tau \times d^3$$

∴ Torque depends on torsional stress only.

3.14 (d)

Ball bearing - Light loads.

Tapered roller bearing - Carrying both radial and thrust load.

Spherical roller bearing - Self aligning bearing

Needle roller bearing - Heavy load with oscillatory motion.

3.15 (b)

$$x = \mu R$$

3.16 (a)

First statements is not valid for rolling contact bearing.

3.17 (b)

Woodruff Key: It is a sunk key, in the form of an almost semiconductor disk of uniform thickness. Once placed in position, the woodruff key tilts and aligns itself on the shaft.

Kennedy Key: It consists of two square keys and it is used for heavy duty applications.

Feather Key: It is used for light duty.

Flat Key: Normal industrial use.

3.18 (b)

Axle supports rotating member but itself it never rotates. So torque is absent.
∴ Therefore designed only for bending stress.
Connecting rod takes tensile and compressive force arising from piston moment.
Wear is the criteria for Journal bearing.

3.19 (d)

Splines are used when there is requirement of relative axial motion between shaft and hub. The gear shifting mechanism in automobile uses this mechanism.

3.20 (b)

Key should be weakest member as it should fail first to give notice that torque has exceeded hence to save the shaft and mechanical elements mounted on it.

3.21 (a)

The correct option is (a) i.e., both A and R are true and R is the correct explanation of (a)' A.
Since in hydrodynamic lubrication the fluid pressure is generated by the rotation of journal therefore at starting and stopping of journal bearing their will be a metal to metal contact since their is no sufficient pressure therefore in this case hydrostatic lubrication is more advantageous.

3.22 (d)

End thrust – Tapered roller bearing
No cage – Needle bearing
More accurate centering – Ball bearing
Can be overloaded – Plain bearing.

3.23 (c)

Shearing area = $L \times b$
Where, L is length of key, and b is width of key.

3.24 (d)

In a single row deep grove ball bearing, cages are needed to ensure that the balls do not cluster at one point and maintain proper relative angular portion.

3.25 (c)

Rolling contact bearings are also called anti friction bearing or simply ball bearing. It is employed in shaft of gear boxes of automobiles.

■■■■

4 Gears

4.1 The design of gear on account of Spott's equation which account for dynamic load is based on
(a) contact stress based on Hertz theory
(b) allowable stress based on maximum shear stress theory
(c) distortion energy theory
(d) Octahedral stress theory [ESE : 1998]

4.2 Consider the following characteristics:
1. Small interference
2. Strong tooth
3. Low production cost
4. Gear with small number teeth

Those characteristics which are applicable to Stub 20° involute system would include
(a) 1 alone (b) 2, 3 and 4
(c) 1, 2, and 3 (d) 1, 2, 3 and 4 [ESE : 1998]

4.3 **Assertion (A):** Shafts supporting helical gears must have only deep groove ball-bearings.
Reason (R): Helical gears produce axial thrusts.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1999]

■■■■

Answers Gears

4.1 (a) **4.2** (d) **4.3** (a)

Explanations Gears

4.1 (a)

It is based on contact stress based on Hertz theory. It arises when-there is point contact and dynamic load is acting.

4.2 (d)

20° stub tooth involute: Stub mean 20% less working depth than full depth gear so addendum is shorter (small interference is stub system. (The tooth becomes stronger as the lever arm of bending moment on tooth is reduced. Machining cost is less as compared to full depth system as less metal must be cut away minimum no of teeth on pinion to avoid interference is 14.

4.3 (a)

Helical gears has three force component F_t, F_r, F_a (Tangential, radial and axial) so deep groove ball bearing must be used as it can take radial and thrust force simultaneously.

■■■■

5 Brakes, Clutches and Ropes

(Ropes out of Syllabus)

5.1 Effective stress in wire ropes during-normal working is equal to the stress due to
(a) axial load plus stress due to bending
(b) acceleration/retardation of masses plus stress due to bending
(c) axial load plus stress due to acceleration/ retardation
(d) bending plus stress due to acceleration/ retardation [ESE : 1996]

5.2 Given that W = Weight of load handled, W_r = Weight of rope and f = Acceleration, the additional load in ropes of a hoist during starting is given by
(a) $F_a = \left(\frac{W - W_r}{g}\right)f$ (b) $F_a = \left(\frac{W + W_r}{g}\right)f$
(c) $F_a = \frac{W}{g}f$ (d) $F_a = \frac{W_r}{g}f$
[ESE : 1997]

5.3 In a multiple disc dutch, if there are 6 discs on the driving shaft and 5 discs on driven shaft, the number of pairs of contact surfaces will be equal to
(a) 11 (b) 12
(c) 10 (d) 22 [ESE : 1997]

5.4 On the motors with low starting torque, the type of the clutch to be used is
(a) multiple-plate clutch
(b) cone clutch
(c) centrifugal clutch
(d) single-plate clutch with both sides effective [ESE : 1999]

5.5 **Assertion (A):** In case of friction clutches, uniform wear theory should be considered for power transmission calculation rather than the uniform pressure theory.
Reason (R): The uniform pressure theory gives a higher friction torque than the uniform wear theory.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1999]

■■■■

Answers Brakes, Clutches and Ropes

5.1 (a) 5.2 (b) 5.3 (c) 5.4 (c) 5.5 (b)

Explanations Brakes, Clutches and Ropes

5.1 (a)

Because during normal operation acceleration avoided. So direct stress and bending stress accounted.

5.2 (b)

$$\begin{pmatrix}\text{mass of rope + mass of weight} \\ \text{to be raised be raised}\end{pmatrix} \times \text{accl}^n$$

= inertia force acting as additional load

5.3 (c)

$n_1 = 6, \quad n_2 = 5$

$N = n_1 + n_2 - 1 = 6 + 5 - 1 = 10$

5.4 (c)

Low starting torque permits the shoes to stick before running to full speed.
All the other clutches mentioned are for high torque.

5.5 (b)

Uniform pressure theory is applicable only when the clutches are new i.e., the assumption involved is that axial force W is uniformly distributed.
Moreover torque transmitted in uniform pressure is more hence for safety in design uniform wear theory is used.

■■■■

6 Power Screws

(Out of Current Syllabus)

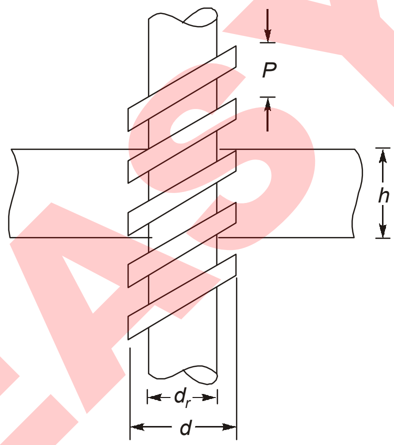
6.1 While designing a screw in a screw jack against buckling failure, the end conditions for the screw are taken as
(a) both the ends fixed
(b) both the ends hinged
(c) one end fixed and other end hinged
(d) one end fixed and the other end free
[ESE : 1995]

6.2 The load cup of a screw jack is made separate from the head of the spindle to
(a) enhance the load carrying capacity of the jack
(b) reduce the effort needed for lifting the working load
(c) reduce the value of frictional torque to be countered for lifting the load
(d) prevent the rotation of load being lifted
[ESE : 1995]

6.3 To ensure self-locking in a screw jack it is essential that helix angle is
(a) larger than friction angle
(b) smaller than friction angle
(c) equal to friction angle
(d) such as to give maximum efficiency in lifting
[ESE : 1996]

6.4 The friction torque for square thread at mean radius while raising load is given by
(w = load, R_0 = mean radius, ϕ = angle of friction, α = lead angle)
(a) $wR_0\tan(\phi - \alpha)$ (b) $wR_0\tan(\phi + \alpha)$
(c) $wR_0\tan\alpha$ (d) $wR_0\tan\phi$
[ESE : 1997]

6.5 Consider the case of square threaded screw loaded by a nut as shown in the given figure. The value of the average shearing stress of the screw is given by (symbols have the usual meaning)



(a) $\frac{2F}{\pi d_r h}$ (b) $\frac{F}{\pi d_r h}$
(c) $\frac{2F}{\pi dh}$ (d) $\frac{F}{\pi dh}$
[ESE : 1997]

6.6. The maximum efficiency of self locking screw is
(a) 50% (b) 70%
(c) 75% (d) 80%
[ESE : 1997]

6.7 The diameter of tommy bar for a screw jack is designed for
(a) bending moment due to effort applied
(b) torque on the tommy bar due to effort applied
(c) a percentage of axial loads
(d) some axial loads coupled with transverse loads
[ESE : 1999]

6.8 Which of the following screw thread is adopted for power transmission in either direction?
(a) Acme thread (b) Square thread
(c) Buttress thread (d) Multiple thread
[ESE : 1999]

■■■■

Answers Power Screws

6.1 (d) 6.2 (d) 6.3 (b) 6.4 (b) 6.5 (c) 6.6 (a) 6.7 (a) 6.8 (a)

Explanations Power Screws

6.1 (d)

One end fixed and other end free. as lower part of screw is free to rotate. The screw acts as column.

6.2 (d)

There is provision to prevent rotation by making load cup separate from the head of the spindle.

6.3 (b)

$\phi > \alpha$ [i.e. Friction Angle > Helix Angle]

$\tan\phi \geq \tan\alpha$

$$\tan\phi \geq \frac{np}{\pi d_m}$$

6.4 (b)

Torque required to raise the load

$T_1 = WR\ \tan(\phi + \alpha)$.

Torque required to lower load

$T_2 = WR\ \tan(\phi - \alpha)$.

6.5 (c)

The correct option is (c)

Shea stress $\tau = \dfrac{F}{\pi d_r Zt}$

Where Z is the no. of threads in engagement with the nut

t = thread thickness at the core diameter

also height of the nut $h = ZP$

where P is the pitch of the thread for square thread

$$t = \frac{P}{2}$$

$$\tau = \frac{F}{\pi d_r Z\frac{P}{2}} = \frac{2F}{\pi d_r ZP} = \frac{2F}{\pi d_r h}$$

i.e., $$\tau = \frac{2F}{\pi d_r h}$$

6.6 (a)

η of screw

$$\therefore \quad \eta = \frac{\tan\phi}{\tan(\alpha+\phi)}$$

$\therefore$ for self locking $\phi \geq \alpha$ or $\alpha \leq \phi$

$$\eta \leq \frac{\tan\phi}{\tan(\phi+\phi)} \text{ or } \frac{1}{2} - \frac{\tan^2\phi}{2}$$

$\therefore$ From this expression η of self locking screw is less than ½ or 50% if the η is more then 50% screw is said to be overhauling.

So maximum η is 50%

6.7 (a)

The diameter of tommy bar of screw jack is designed for bending moment due to effort applied at its end.

6.8 (a)

Acme thread is used for power transmission in either direction.

■■■■

7 Helical Springs

7.1 In the calculation of induced shear stress in the helical springs, the wahl correction factor is used to take of

(a) combined effect of transverse shear stress and bending stress is wire

(b) combined effect of bending stress and curvature of wire

(c) combined effect of transverse shear stress and curvature of wire

(d) combined effect of torsional shear stress & transverse shear stress of wire

[ESE : 1995]

7.2 A closely coiled helical spring is acted upon by axial force. The maximum shear stress developed in the spring is τ. Half of the length of spring is cut off and the remaining spring is acted upon by the same axial force. The maximum shear stress in the spring the new condition will be

(a) $1/2\,\tau$ (b) τ

(c) 2τ (d) 4τ

[ESE : 1995]

7.3 Given that

d = diameter of spring

R = mean radius of coils

n = number of coils and

G = modulus of rigidity

The stiffness of the close-coiled helical spring subject to an axial load W is equal to

(a) $\dfrac{Gd^4}{64R^3n}$ (b) $\dfrac{Gd^3}{64R^3n}$

(c) $\dfrac{Gd^4}{32R^3n}$ (d) $\dfrac{Gd^4}{64R^2n}$

[ESE : 1996]

7.4 When a close coiled helical spring is subjected to a couple about its axis, the stress induced in the wire material of the spring is

(a) bending stress only

(b) direct shear stress only

(c) a combination of torsional shear stress and bending stress

(d) a combination of bending stress and direct shear stress

[ESE : 1996]

7.5 A long helical spring having a spring stiffness of 12 kN/m and number of turns 20, breaks into two parts then stiffness of the resultant spring will be

(a) 6 kN/m (b) 12 kN/m

(c) 24 kN/m (d) 30 kN/m

[ESE : 1996]

7.6 Wahl stress factor takes into account

(a) direct shear stress

(b) torsional shear stress

(c) wire curvature effect

(d) direct shear and wire curvature effect

[ESE : 1997]

7.7 Two closed coil springs are made from the same small diameter wire, one wound on 2.5 cm diameter core and the other on 1.25 cm diameter core. If each spring had 'n' coils, then the ratio of their spring constants would be

(a) 1/16 (b) 1/8

(c) 1/4 (d) 1/2

[ESE : 1998]

7.8 A closed-coil helical spring is subjected to a moment about its axis. The spring wire would experience a

(a) bending stress

(b) direct tensile stress of uniform intensity at its cross-section

(c) direct shear stress

(d) torsional shearing stress **[ESE : 1998]**

7.9 A helical spring has N turns of coil of diameter D, and a second spring, made of same wire diameter and a same material, has $N/2$ turns of coil of

diameter $2D$. If the stiffness of the first spring is k, then the stiffness of the second spring will be
(a) $k/4$ (b) $k/2$
(c) $2k$ (d) $4k$ [ESE : 1999]

7.10 The maximum shear stress occurs on the outermost fibres of a circular shaft under torsion. In a close-coiled helical spring the maximum shear stress occurs on the
(a) outermost fibres
(b) fibres at mean diameter
(c) innermost fibres
(d) end coils [ESE : 1999]

7.11 If a compression coil spring is cut into two equal parts and the parts are then used in parallel, the ratio of the spring rate to its initial value will be
(a) 1
(b) 2
(c) 4
(d) Indeterminable for want of sufficient data [ESE : 1999]

■■■■

Answers Helical Springs

7.1 (c) 7.2 (b) 7.3 (a) 7.4 (a) 7.5 (c) 7.6 (d) 7.7 (b) 7.8 (a) 7.9 (a)
7.10 (c) 7.11 (c)

Explanations Helical Springs

7.1 (c)

Resultant shear stress in wire

$$\tau = \tau_1 + \tau_2 = \frac{8WD}{\pi d^3} + \frac{4W}{\pi d^2}$$

Maximum shear stress in wire
= Torsional shear stress + Direct shear stress

$$= \frac{8WD}{\pi d^3} + \frac{4W}{\pi d^2} = \frac{8WD}{\pi d^3}\left(1 + \frac{d}{2D}\right)$$

$$\tau = k \times \frac{8WD}{\pi d^3},\ k = \frac{4c-1}{4c-4} + \frac{0.615}{c}$$

{to consider the effect of both direct shear as well as curvature of the wire}
or $k = k_s \times k_c$
k_s = direct shear stress correction factor
k_c = correction factor for curvature effect

7.2 (b)

Shear stress in helical spring = $k_s\left(\frac{8WD}{\pi d^3}\right)$ where

k_s = shear stress correction factor $= \left(1 + \frac{0.5}{C}\right)$

Hence shear stress is independent of the length of spring.

7.3 (a)

The deflection of a close coil helical spring subjected to axial force 'W' is

$$\delta = R \times \theta$$

where δ = Deflection of spring

θ_C = angle of twist $= \frac{TL}{GJ}$

$$\therefore \quad \delta = R \times \frac{TL}{GJ} \quad \text{...(i)}$$

Now $T = W \times R$
$L = 2\pi Rn$

$$J = \frac{\pi}{32} d^4$$

From equation ...(i)

$$\delta = R \times \frac{W \times R \times 2\pi R \times n}{G \times \frac{\pi}{32} d^4} = \frac{64WR^3 n}{Gd^4}$$

Spring constant or stiffness factor is defined as the axial force required to produce unit deflection.

$$\therefore \text{ spring constant } (k) = \frac{W}{\delta}$$

$$\therefore \quad k = \frac{Gd^4}{64R^3 n}$$

7.4 (a)

When twist is applied to closed helical spring, then only bending stresses are induced

7.5 (c)

$$k = \frac{Gd^4}{64R^3 n}$$

$$k \propto \frac{1}{n} \quad \Rightarrow \frac{k_2}{k_1} = \frac{n_1}{n_2} \qquad \therefore \frac{k_2}{12} = \frac{20}{10}$$

$$\therefore \qquad k_2 = 24 \text{ kN/m}$$

7.6 (d)

Since the spring rod is bent into a curve, the shear stress on the inner surface is more than the shear stress developed on the outer surface. To take into account the curvature effect. Wahl's correction factor may be applied and maximum shear stress can be calculated as follows.

$$\tau_{max} = K_W \left(\frac{16WR}{\pi d^3}\right)$$

where K_W is Wahl's correction factor and is given by

$$K_W = \left(\frac{4c-1}{4c-4} + \frac{0.615}{c}\right)$$

where 'c' is the spring index

7.7 (b)

Spring constant : $k = \dfrac{Gd^4}{8D^3 n}$

$$\therefore \quad k \propto \frac{1}{D^3}$$

$$k_1 \times (2.5)^3 = k_2 \times (1.25)^3$$

$$\therefore \quad \frac{k_1}{k_2} = \frac{1}{8}$$

7.8 (a)

When a closed coil helical spring, fixed at one end is subjected at the other end to a twisting couple about the central axis of the spring, bending moment will be produced at all the cross-sections.

7.9 (a)

Stiffness; $k = \dfrac{Gd^4}{8D^3 N}$

Now $$k' = \frac{Gd^4}{8(2D)^3 \times \frac{N}{2}} = \frac{k}{4}$$

7.11 (c)

When a spring is cut into two number of coils So stiffness of each spring becomes doubled when type are connected in parallel.

stiffness = $2k + 2k = 4k$

■■■■

8 Miscellaneous

(Out of Syllabus from 2016)

8.1 Sources of power loss in a chain drive are given below:

1. Friction between chain and sprocket teeth.
2. Overcoming the chain stiffness.
3. Overcoming the friction in shaft bearing.
4. Frictional resistance to the motion of the chain in air or lubricant.

To correct sequence of descending order of power loss due to these sources is

(a) 1, 2, 3, 4 (b) 1, 2, 4, 3
(c) 2, 1, 3, 4 (d) 2, 1, 4, 3

[ESE : 1995]

8.2 Match **List-I** (Different type of detachable joints) with **List-II** (Specific use of detachable Joints) and select the correct answer using the codes given below the lists:

List-I
A. Cotter joint
B. Knuckle joint
C. Suspension Link joint
D. Turn buckle (adjustable joint)

List-II
1. Tie rod of wall crane
2. Suspension bridge
3. Diagonal stays in boiler
4. Cross head of a steam engine

Codes:

	A	B	C	D
(a)	4	2	3	1
(b)	4	3	2	1
(c)	3	2	1	4
(d)	2	1	4	3

[ESE : 1995]

8.3 The power transmitted by a belt is dependent on the centrifugal effect in the belt. The maximum power can be transmitted when the centrifugal tension is

(a) 1/3 of tension (T_1) on the tight side
(b) 1/3 of total tension (T_t) on the tight side
(c) 1/3 of the tension (T_2) on the slack side
(d) 1/3 of sum of tension T_1 and T_2 i.e., 1/3(T_1 + T_2)

[ESE : 1996]

8.4 In flat belt drive, if the slip between the driver and the belt is 1%, that between belt and follower is 3% and driver and follower pulley diameters are equal, then the velocity ratio of the drive will be

(a) 0.99 (b) 0.98
(c) 0.97 (d) 0.96

[ESE : 1996]

8.5 When belt drive is transmitting maximum power

(a) effective tension is equal to centrifugal tension
(b) effective tension is half of centrifugal tension
(c) driving tension on slack side is equal to the centrifugal tension
(d) driving tension on tight side is twice the centrifugal tension

[ESE : 1996]

8.6 **Assertion (A):** It is desirable to increase the length of arc over which the oil film has to be maintained in a journal bearing.

Reason (R): The oil pressure becomes negative in the divergent part and the partial vacuum created will cause air to leak in from the ends of bearing.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

8.7 If μ is the actual coefficient of friction in a belt moving in a grooved pulley, the groove angle being 2α, the virtual coefficient of friction will

(a) $\mu/\sin\alpha$ (b) $\mu/\cos\alpha$
(c) $\mu\sin\alpha$ (d) $\mu\cos\alpha$

[ESE : 1997]

8.8 In the case of a vertical belt pulley drive with T_C as centrifugal tension and T_0 as the initial tension, the belt would tend to hang clear of the lower pulley when

(a) $T_C < T_0$ (b) $T_C = T_0/3$

(c) $T_C > T_0$ (d) $T_C = T_0/2$

[ESE : 1997]

8.9 Given that T_1 and T_2 are the tensions on the tight and slack of the belt respectively, the initial tension of the belt taking centrifugal tension T_C is equal to

(a) $\frac{T_1 + T_2 + T_C}{3}$ (b) $\frac{T_1 + T_2 + 2T_C}{2}$

(c) $\frac{T_1 + T_2 + 3T_C}{3}$ (d) $\frac{T_1 + T_2 + 4T_C}{4}$

[ESE : 1997]

8.10 When the shafts are neither parallel nor intersecting, power can be transmitted by using

(a) a pair of spur gears

(b) a pair of helical gears

(c) an oldham coupling

(d) a pair of spiral gears [ESE : 1998]

8.11 Which of the following stresses are associated with design of pins in bushed pin-type flexible coupling?

1. Bearing stress
2. Bending stress
3. Axial tensile stress
4. Transverse shear stress

(a) 1, 3 and 4 (b) 2, 3 and 4

(c) 1, 2 and 3 (d) 1, 2 and 4

[ESE : 1998]

8.12 Centrifugal tension in belts is

(a) useful because it maintains some tension even when no power is transmitted

(b) not harmful because it does not take part in power transmission

(c) harmful because it increases belt tension and reduces the power transmitted

(d) a hypothetical phenomenon and does not actually exist in belts [ESE : 1999]

8.13 Match **List-I** (Different types of detachable joints) **List-II** (Specific use of these detachable joints) and select the correct answer using the codes given below the lists:

List-I

A. Cotter joint

B. Knuckle joint

C. Suspension link joint

D. Turn buckle (adjustable joint)

List-II

1. Tie rod of a wall crane

2. Suspension bridges

3. Diagonal stays in boiler

4. Cross-head of a steam engine

Codes:

	A	B	C	D
(a)	4	2	3	1
(b)	4	3	2	1
(c)	3	2	1	4
(d)	2	1	4	3

[ESE : 1999]

Answers Miscellaneous

8.1 (a) **8.2** (a) **8.3** (b) **8.4** (d) **8.5** (d) **8.6** (a) **8.7** (a) **8.8** (c) **8.9** (b)

8.10 (d) **8.11** (d) **8.12** (c) **8.13** (a)

Explanations Miscellaneous

8.1 (a)

This is the decreasing order in which losses takes place.

8.2 (a)

A. Cotter joint is used to connect two co-axial rods, which are subjected to either axial tensile force or axial compressive force application-joint between the piston rod and the cross-head of steam engine.

B. Knuckle joint is used to connect two rods whose axes either coincide or intersect and lie in one plane.

Application joint between the links of suspension bridge.

C. Suspension link joint diagonal stays in boiler.

D. Turn buckle (adjustable joint)
Application Tie rod of wall crane.

8.3 (b)

$$P = (F_1 - F_2)v$$

$$P = F_1\left(1 - \frac{1}{F_1/F_2}\right)v = F_1\left(1 - e^{-\mu\theta}\right)v$$

$$P = (F_{t_1} - F_c)v\left(1 - e^{-\mu\theta}\right)$$

$$\frac{dP}{dV} = 0 \qquad (\because Fe = mv^2)$$

$$F_{t_1} - 3mV^2 = 0$$

$$F_{t_1} = 3F_c$$

$$F_c = \frac{F_{t_1}}{3}$$

$\frac{1}{3}$ of total tension on tight side.

8.4 (d)

$$\frac{N_2}{N_1} = \frac{d_1}{d_2}\left[1 - \frac{S_1}{100} - \frac{S_2}{100}\right]$$

$$\Rightarrow \quad \frac{V_2}{V_1} = 1 - \frac{S_1}{100} - \frac{S_2}{100}$$

$$\Rightarrow \quad \frac{V_2}{V_1} = 1 - \frac{1}{100} - \frac{3}{100} = 0.96$$

8.5 (d)

$$F_c = \frac{F_{t_1}}{3} = \frac{F_1 + F_c}{3} \Rightarrow 3F_c = F_1 + F_c$$

$$2F_c = F_1$$

8.6 (a)

Side leak (axial) in nature and is constantly leaking through the end of bearing as the journal speeds up.

8.7 (a)

Limiting tension ratio of the v-belt is

$$\frac{T_1}{T_2} = e^{\left(\frac{\mu}{\sin\alpha}.\theta\right)}$$

where $\mu' = \frac{\mu}{\sin\alpha}$ μ called effective coefficient of friction

8.9 (b)

$$F_{t_1} = F_i + F_i - F_{t_2}$$

$$2F_i = F_{t_1} + F_{t_2}$$

$$F_i = \frac{F_1 + F_2 + 2F_c}{2} = \frac{T_1 + T_2 + 2T_c}{2}$$

8.10 (d)

Spiral gears — Non-parallel and non intersecting.

8.11 (d)

Stresses associated with design of bushed pin-type flexible coupling.

1. Bearing stress
2. Bending stress
3. Compressive stress
4. Transverse shear stress

8.12 (c)

Increase in centrifugal force is harmful as belt tries to come out of the pulley and it also reduces the power transmission.

8.13 (a)

Cotter joint - cross head of steam engine
Knuckle joint - Diagonal stays of boiler
Suspension joint - Suspension bridge
Turn buckle - Tie rod of a wall crane.

■■■■

UNIT

V

Manufacturing Engineering

Syllabus

Metal casting-Metal forming, Metal Joining, Machining and machine tool operations, Limits, fits and tolerances, Metrology and inspection, computer Integrated manufacturing and FMS.

Contents

❍❍❍❍

1 Metal Casting

1.1 **Assertion (A):** Aluminium alloys are cast in hot chamber die casting machine.
Reason (R): Aluminium alloys require high melting when compared to zinc alloys.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE : 1995]**

1.2 Match **List-I** (Product) with **List-II** (Process of Manufacture) and select the correct answer using the codes given below the lists:

List-I
A. Automobile piston in aluminium alloy
B. Engine crankshaft in spheroidal graphite iron
C. Carburettor housing in aluminium alloy
D. Cast titanium blades

List-II
1. Pressure die-casting
2. Gravity die-casting
3. Sand casting
4. Precision investment casting
5. Shell moulding.

Codes:

	A	B	C	D
(a)	2	3	1	5
(b)	3	2	1	5
(c)	2	1	3	4
(d)	4	1	2	3

[ESE : 1995]

1.3 Directional solidification in castings can be improved by using
(a) chills and chaplets
(b) chills and padding
(c) chaplets and padding
(d) chills, chaplets and padding **[ESE : 1995]**

1.4 Consider the following ingredients used in moulding
1. Dry silica sand
2. Clay
3. Phenol formaldehyde
4. Sodium silicate

Those used for shell mould casting include
(a) 1, 2 and 4 (b) 2, 3 and 4
(c) 1 and 3 (d) 1, 2, 3, and 4
[ESE : 1996]

1.5 Which of the following methods are used for obtaining directional solidification for riser design?
1. Suitable placement of chills.
2. Suitable placement of chaplets.
3. Employing padding.

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2, and 3
[ESE : 1996]

1.6 Misrun is a casting defect which occurs due to
(a) very high pouring temperature of the metal.
(b) insufficient fluidity of the molten metal.
(c) absorption of gases by the liquid metal.
(d) improper alignment of the mould flasks.
[ESE : 1996]

1.7 Which of the following pairs are correctly matched?
1. Pit moulding ...For large jobs
2. Investment moulding ...Lost wax process
3. Plaster moulding ...Mould prepared in gypsum

(a) 1, 2, and 3 (b) 1 and 2
(c) 1 and 3 (d) 2 and 3
[ESE : 1996]

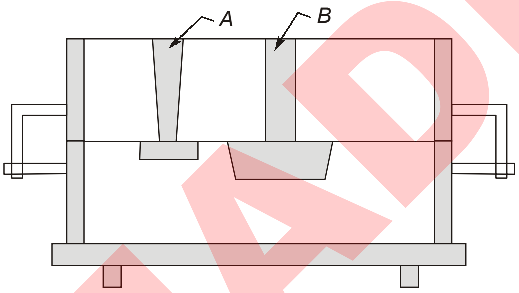
1.8 Which one of the following pairs is not correctly matched?
(a) Aluminium alloy piston ...Pressure die casting
(b) Jewellery ... Lost wax process
(c) Large pipes ... Centrifugal casting
(d) Large bells ... Loam moulding
[ESE : 1997]

1.9 If the melting ratio of a cupola is 10 : 1, then the coke requirement for one ton melt will be
(a) 0.1 ton (b) 10 tons
(c) 1 ton (d) 11 tons **[ESE : 1997]**

1.10 **Assertion (A):** Steel can be melted in hot blast cupola.
Reason (R): In hot blast cupola, the flue gases are used to preheat the air blast to the cupola so that the temperature in the furnace is considerably higher than that in a conventional cupola.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE : 1997]**

1.11 Which one of the following refractory materials is recommended for steel furnaces containing CaO slag?
(a) Alumina (b) Silica
(c) Magnesia (d) Fireclay **[ESE : 1997]**

1.12 A sand casting mould assembly is shown in the given figure. The elements marked *A* and *B* are respectively



(a) Sprue and riser (b) Ingate and riser
(c) Drag and runner (d) Riser and runner
[ESE : 1998]

1.13 Which of the following are the requirements of an ideal gating system?
1. The molten metal should enter the mould cavity with as high a velocity as possible.
2. It should facilitate complete filling of the mould cavity.
3. It should be able to prevent the absorption of air or gases from the surroundings on the molten metal while flowing through it.

Select the correct answer using the codes given below:
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (b) 1 and 3 **[ESE : 1998]**

1.14 A spherical drop of molten metal of radius 2mm was found to solidify in 10 seconds. A similar drop of radius 4mm would solidify in
(a) 14.14 second (b) 20 seconds
(c) 18.30 second (d) 40 seconds
[ESE : 1998]

1.15 In solidification of metal during casting, compensation for solid contraction is
(a) Provided by the oversize pattern
(b) Achieved by properly placed risers
(c) Obtained by promoting direction solidification
(d) Made by providing chills **[ESE : 1999]**

■■■■

Answers Metal Casting

1.1	(d)	1.2	(a)	1.3	(b)	1.4	(c)	1.5	(b)	1.6	(b)	1.7	(a)	1.8	(a)	1.9	(a)
1.10	(a)	1.11	(b)	1.12	(a)	1.13	(c)	1.14	(d)	1.15	(a)						

Explanations Metal Casting

1.1 (d)

Due to sticking tendency of Al life of goosneck is reduced. It is not used in hot chamber die casting. Material are used and aluminium alloy having high melting point. The melting point of Aluminium and zinc are 660°C and 422°C respectively.

1.3 (b)

Chills and padding can be used to improve directional solidification.

1.4 (c)

In shell moulding, dry silica sand and phenol formaldehyde used.

1.5 (b)

Chills and padding are use to increase the rate of cooling. Chaplet are anchors of core.

1.6 (b)

Mis-run is caused when the metal is unable to fill the mould cavity completely and thus leaves unfilled cavities, it occurs due to low pouring temperature, lack of fluidity.

1.7 (a)

Pit moulding is used for large job and in investment casting wax is used and Plaster of Paris or Gypsum ($CaSO_4\ nH_2O$) is extensively used in plaster mould casting.

1.8 (a)

Gravity die casting is used to manufacturing of aluminium alloy piston.

1.11 (b)

Silica is used refractory material.

1.12 (a)

A is sprue, it should be tapered down to take into account the gain in velocity of the metal as it flows reducing the air aspiration.
B is riser, it acts as a reservoir of molten metal is to be maintained from which the metal can flow readily into the casting when the need arises.

1.13 (c)

Main requirements of an ideal gating system is it should facilitate complete filling of the mould cavity and should be able to prevent the absorption of air or gases from the surroundings on the metal while flowing through it.

1.14 (d)

Chvorinov's equation;

$$\text{Solidification rate} = \left(\frac{V}{A}\right)^2 \times k \quad [k = \text{constant}]$$

$$\frac{t_1}{t_2} = \left(\frac{r_1}{r_2}\right)^2$$

$$\Rightarrow \quad t_2 = (2)^2 \times 10 = 40 \text{ second}$$

1.15 (a)

In solidification of metal during casting, compensation for solid contraction is (shrinkage allowance) is provided by the oversize pattern.

■■■■

2 Metal Forming and Sheet Metal Operations

2.1 Match **List-I** (Metal forming process) with **List-II** (Associated force) and select the correct answer using the codes given below the lists:

	List-I		List-II
A.	Wire drawing	1.	Shear force
B.	Extrusion	2.	Tensile force
C.	Blanking	3.	Compressive force
D.	Bending	4.	Spring back force

Codes:

	A	B	C	D
(a)	4	2	1	3
(b)	2	1	3	4
(c)	2	3	1	4
(d)	4	3	2	1

[ESE : 1996]

2.2 In wire drawing process, the bright shining surface on the wire is obtained if one
(a) not using a lubricant
(b) low tooling cost
(c) uses thick paste lubricant
(d) use thin fluid lubricant

[ESE : 1996]

2.3 Which one of the following is an advantage of forging?
(a) Good surface finish
(b) Low tooling cost
(c) Close tolerance
(d) Improved physical property

[ESE : 1996]

2.4 **Assertion (A):** In drop forging besides the provision for flash, provision is also to be made in the forging die for additional space called gutter.
Reason (R): The gutter helps to restrict the outward flow of metal thereby helping to fill thin ribs and bases in the upper die.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

2.5 A cup of 10 cm height and 5 cm diameter is to be made from a sheet metal of 2 mm thickness. The number of deductions necessary will be
(a) one (b) two
(c) three (d) four

[ESE : 1997]

2.6 Which one of the following processes is most commonly used for the forging of bolt heads of hexagonal shape?
(a) Closed die drop forging
(b) Open die upset forging
(c) Close die press forging
(d) Open die progressive forging

[ESE : 1998]

2.7 The bending force required for V-bending, U-bending and Edge-bending will be in the ratio of
(a) 1 : 2 : 0.5 (b) 2 : 1 : 0.5
(c) 1 : 2 : 1 (d) 1 : 1 : 1

[ESE : 1998]

2.8 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Drawing
B. Rolling
C. Wire drawing
D. Sheet metal operations using progressive dies

List-II
1. Soap solution
2. Camber
3. Pilots
4. Crater
5. Ironing

Codes:

	A	B	C	D
(a)	2	5	1	4
(b)	4	1	5	3
(c)	5	2	3	4
(d)	5	2	1	3

[ESE : 1999]

2.9 Consider the following operations involved in forging a hexagonal bolt from a round bar stock, whose diameter is equal to the bolt diameter

1. Flattening
2. Upsetting
3. Swaging
4. Cambering

The correct sequence of these operations is

(a) 1, 2, 3, 4 (b) 2, 3, 4, 1
(c) 2, 1, 3, 4 (d) 3, 2, 1, 4

[ESE : 1999]

2.10 Which one of the following is the correct temperature range for hot extrusion of aluminium?

(a) 300 – 340°C (b) 350 – 400°C
(c) 430 – 480°C (d) 550 – 650°C

[ESE : 1999]

2.11 Assertion (A): In a two high rolling mill there is a limit to the possible reduction in thickness in one pass.

Reason (R): The reduction possible in the second pass is less than that in the first pass.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

2.12 Consider the following statements:

Earing in a drawn cup can be due to non-uniform

1. Speed of the press
2. Clearance between tools
3. Material properties
4. blank holding

Which of these statements are correct?

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 3 and 4 (d) 1, 2 and 4

[ESE : 1999]

2.13 Assertion (A): In sheet metal blanking operation, clearance must be given to the die.

Reason (R): The blank should be of required dimensions.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1999]

■■■■

Answers Metal Forming and Sheet Metal Operations

2.1 (c) 2.2 (d) 2.3 (d) 2.4 (c) 2.5 (c) 2.6 (c) 2.7 (a) 2.8 (d) 2.9 (a)
2.10 (c) 2.11 (b) 2.12 (b) 2.13 (d)

Explanations Metal Forming and Sheet Metal Operations

2.1 (c)

Spring back force is present in bending of sheets.

2.2 (d)

Uses thin fluid lubricant, makes the bright shining surface.

2.3 (d)

Improved physical property.

2.5 (c)

The number of deductions necessary will be three.

2.6 (c)

Close die press forging

2.8 (d)

Camber: As a result of the roll bending the rolled strip tends to be thicker (have a crown (at its centre that at its edges. The usual method of avoiding this problem is to grind the rolls so that their diameter at the centre is slightly larger than at their edges by giving them Camber. Thus when the roll bends, contact along the width of the strip becomes straight and the strip being rolled has a constant thickness along its width.

Ironing: Ironing is a process in which the wall thickness of a drawn cup is made constant by the pushing of the cup through the Ironing rings.

Craters: are shallow depressions.

2.9 (a)

The correct sequence of these operations is:

→ Flattening

→ Upsetting

→ Swaging

→ Cambering

2.10 (c)

The temperature of the metals in the die are as follows:

(a) 325 to 425°C for Mg

(b) 425 to 480°C for Al

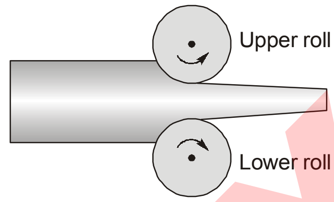
(c) 650 to 900°C for Cu Alloys

(d) 1100 to 1250°C for Steel

(e) 200 to 250°C for lead

2.11 (b)

Two high or three high rolling mills are used for hot rolling in initial break down passes.



The space between the rolls can be adjusted by the raising or lowering the upper roll. The positions of the lower roll is fixed, both the rolls rotate in the opposite direction to one another. Their direction of the rotation is fixed and cannot be reversed. Thus the work can be rolled by feeding from one direction only.

2.12 (b)

Earing: In drawing the edges of cups may become wavy this phenomenon is called as the earing. The earing condition is caused by the planar anisotropy of the sheet.

2.13 (d)

In the sheet metal blanking operation, clearance must be given to the punch.

■■■■

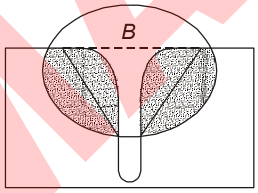
3 Joining/Welding

3.1 Consider the following statements:
MIG welding process uses
1. consumable electrode
2. non-consumable electrode
3. D.C. power supply
4. A.C. power supply

Which of these statements are correct?
(a) 2 and 4 (b) 2 and 3
(c) 1 and 4 (d) 1 and 3 **[ESE : 1997]**

3.2 **Assertion (A):** The electrodes of AC arc welding are coated with sodium silicate, whereas electrodes used for DC arc welding are coated with potassium silicate binders.
Reason (R): Potassium has a lower ionisation potential than sodium.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE : 1997]**

3.3 An arc welded joint is shown in the above figure. The part labelled '*B*' in the figure is known as



(a) Weld preparation (b) Penetration
(c) Reinforcement (d) Slag **[ESE : 1998]**

3.4 The voltage-current characteristics of a dc generator for arc welding is a straight line between an open-circuit voltage of 80 V and short-circuit current of 300 A. The generator settings for maximum arc power will be
(a) 80 V & 150 A (b) 40 V & 300 A
(c) 40 V & 150 A (d) 80 V & 300 A
[ESE : 1998]

3.5 Which of the following joining processes are best suited for manufacturing pipes to carry gas products?
1. Riveting 2. Welding
3. Bolts and nuts

Select the correct answer using the codes given below:
(a) 1 and 2 (b) 1 and 3
(c) 2 alone (d) 1, 2 and 3
[ESE : 1998]

3.6 In oxy-acetylene gas welding, for complete combustion, the volume of oxygen required per unit of acetylene is
(a) 1 (b) 1.5
(c) 2 (d) 2.5 **[ESE : 1998]**

3.7 The correct sequence of the given materials in ascending order of their weldability is
(a) MS, copper, cast iron, aluminium
(b) Cast iron, MS, aluminium copper
(c) Copper, cast iron, MS, aluminium
(d) Aluminium, copper, cast iron, MS
[ESE : 1999]

■■■■

Answers **Joining/Welding**

3.1 (d) **3.2** (d) **3.3** (c) **3.4** (c) **3.5** (c) **3.6** (d) **3.7** (d)

Explanations Joining/Welding

3.1 (d)

Metal inert gas arc welding or more appropriately called as gas metal arc welding utilizes a consumable electrode. Normally DC arc welding machines are used for MIG with electrode positive.

3.2 (d)

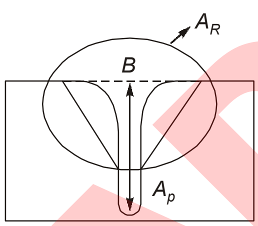
The electrodes of AC arc welding are coated with potassium silicate binder. It is so because an AC arc must reignite itself when it crosses zero current instant energy 0.01 sec. Reignition require high voltage than normal arc voltage. The process of reignition if facilitated by presence of ions having lower ionization potential and potassium has lower ionization potential.

3.3 (c)

A_R - Reinforcement

A_p - Penetration

$$\text{Dilution} = \frac{A_p}{A_p + A_R}$$



3.4 (c)

The voltage-length characteristics of D.C. current are is given by

$$\therefore \quad V = \left\{80 - \frac{80}{300}I\right\} \text{volt}$$

$$P = VI = \left(80 - \frac{80}{300}I\right)I$$

For maximum power;

$$\frac{dP}{dI} = 80 - \frac{80}{300} \times 2I = 0$$

$$\therefore \quad I = 150 \text{ A and } V = 40 \text{ V}$$

3.5 (c)

Joining process depends upon type of service required and welding gives permanent nature of joint and strength being equal to or sometimes greater than that of parent metal makes welding one of the most extensively used fabrication method. Leakage is very less in welding.

3.6 (d)

$$C_2H_2 + 5/2O_2 \rightarrow 2CO_2 + H_2O$$

1 mole C_2H_2 requires 2.5 moles of O_2

3.7 (d)

Weldibality signifies the ability of the metal to be welded. It is capacity of metal to be welded into a specific structure.

Low carbon - excellent weldability

High carbon - poor weldability

In case of Al main problem is removal of oxide layer, so high costly welding techniques are used.

■■■■

4 Machining and Machine Tool Operation

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.1 **Assertion (A):** Non-ferrous materials are best machined with diamond tools.
Reason (R): Diamond tools are suitable for high speed machining. [ESE : 1995]

4.2 **Assertion (A):** A chip breaker is employed to improve the machinability of brass.
Reason (R): A chip breaker facilitates the curling and breakage of long continuous chips. [ESE : 1995]

4.3 The angle between the face and the flank of the single point cutting tool is known as
(a) rake angle (b) clearance angle
(c) lip angle (d) point angle
[ESE : 1995]

4.4 Single point thread cutting tool should ideally have
(a) zero rake (b) positive rake
(c) negative rake (d) normal rake
[ESE : 1995]

4.5 Consider the following statements about nose radius
1. It improves tool life
2. It reduces the cutting force
3. It improves the surface finish

Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3
[ESE : 1995]

4.6 The straight grades of cemented carbide cutting tool materials contain
(a) tungsten carbide only
(b) tungsten carbide and titanium carbide
(c) tungsten carbide and cobalt
(d) tungsten carbide and coal carbide
[ESE : 1995]

4.7 Crater wear is predominant in
(a) carbon steel tools
(b) tungsten carbide tools
(c) high speed steel tools
(d) ceramic tools [ESE : 1995]

4.8 Consider the following work materials:
1. Titanium 2. Mild steel
3. Stainless steel 4. Grey cast iron

The correct sequence of these materials in terms of increasing order of difficulty in machining is
(a) 4, 2, 3, 1 (b) 4, 2, 1, 3
(c) 2,4, 3, 1 (d) 2, 4, 1, 3
[ESE : 1995]

4.9 The primary tool force used in calculating the total power consumption in machining is the
(a) radial force (b) tangential force
(c) axial force (d) frictional force
[ESE : 1995]

4.10 The effects of setting a boring tool above centre height leads to a/an
(a) increase in the effective rake angle and a decrease in the effective clearance angle
(b) increase in both effective rake angle and effective clearance angle
(c) decrease in the effective rake angle and an increase in the effective clearance angle
(d) decrease in both effective rank angle and effective clearance angle [ESE : 1995]

4.11 Assertion (A): Up milling or climb is commonly used for machining castings and forgings.
Reason (R): Up milling can be done on universal milling machines.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE : 1995]**

4.12 In a milling operation two side milling cutters are mounted with a desired distance between them so that both sides of a work piece can be milled simultaneously. This setup is called
(a) gang milling (b) straddle milling
(c) string milling (d) side milling
[ESE : 1995]

4.13 In the grinding wheel of *A*60 *G*7 *B* 23, *B* stands for
(a) resinoid bond (b) rubber bond
(c) shellac bond (d) silicate bond
[ESE : 1995]

4.14 Soft material cannot be economically grounded due to
(a) the high temperature involved
(b) frequent wheel clogging
(c) rapid wheel wear
(d) low work piece stiffness **[ESE : 1995]**

4.15 Assertion (A): In a Swiss-type automatic lathe, the turret is given longitudinal feed for each tool in a specific order with suitable indexing.
Reason (R): A turret is a multiple tool holder to facilitate machining with each tool by indexing without the need to change the tools.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1995]

4.16 In a mechanical shaper, the length of stroke is increased by
(a) increasing the centre distance of bull gear and crank pin.
(b) decreasing the centre distance of bull gear and crank pin.
(c) increasing the length of the ram.
(d) decreasing length of the slot in the slotted lever. **[ESE : 1995]**

4.17 While cutting helical gears on a non-differential gear hobber, the feed change gear ratio is
(a) independent of index change gear ratio
(b) dependent on speed change gear ratio
(c) interrelated to index change gear ratio
(d) independent of speed and index change gear ratio **[ESE : 1995]**

4.18 Match **List-I** (Task) with **List-II** (Recommendation) and select the correct answer using the codes given below the lists:
List-I
A. Three components in a straight line should worked in one loading
B. Unloading of clamp element from jig is essential
C. Clamping of rough surface
D. Need for heavy clamping force
List-II
1. Clamp with a floating pad
2. Quick action nut
3. Cam clamp
4. Equalising clamp
5. Strap clamp
Codes:

	A	B	C	D
(a)	5	2	3	4
(b)	4	2	1	5
(c)	1	4	2	3
(d)	4	1	5	3

[ESE : 1995]

4.19 If the diameter of the hole is subject to considerable variation, then for locating in jigs and fixtures, the pressure type of locator used is
(a) conical locator (b) cylindrical locator
(c) Diamond pin locator (d) Vee locator
[ESE : 1995]

4.20 Chip equivalent is increased by
(a) an increase in side-cutting edge angle of tool
(b) an increase in nose radius and side cutting edge angle of tool
(c) increasing the plan area if cut
(d) increasing the depth of cut **[ESE : 1996]**

4.21 A machinist desires to turn a round steel stock of outside diameter 100 mm at 1000 rpm. The material has tensile strength of 75 kg/mm^2. The depth of cut chosen is 3 mm at a feed rate of 0.3 mm/rev. Which one of the following tool materials will be suitable for machining the component under the specified cutting conditions?
(a) Sintered carbides (b) Ceramic
(c) HSS (d) Diamond
[ESE : 1996]

4.22 Which of the following indicate better machinability?
1. Smaller shear angle
2. Higher cutting forces
3. Longer tool life
4. Better surface finish

(a) 1 and 3 (b) 2 and 4
(c) 1 and 2 (d) 3 and 4
[ESE : 1996]

4.23 Which of the following forces are measured directly by strain gauges or force dynamometers during metal cutting?
1. Force exerted by the tool on the chip acting normally to the tool face.
2. Horizontal cutting force exerted by the tool on the work piece.
3. Frictional resistance of the tool against the chip flow acting along the tool face.
4. Vertical force which helps in holding the tool in position.

(a) 1 and 3 (b) 2 and 4
(c) 1 and 4 (d) 2 and 3
[ESE : 1996]

4.24 Consider the following statements
The cutter setting block in a milling fixture
1. sets the cutting tool with respect of two of its surface.
2. Limits the total travel required by the cutter during machining.
3. Takes location from the location scheme of component.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3
[ESE : 1996]

4.25 Specific energy requirements in a grinding process are more than those in turning for the same metal removal rate because of the
(a) specific pressures between wheel and work being high.
(b) size effect of the larger contact areas between wheel and work.
(c) high cutting velocities.
(d) high heat produced during grinding.
[ESE : 1996]

4.26 A Grinding wheel of 150 mm diameter is rotating at 3000 r.m.p. The grinding speed is
(a) 7.5π m/s (b) 15π m/s
(c) 45π m/s (d) 450π m/s
[ESE : 1996]

4.27 Grinding wheel is said to be loaded when the
(a) Metal particles get embedded in the wheel surface blocking the interspaces between cutting grains.
(b) bonding material comes on the surface and the wheel becomes blunt.
(c) work piece being ground comes to a stop in cylindrical grinding.
(d) grinding wheel stops because of very large depth of cut. [ESE : 1996]

4.28 Which of the following statements are correct?
1. A boring machine is suitable for a job shop
2. A jig boring machine is designed specially for doing more accurate work when compared to a vertical milling machine.
3. A vertical precision boring machine is suitable for boring holes in cylinder blocks and linear.

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3 [ESE : 1996]

4.29 Consider the following processes of gear manufacture
1. Milling with form cutter
2. Rack type gear shaper (gear planer)
3. Rotary gear shaper (gear shaper)
4. Gear hobbing

The correct sequence of these processes in increasing order of accuracy of convolute profile of the gear is
(a) 3, 2, 4, 1 (b) 2, 3, 4, 1
(c) 3, 2, 1, 4 (d) 2, 3, 1, 4
[ESE : 1996]

4.30 Gear cutting on a milling machine using an involute profile cutter is a
(a) gear forming process.
(b) gear generating process.
(c) gear shaping process.
(d) highly accurate gear producing process.
[ESE : 1996]

4.31 For the manufacture of full depth spur gear by hobbing process, the number of teeth to be cut = 30, module = 3 mm and pressure angle = 20°. The radial depth of cut to be employed should be equal to
(a) 3.75 mm
(b) 4.50 mm
(c) 6.00 mm
(d) 6.75 mm
[ESE : 1996]

4.32 **Assertion (A):** Special purpose machine tools can do special types of machining work automatically.
Reason (R): Vertical boring machine is an example of special purpose machine tool.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1996]

4.33 Internal gears can be made by
(a) hobbing
(b) gear shaping with rack cutter
(c) gear shaping with pinion cutter
(d) gang milling
[ESE : 1996]

4.34 **Assertion (A):** A workpiece with rough unmachined surface can be located in a jig or fixture on three supporting points.
Reason (R): Indexing is made accurate by supporting on three points.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1996]

4.35 Which of the following is/are the advantage(s) of numerical control of machine tools?
1. Reduced lead time
2. Consistently good quality
3. Elaborate Fixtures are not required
Select the correct answer using the codes given below:
Codes:
(a) 2 and 3 (b) 1 and 2
(c) 1 alone (d) 1 and 3
[ESE : 1996]

4.36 In orthogonal cutting, the depth of cut is 0.5 mm at a cutting speed of 2 m/s. If the chip thickness is 0.75 mm, the velocity is
(a) 1.33 m/s (b) 2 m/s
(c) 2/5 m/s (d) 3 m/s [ESE : 1997]

4.37 Consider the following elements
1. Nose radius 2. Cutting speed
3. Depth of cut 4. Feed
The correct sequence of these elements in DECREASING order of their influence on tool life is
(a) 2, 4, 3, 1 (b) 4, 2, 3, 1
(c) 2, 4, 1, 3 (d) 4, 2, 1, 3
[ESE : 1997]

4.38 The rake angle in a twist drill
(a) varies from minimum near the dead centre to a maximum value at the periphery.
(b) is maximum at the dead centre and zero at the periphery.
(c) is constant at every point of the cutting edge.
(d) is a function of the size of the chisel edge.
[ESE : 1997]

4.39 Consider the following statement with respect to relief angle of cutting tool
1. This affects the direction of chip flow
2. This reduces excessive friction between the tool & work piece.
3. This affects tool life.
4. This allow better access of coolant the tool-workpiece interface.
Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 2 and 4 (d) 3 and 4
[ESE : 1997]

4.40 Assertion (A): Ceramic tools are used only for light, smooth and continuous cuts at high speeds.
Reason (R): Ceramics have a high wear resistance and high temperature resistance.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1997]

4.41 Consider the following statements:
In Up milling process,
1. the cutter starts the cut from the machined surface and proceeds upwards.
2. the cutter starts the cut from the top surface and proceeds downwards
3. the job is fed in a direction opposite to that of cutter rotation.
4. the job is fed in the same direction as that of cutter rotation.

Which of these statements are correct?
(a) 1 and 3 (b) 1 and 4
(c) 2 and 3 (d) 2 and 4 [ESE : 1997]

4.42 Which one of the following materials is used as the bonding material for grinding wheels?
(a) Silicon carbide (b) Sodium silicate
(c) Boron carbide (d) Aluminium oxide
[ESE : 1997]

4.43 Which of the following are the advantages of a hydraulic shaper over a mechanically driven shaper?
1. More strokes per minute can be obtained at a given cutting speed.
2. The cutting stoke has a definite stopping point.
3. It is simpler in construction
4. Cutting speed is constant throughout most of the cutting stroke.

Select the correct answer using the codes given below:
(a) 1 and 2 (b) 1 and 4
(c) 2 and 4 (d) 1, 3 and 4
[ESE : 1997]

4.44 Consider the following operations:
1. Under cutting 2. Plain turning
3. Taper turning 4. Thread cutting

The correct sequence of these operations in machining a product is:
(a) 2, 3, 4, 1 (b) 3, 2, 4, 1
(c) 2, 3, 1, 4 (d) 3, 2, 1, 4
[ESE : 1997]

4.45 Which of the following motions are not needed for spur gear cutting with a hob?
1. Rotary motion of hob.
2. Linear axial reciprocatory motion of hob?
3. Rotary motion of gear blank.
4. Radial advancement of hob.

Select the correct answer using the codes given below:
(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 1, 2 and 4 (d) 2, 3 and 4
[ESE : 1997]

4.46 Match **List-I** (Gear component) with **List-II** (Preferred method of manufacturing) and select the correct answer using the codes given below the lists:

List-I
A. Gear for clocks
B. Bakelite gears
C. Aluminium gears
D. Automobile transmission gears

List-II
1. Hobbing
2. Stamping
3. Powder compacting
4. Sand casting
5. Extrusion

Codes:

	A	B	C	D
(a)	2	3	5	1
(b)	5	3	4	2
(c)	5	1	2	3
(d)	2	4	5	3

[ESE : 1997]

4.47 Assertion (A): In a slow speed high pressure metal cutting process such as gear cutting, chlorinated or sulphonated oils are used.
Reason (R): Reduction of coefficient of friction is achieved by the formation of a solid film at the rubbing interface of tool and chip.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1997]

4.48 Consider the following statement:
During third stage of tool-wear, rapid deterioration of tool edge takes place because
1. Flank wear is only marginal
2. Flank wear is large
3. Temperature of tool increase gradually
4. Temperature of tool increase drastically

(a) 1 and 3 (b) 2 and 4
(c) 1 and 4 (d) 2 and 3

[ESE : 1998]

4.49 In metal cutting operation, the approximate ratio heat distributed among chip, tool and work, in that order is
(a) 80 : 10 : 10
(b) 33 : 33 : 33
(c) 20 : 60 : 10
(d) 10 : 10 : 80

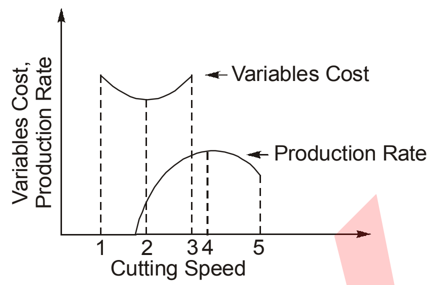
[ESE : 1998]

4.50 Poor machinability of centrifugally cast iron pipe is due to
(a) Chilling
(b) Segregation
(c) Dense structure
(d) High mould rotation speed [ESE : 1998]

4.51 On a lathe, the actual machining time required per work piece is 30 minutes. Two types of carbide tools are available, both having a tool life of 60 minutes.
Type-I : Brazed type of original cost Rs. 50/-
Type-II : Throw away tip (square) of original cost Rs. 70/-
If the overall cost of grinding the cutting edge is Rs. 10/-, assuming all the costs are the same for both the types, for break even costs, the appropriate batch size would be
(a) 2 pieces (b) 4 pieces
(c) 6 pieces (d) 8 pieces

[ESE : 1998]

4.52 The variable cost and production rate of a machining rate of a machining process against cutting speed are shown in the given figure. for efficient machining the range of best cutting speed would be



(a) 1 and 3 (b) 1 and 5
(c) 2 and 4 (d) 3 and 5 [ESE : 1998]

4.53 Consider the following criteria in evaluating machinability
1. Surface finish
2. Type of chips
3. Tool life
4. Power consumption

In modern high speed CNC machining with coated carbide tools, the correct sequence of these criteria in DECREASING order of their importance is
(a) 1, 2, 4, 3 (b) 2, 1, 4, 3
(c) 1, 2, 3, 4 (d) 2, 1, 3, 4

[ESE : 1998]

4.54 Which one of the following pairs of parameters and effects is not correctly matched?
(a) Large wheel diameter ... Reduced wheel wear
(b) Large depth of cut ... Increased wheel wear
(c) Large work diameter... Increased wheel wear
(d) Large wheel speed... Reduced wheel wear

[ESE : 1998]

4.55 The gauge factor of a resistive pick-up of cutting force dynamometer is defined as the ratio of
(a) Applied strain to the resistance of the wire
(b) The proportional change in resistance to the applied strain
(c) The resistance to the applied strain
(d) Change in resistance to the applied strain

[ESE : 1998]

4.56 A 400 mm long shaft has a 100 mm tapered step at the middle with 4° included angle. The tailstock offset required to produce this taper on a lathe would be
(a) 400 sin 4° (b) 400 sin 2°
(c) 100 sin 4° (d) 100 sin 2°

[ESE : 1998]

4.57 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Reaming
B. Counter-boring
C. Counter-sinking
D. Spot facing

List-II

1. Smoothing and squaring surface around the hole for proper seating
2. Sizing and finishing the hole
3. Enlarging the end of the hole
4. Making a conical enlargement at the end of the hole

Codes:

	A	B	C	D
(a)	3	2	4	1
(b)	2	3	1	4
(c)	3	2	1	4
(d)	2	3	4	1

[ESE : 1998]

4.58 A component requires a hole which must be within the two limits of 25.03 and 25.04 mm diameter. Which of the following statement about the reamer size are correct?

1. Reamer size cannot be below 25.03 mm
2. Reamer size cannot be above 25.04 mm
3. Reamer size can be 25.04 mm
4. Reamer size can be 25.03 mm.

Select the correct answer using the code given below:

(a) 1 and 3 (b) 1 and 2
(c) 3 and 4 (d) 2 and 4

[ESE : 1998]

4.59 **Assertion (A):** Internal gears are cut on a gear shaper.

Reason (R): Hobbing is not suitable for cutting internal gear.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

4.60 Which one of the following sets of forces are encountered by a lathe parting tool while groove cutting?

(a) Tangential, radial and axial
(b) Tangential and radial
(c) Tangential and axial
(d) Radial and axial

[ESE : 1999]

4.61 In a single-point turning operation of steel with a cemented carbide tool, Taylor's tool life exponent is 0.25. If the cutting speed is halved, the tool life will increase by

(a) Two times (b) Four times
(c) Eight times (d) Sixteen times

[ESE : 1999]

4.62 Consider the following approaches normally applied for the economic analysis of machining

1. Maximum productions rate
2. Maximum profit criterion
3. Minimum cost criterion

The correct sequence in ascending order of optimum cutting speed obtained by these approaches is:

(a) 1, 2, 3 (b) 1, 3, 2
(c) 3, 2, 1 (d) 3, 1, 2

[ESE : 1999]

4.63 Match **List-I** (ISO classification of carbide tools) with **List-II** (Applications) and select the correct answer using the codes given below the lists:

List-I

A. P – 10
B. P – 50
C. K – 10
D. K – 50

List-II

1. Non-ferrous, roughing cut
2. Non-ferrous, finishing cut
3. Ferrous material, roughing cut
4. Ferrous material, finishing cut

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	3	4	2	1
(c)	4	3	2	1
(d)	3	4	1	2

[ESE : 1999]

4.64 Consider the following statements:
For precision machining of non-ferrous alloys, diamond is preferred because it has:
1. Low coefficient of thermal expansion
2. High wear resistance
3. High compression strength
4. Low fracture toughness

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 4
(c) 2 and 3 (d) 3 and 4
[ESE : 1999]

4.65 In turning operation, the feed could be doubled to increase the metal removal rate. To keep the same level of surface finish, the nose radius of the tool should be
(a) Halved
(b) Kept unchanged
(c) Doubled
(d) Made four times
[ESE : 1999]

4.66 The radial force in single-point tool during turning operation varies between
(a) 0.2 to 0.4 time the main cutting force
(b) 0.4 to 0.6 times the main cutting force
(c) 0.6 to 0.8 times the main cutting force
(d) 0.5 to 0.6 times the main cutting force
[ESE : 1999]

4.67 A straight teeth slab milling cutter of 100 mm diameter and 10 teeth rotating at 200 rpm is used to remove a layer of 3 mm thickness from a steel bar. If the table feed is 400 mm/minute, the feed per tooth in this operation will be
(a) 0.2 mm (b) 0.4 mm
(c) 0.5 mm (d) 0.6 mm
[ESE : 1999]

4.68 Consider the following reasons
1. Grinding wheel is soft
2. RPM of grinding wheel is too low
3. Cut is very fine
4. An improper cutting fluid is used

A grinding wheel may become loaded due to reasons stated at
(a) 1 and 4 (b) 1 and 3
(c) 2 and 4 (d) 2 and 3
[ESE : 1999]

4.69 Match **List-I** (Drill bits) with **List-II** (Applications) and select the correct answer using the codes given below the lists:

List-I
A. Core drill
B. Reamer
C. Counter bore drill
D. Tap drill

List-II
1. To enlarge a hole to a certain depth so as to accommodate the bolt head of a screw
2. To drill & enlarge an already existing hole in a casting
3. To drill a hole before making internal thread
4. To improve the surface finish and dimensional accuracy of the already drilled hole

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	2	3	1	4
(c)	2	4	1	3
(d)	3	2	4	1

[ESE : 1999]

4.70 Which one of the following processes results in the best accuracy of the hole made?
(a) Drilling (b) Reaming
(c) Broaching (d) Boring [ESE : 1999]

4.71 Consider the following statements regarding reaming process:
1. reaming generally produces a hole larger than its own diameter
2. Generally rake angels are not provided on reamers.
3. Even numbers of teeth are preferred in reamer design.

Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3
[ESE : 1999]

4.72 A 60-teeth gear when hobbed on a differential hobber with a two-start hob, the index change gear ratio is governed by which one of the following kinematic balance equations?
(a) 1 revolution of gear blank = 1/60 of hob revolutions
(b) 1 revolution of gear blank = 2/60 of hob revolutions
(c) 1 revolution of hob = 2/60 of blank revolutions
(d) 1 revolution of hob = 1/60 of blank revolutions
[ESE : 1999]

4.73 Diamond pin location is used in a fixture because

(a) It does not wear out

(b) It takes care of any variation in centre distance between two holes

(c) It is easy to clamp the part on diamond pins

(d) It is easy to manufacture [ESE : 1999]

4.74 Assertion (A): Spherical washers are used to locate the job in the fixtures.

Reason (R): 3 – 2 – 1 principle should be adopted to locate the job.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true [ESE : 1999]

Answers Machining and Machine Tool Operation

4.1	(b)	4.2	(d)	4.3	(c)	4.4	(a)	4.5	(c)	4.6	(c)	4.7	(b)	4.8	(a)	4.9	(b)
4.10	(c)	4.11	(d)	4.12	(b)	4.13	(a)	4.14	(b)	4.15	(b)	4.16	(a)	4.17	(c)	4.18	(d)
4.19	(a)	4.20	(b)	4.21	(b)	4.22	(d)	4.23	(b)	4.24	(d)	4.25	(b)	4.26	(a)	4.27	(a)
4.28	(a)	4.29	(d)	4.30	(b)	4.31	(d)	4.32	(b)	4.33	(c)	4.34	(c)	4.35	(a)	4.36	(a)
4.37	(a)	4.38	(a)	4.39	(b)	4.40	(b)	4.41	(a)	4.42	(b)	4.43	(c)	4.44	(a)	4.45	(a)
4.46	(a)	4.47	(a)	4.48	(d)	4.49	(a)	4.50	(c)	4.51	(a)	4.52	(c)	4.53	(c)	4.54	(c)
4.55	(b)	4.56	(b)	4.57	(d)	4.58	(b)	4.59	(b)	4.60	(a)	4.61	(d)	4.62	(c)	4.63	(c)
4.64	(a)	4.65	(d)	4.66	(a)	4.67	(a)	4.68	(c)	4.69	(c)	4.70	(b)	4.71	(b)	4.72	(c)
4.73	(b)	4.74	(d)														

Explanations Machining and Machine Tool Operation

4.1 (b)

Diamond tools have low tool-chip friction, high wear resistance and ability to maintain a sharp cutting edge and are used for high speed machining of non ferrous material (Al, Cu, brass of bronze or where silicon content is more). Non ferrous material generally have continuous chip formation. Feed rate is kept low.

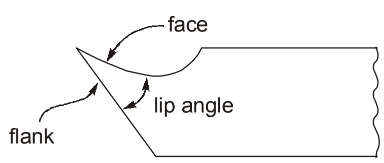
While machining ferrous material they have strong chemical affinity for it so not recommended for ferrous material.

4.2 (d)

Machinability of a material depends upon the property of material by which the ease with which it can cut to give better surface, tool life obtained. Force and power requirement, chip control (As for chip control, long and thin, curved chip should be produced itself). For brass, the chip produced is discontinuous so no use of chip breaker.

4.3 (c)

Lip angle is defined as the angle between the face and flank of the tool.



4.4 (a)

It is true form-cutting procedure, no rake should be ground on the tool, and the top of the tool must be horizontal and be set exactly in line with the axis of rotation of the work; otherwise, the resulting thread profile will not be correct. An obvious disadvantage of this method is that the absence of side and back rake results in poor cutting (except on cast iron or brass). The surface finish on steel usually will be poor.

4.5 (c)

Large nose radius gives better surface finish and improves tool life.

However cutting force and possibility of chatter increases when the nose radius is increased.

4.6 (c)

Tungsten	
Straight tungsten carbide	Alloyed tungsten carbide
(powder metallurgy)	Alloyed tungsten carbide has addition of carbide of titanium and niobium etc.
(85–97 tungsten carbide) + cobalt (5– 15%) which acts as bonding agent	

4.7 (b)

Tungsten carbide tool: because when the interface temperature is high then the carbides disintegrate ($wc \rightarrow w + c$) and carbon diffuses to the softer matrix of machining part, this phenomena reduces the strength of tool and after some time it dislodges it.

4.9 (b)

Tangential force because power consumption is $F_c . V$ (cutting force × cutting velocity).

4.10 (c)

The effect of setting a boring tool above centre height leads to an decrease in rake angle and increase in effective clearance angle.

4.11 (d)

Climb milling (Up milling) is not suitable for machining of workpiece having surface scale such as hot-worked metals, forging and casting. The scale is hard and abrasive causes excessive wear and damage to the cutter teeth, shortening its life.

In universal milling machine table is placed on the swivel and the swivel is placed on the saddle. Because of the swivel, the table and hence the job can be fixed at desired angle, so that inclined cuts can be taken and hence the job can be fixed at desired angle, so that inclined cuts can be taken and hence the helical gear and drilling flutes are easily cut by the machine.

4.13 (a)

A	60	*G*	7	*B*	23
1	2	3	4	5	6

1. Abrasive type *A* – aluminium oxide, *C* – Silicon carbide
2. Abrasive grain size, 60 – Medium
3. Grade *A* (Soft) - to *z* (hard)
4. Structure 1 (Dense) to 16 (Open)
5. Bond type *B*-Resinoid, *R*-Rubber, *E*- Shellac, *S*-Silicate
6. Manufacturer's record

4.14 (b)

Soft material can not be economically grinded because ductile nature (small chips produced and get clogged in between randomly oriented teeth).

4.15 (b)

Swiss type they are designed for machining long accurate part of small diameter (4 to 25 mm). An exclusive feature of these machine is the longitudinal travel of head stock or of a quite carrying the rotating work spindle.

The main characteristic of turret lathe is 6-sided block mounted on one end of the bed replacing tail stock this allow mounting six tool block each one of then containing one or more tool according to requirement thus total tool carrying capacity is 14 tools.

4.16 (a)

Shaper makes use of a single point tool that transverse the work and feed once at the end of each stroke. Since amount of metal removed at one time is relatively small in area, therefore little pressure is imposed upon work and elaborate holding fixtures are not needed. Shaper is very well suited for contour work which is done by coordinating the tool hand feed to a layout line or by a duplicating attachment placed on machine like deep internal slot and difficult contours.

It occupies less space, consumes less power, cost less, occupies less floor area, is easier to operate and about three times quicker in action. It gets its drive from the quick return mechanism which makes it run faster while returning and slower while cutting. The size of shaper is given by maximum length of stroke or ram movement. Size varying from 175 to 900 mm stroke.

The length of stroke can be increased by increasing the centre distance of bull gear and crank pin.

4.17 (c)

Helical teeth are to be cut, the axis of hob can be set over at an angle to produce the proper helix. The hob axis is set at angle equal to helix angle of thread in reference to the axis of gear blank. This brings the blank teeth in the plane of hob's teeth. This plane is termed as generating plane. The cutter finishes all the teeth in one pass over the work.

Work table and hob have to rotate in definite relationship obtained by index change gear formula is:

$$\frac{\text{Number of teeth on index change gear}}{\text{Number of teeth on index gear}}$$

$$\frac{\text{Indexing constant} \times \text{Number of teeth of hob}}{\text{Number of teeth to be cut}}$$

For hobbing helical gear the rotation of work table is slightly advanced or retarded in relation to rotation of axial feed screw by means of another set of change gear called differential change gears. The differential change gears are calculated to satisfy the following basic relations between axial feed screw and work table rotation. Revolution of axial feed screw × lead of axial feed screw = additional revolution of work table × Lead of work piece helix.

4.18 (d)

Equalizing Clamp: Three components in a straight line should working in one loading.

Clamp with a floating pad: unloading of clamp element ram jig is essential.

Strap clamp: Clamping of rough surface.

Cam Clamp: Need for heavily clamping force.

4.19 (a)

Locator: Application.

Conical locator: These are used to locate a work piece which is cylindrical and with or without a hole.

Cylindrical locator: In these, the locating diameter of the pin is made a push fit with the hole in the workpiece.

Diamond pin locator: These are used to constrain the pivoting of the workpiece around the principal location

V-locator: These are used, in circular and semicircular profile.

4.20 (b)

According to Colding's equation:

$$q = \frac{\text{Engaged cutting edge length}}{\text{Plan area of cut}}$$

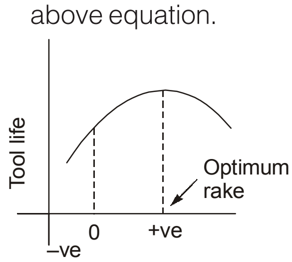
$$= \frac{\dfrac{[d - r_n(1 - \sin\gamma_s)]}{[\cos\gamma_s + (\pi/2 - \gamma_s)r_n + f/2]}}{fd}$$

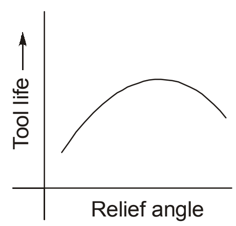
where

γ_s = side cutting edge angle

f = feed rate; d = depth of cut; r_n = nose radius

When side cutting edge angle is increased, the chip equivalent q as well as area of chip tool contact is increased without significantly changing the cutting the forces. Increase in nose radius increases the value of chip equivalent q and improves life. Increases in nose radius also increases the value of chip equivalent q from above equation.





4.21 (b)

Ceramic because ceramic tool should be used for low depth of cut and low feed rate but at very high speed, cutting takes place.

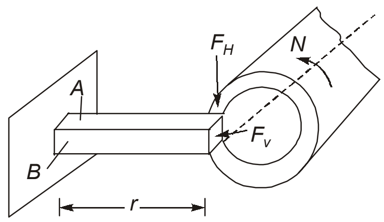
4.22 (d)

Larger shear angle implies F_c will be more

$$F_c = F_s \cdot \frac{bt_1}{\sin\phi} \frac{\cos(\beta - \alpha)}{\cos(\phi + \beta - \alpha)} \qquad \boxed{F_c \uparrow \text{as } \phi \downarrow}$$

Good machinability indicates good surface finish and integrity, long tool life, low force and power requirement and easy collection of chips that does not interfere with the cutting operations.

4.23 (b)



The tangential force and axial component along the tool is measured. For any cutting process it is desirable to measure the three force components in a set of rectangular coordinates. While measuring these three forces, the dynamometer should be so designed that force in x-direction should give no reading in y and z-directions, i.e., there be no cross-sensitivity.

4.24 (d)

Cutter setting block sets the workpiece in correct relationship with cutter with the help of filler gauge Cutter setting block also gives correct correlation (location) for milling operation.

4.25 (b)

Grinding process is a very inefficient one compared to the conventional metal cutting process.

Specific energy of grinding = 50 J/mm^3

Specific energy of other = 2 to 5 J/mm^3

A large number of cutting edges are involved in cutting this result in large contact area between wheel and work.

4.26 (a)

$$V = \frac{\pi DN}{60} = \frac{\pi \times 150 \times 3000}{60 \times 1000} = 7.5\,\pi \text{ m/s}$$

4.27 (a)

Grinding wheel is said to be loaded when the metal particles get embedded in the wheel surface blocking the interspaces between cutting grains. Loading is generally caused during the grinding of soft and ductile materials. A loaded. grinding wheel cannot cut properly. Such a grinding wheel can be cleared and sharpened by means of process called dressing.

4.28 (a)

JIG Boring Machines: These are precision boring machines having precision spindles and slides. These are used for machining drilling, boring of precision components as well as for making tools and dies for press work and machining of components for jigs and fixtures etc. The machines are generally equipped with high precision optical scales for motion measurement of every slide. For high accuracy the machines should be kept in a clean and temperature controlled (air- conditioned) environment.

Vertical precision boring are used to machine inside and outside diameters of large pipes and pressure vessels. Since boring machines are very heavy and big i.e., Standard vertical boring machine is largest of machine tool so boring machine are kept at job shops.

4.29 (d)

Planer < Shaper < Milling with form cutter < Hobbing

4.30 (b)

Gear cutting on a milling machine using an involute profile cutter is a gear generating process.

Form cutting	:	Such as gear milling broaching.
Generation	:	Which generate the involute surface of gear teeth.
Forming	:	Which form gear teeth by plastic deformation of the work material.

4.31 (d)

Radial depth of cut = Tooth depth (h)

Tooth depth (h) = 2.25 m

= 2.25 × 3 = **6.75 mm**

4.33 (c)

Internal gears will be made by gear shaping with pinion cutter.

4.34 (c)

Indexing Jigs and Fixtures are used when holes or slots are to be machined to some specific relationship, in a work piece.

4.35 (a)

Numerical control has following advantages over conventional method of machines control:

1. Flexibility of operation is improved, as well as the ability to produce compex shapes with good dimensional accuracy, good repeatability, reduced scrap loss, high production rates, high productivity, and high product quality.
2. Tooling costs are reduced, because templates and other **fixtures are not required**.
3. More operation can be performed with each setup, and the **lead time** for setup and machining **required is less**, as compared to conventional method.

4.36 (a)

Volume of metal removal.

$$l_1 b_1 t_1 = l_2 b_2 t_2 (\text{mm}^3)$$

$$V_1 b_1 t_1 = V_2 \cdot b_2 \cdot t_2 (\text{mm}^3/s) \quad b_1 = b_2$$

∵ no side flow

$$V_2 = V_1 \cdot \frac{t_1}{t_2} = \frac{2 \times 0.5}{0.75} = 1.33 \text{ m/s}$$

4.37 (a)

Effect on tool life

$V > f > d >$ nose radius

4.38 (a)

Normal rake angle α at a distance r from center is given by

$$\alpha = \tan^{-1}\left[\frac{\left(\frac{2r}{D}\right)\tan\psi}{\sin\beta}\right]$$

where ψ = helix angle, β = half point angle

'r' being the radius of the point on the cutting edge where the normal rake is being evaluated.

4.39 (b)

The relief is provided to side and end flanks in order to minimize physical interference or rubbing contact with the machined surface of workpiece.

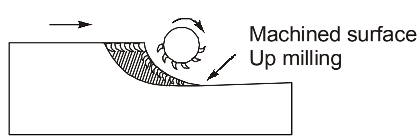
It is prescribed to use smaller relief angle when either the tool material is brittle or workpiece has high tensile strength or both because small relief do not weaken cutting edge.

Increased relief angle provide a cleaner cut and reducing the friction at the flank causing reduction in cutting force.

4.40 (b)

Ceramic tools are used only for light smooth and continuous cut at high speed because they are brittle and have poor shock resistance. Since they contain pure aluminium oxide (97%) and carbides they are very hard and have good resistance to abrasion wear and cratering. The main problem with ceramic tools are their low strength, poor thermal characteristic and their tendency towards chipping.

4.41 (a)



Cutter starts the cut from the machined surface and proceeds upwards and the job is fed in a direction opposite to that of cutter rotation.

4.42 (b)

Sodium silicate is bonding material, while other three are abrasive particles, other examples of bonds are:

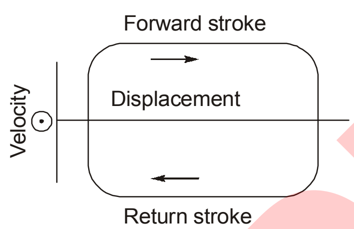
Vitrified, Synthesis, Resin, Rubber, Shellac

Vitrified: This is actually clay mixed with fluxes such as feldspar, which harder to glass like substance on firing to a temperature of about 1250°C and develops the strength.

4.43 (c)

Hydraulic mechanism are becoming increasingly popular because of the following advantages:

(a) Greater flexibility of speed
(b) Smoother operation.
(c) Possibility of changing speed and feed during operation
(d) Velocity diagram of hydraulically operated shaper-shows a very nearly constant velocity as compared with the crank shaper



In one stroke it moves at low speed and in opposite stroke it moves at high speed.

4.44 (a)

Plain turning → Taper turning → Thread cutting → Under cutting.

4.45 (a)

In spur gear cutting, Rotary motion and axial feed is given to hob. Gear blank is given Rotary motion. Linear axial reciprocatory motion is given to hob.

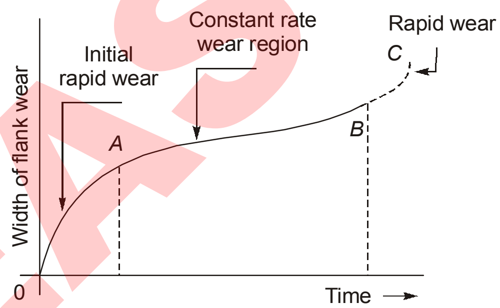
4.46 (a)

Gear of clocks are made by stamping. Materials up to 3mm thickness are practical for this process.

Powder Compacting: In this process a master gear of hard material is rolled against a heated gear-blank, thereby forming the teeth on the hot blank. Bakelite and other plastic materials are the most commonly used materials for manufacture of gear by this method.

4.48 (d)

The wear land is not of uniform width. It is widest at a point farthest from the nose. This is due to the fact that the material cut by this part of cutting edge had been work hardened during the previous cut. The frictional stress and maximum temperature at the flanks also go on increasing with time.



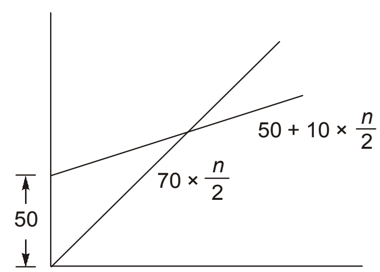
A stage is reached when diffusion becomes the predominant wear mode on the flank. After a critical wear land has formed, further wear takes place at an accelerating rate.

4.49 (a)

Maximum heat is carried away by chip, tool and workpiece share almost equal heat i.e., 10% each while chip contains 80% of total heat.

4.51 (a)

One tool of both the types produces two pieces. Now if break even point is 'n' number of pieces then:



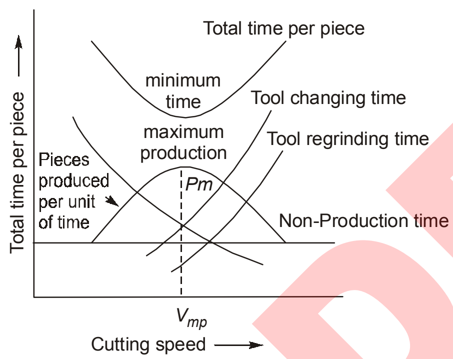
$$50 + 10 \times \left(\frac{n}{2}\right) = \frac{n}{2} \times 70$$

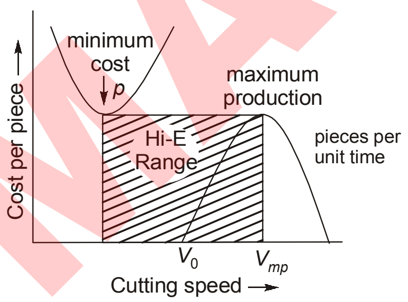
$$\Rightarrow \quad 50 + 5n = 35n$$

$$\Rightarrow \quad n = \frac{5}{3} = 1.667 \simeq 2$$

4.52 (c)

Our main interest is in producing the components at maximum rate and at minimum cost. For this, we adopt the minimum cost and maximum production curves as shown in figure. While observing this diagram we find that the cutting speed (V_0) at which the total production cost in minimum, is not the same as that at which the production rate is maximum. The former is less than the latter. The area lying in between these two values of cutting speeds is knows as "High Efficiency Range" (Hi-E Range) and the cutting speeds lying in this range are either economical or more productive. For efficient and economical production of a workpiece the cutting speed should always be selected from within the range only.





4.53 (c)

The main criteria of using CNC machine is to achieve closer dimensional tolerance (Better surface finish most important criteria) Surface finish > Type of chip > Tool life > Power consumption.

4.54 (c)

Grinding wheel wear is generally correlated with the amount of work piece material ground by a parameter called the grinding ratio, G, which is defined as

$$G = \frac{\text{Volume of material removed}}{\text{Volume of wheel wear}}$$

$$\text{Grain force} \propto \left(\frac{v}{V}\sqrt{\frac{d}{D}}\right)$$

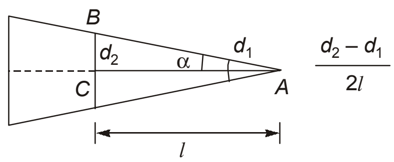
[Strength of the material]

where, v – Velocity of work piece
d – Depth of cut
V – Speed/velocity of grinding wheel
D – Diameter of grinding wheel

The higher the force, the greater the tendency for the grains to fracture or be **dislodged** from the wheel surface, and the higher the wheel wear and the lower the grinding ratio.

We note that the grain force increases with the strength of the work piece material, work speed and depth of cut, and decreases with increasing wheel speed and wheel diameter. Thus a wheel acts soft when v and d increase or when V and D decrease.

4.56 (b)

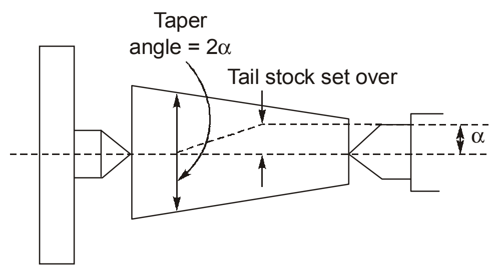


The offset can be calculate as follows:

$$\sin\alpha = \frac{BC}{AB}$$

$S = AB \sin\alpha = L \sin\alpha$

If α is very small, then we can approximate



$$\sin\left(\frac{\alpha}{2}\right) = \tan\left(\frac{\alpha}{2}\right) = \frac{D-d}{2l}$$

$$S = L\frac{(D-d)}{2l}$$

This is most general situation where taper is to be limited and as such this method is suitable for small taper over a long length. The disadvantage is that the centres would not be properly bearing in the centre hole and as such there would be nonuniform wearing.

$$S = L \times \frac{D-d}{2l}$$

$$\sin\left(\frac{\alpha}{2}\right) = \frac{D-d}{2l}$$

$\therefore \quad S = 400 \sin 2°$

4.57 (d)

Reaming: It is operation of sizing and finishing a already existing hole.

Counter-boring : The hole is enlarged with a flat bottom to provide a proper seating for bolt head or nut.

Countersinking: Similar to counter boring additional machining done on a hole is conical to accommodate the counter sink machine screw head.

Spot facing: Similar to counter boring but removes very small portion of material.

4.58 (b)

The reamer drill size to be selected for a particular hole should be in limit less in size than the finish size of hole.

4.59 (b)

A gear shaping pinion cutter is used by which one can cut internal gear. Hobbing has a hob tool which is worm like or thread like cutter which is fed axially along the gear so not possible to make internal gear.

4.60 (a)

In case of groove cutting, the tool is set on centre and fed in until it just touches the work surface. The three component tangential, radial and axial will arise.

4.61 (d)

$$V_1T_1^n = V_2T_2^n$$

$$VT^{0.25} = \frac{V}{2}T_2^{0.25} \qquad [2]^4 \cdot T = T_2$$

$$\boxed{T_2 = 16T}$$

T = Tool life increased by sixteen times.

4.62 (c)

At the cutting speed for minimum cost, the production rate may be too low to maximize profit rate while at the cutting speed for maximum production rate, the cost of production may be too high and hence profit margin is too low

$$V_{op_{min\,cost}} < V_{op_{max\,profit}} < V_{op_{max\ prodution}}$$

4.63 (c)

A-4; B-3; C-2; D-1

P-10 Ferrous material finishing cut

P-50 Ferrous material, roughening

K-10 Non ferrous, finishing cut

K-50 Non ferrous, roughening cut

4.64 (a)

Diamond has lowest thermal expansions (12% that of steel) High heat conductivity (2 times that of steel) very low coefficient of friction against metal and poor electrical thermal conductivity. So they are used to machine soft materials (nonferrous metal) for production of high surface finish.

4.65 (d)

$$H_{max} = \frac{f^2}{8r}$$

where f is feed rate and r is nose radius

$$H_{max} \propto f^2$$

$$\propto \frac{1}{r}$$

$$(H_{max})_1 = k \times \frac{f_1^2}{r_1}$$

$$(H_{max})_2 = k \times \frac{(2f_1)^2}{r_2}$$

$\therefore \ (H_{max})_1 = (H_{max})_2$

$r_2 = 4r_1$

4.66 (a)

F_t for turning varies between $0.3F_c$ to $0.6F_c$
F_r for turning varies between $0.2F_c$ to $0.4F_c$

4.67 (a)

$f = f_T \times Z \times N$ where f = Table feed;

f_T = feed/tooth; Z = Number of teeth

N = RPM

$\therefore \ 400 = f_T \times 10 \times 200$

$$\Rightarrow f_T = \frac{400}{2000} = 0.2 \text{ mm}$$

4.69 (c)

Tap drill: These are used for enlarging and correcting the location of previously made holes as their cutting edges do not extend upto the centre.

Flat drill: It is preferred for drilling soft material such as brass, as it will not feed itself into the material more quickly than is desired.

4.70 (b)

Reaming is the process in which surface finish and dimensional accuracy is improved whereas boring make the hole true.

4.71 (b)

Straight reamers type produce better finish due to smooth shear cutting. The flutes on reamer body act both as cutting teeth and a grooves for accommodating chips removed. The size of reamer is specified by diameter measured across two margins, at the cutting edge on diametrical line. Number of flutes is usually even.

4.73 (b)

Diamond pin location is used in fixture because it takes care of any variation in centre distance between two holes.

4.74 (d)

Spherical washers are used to locate the job in the jigs not in fixtures 3–2–1 principle is used to locate the job. So only statement 2 is correct.

■■■■

5 Metrology and Inspection

5.1 Match **List-I** (Measuring Device) with **List-II** (Parameter Measured) and select the correct answer using the codes given below the lists:

List-I

A. Diffraction grating
B. Optical flat
C. Auto collimators
D. Laser scan micrometer

List-II

1. Small angular deviations on long flat surfaces.
2. Online measurement of moving parts
3. Measurement of gear pitch
4. Joining hydraulic piston rods for agricultural machinery
5. Measurement of very small displacements

Codes:

	A	B	C	D
(a)	5	4	2	1
(b)	3	5	1	2
(c)	3	5	4	1
(d)	5	4	1	2

[ESE : 1998]

■■■■

Answers Metrology and Inspection

5.1 (b)

Explanations Metrology and Inspection

5.1 (b)

Diffraction grating - Measurement of gear pitch.
Optical flat - Measurement of very small displacement.
Autocollimator - Small angular deviations on long flat surface.
Laser scan micrometer - Online measurement of moving part.

■■■■

6 NC, CNC, DNC, APT, Automation

6.1 Match **List-I** (A function connected with NC m/c tool) with **List-II** (Associated parameter) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Interpolation	**1.** Tape preparation
B. Parity check	**2.** Canned cycle
C. Preparatory function	**3.** Drilling
D. Point to point control	**4.** Contouring
	5. Turning

Codes:

	A	B	C	D
(a)	4	1	2	3
(b)	4	1	2	5
(c)	5	1	3	2
(d)	1	4	3	2

[ESE : 1995]

6.2 Consider the following characteristics of production jobs
1. Processing of parts frequently in small lots.
2. Need to accommodate design changes of products.
3. Low rate of metal removal.
4. Need for holding close tolerances.

The characteristics which favour the choice of numerically controlled machines would include
(a) 1, 2 and 3
(b) 2, 3, and
(c) 1, 3, and 4
(d) 1, 2, and 4

[ESE : 1995]

6.3 In APT language, the cutter motion in incremental coordinate mode is addressed as
(a) GO/TO/.....
(b) GO/TO....
(c) GO DLTA/....
(d) GO FWD/....

[ESE : 1995]

6.4 In manual programming and tape preparation for a NC drilling machine, the spindle speed was coded as S 684 (using the magic-three code). The spindle speed in rpm will be
(a) 684
(b) 68.4
(c) 840
(d) 6840

[ESE : 1996]

6.5 Which of the following pairs are correctly matched?
1. CNC machine ... Post processor
2. Machining centre .... Tool magazine
3. DNC ... FMS

Select the correct answer using the code given below :
(a) 1, 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 2 and 3

[ESE : 1996]

6.6 **Assertion (A):** Numerically controlled machines having more than three axes do not exist.
Reason (R): There are only three cartesian coordinates namely x-y-z.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

6.7 Match **List-I** (Track numbers on paper tape) with **List-II** (Holes on those tracks represent) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Track No. 1 to 4	**1.** Alphabets
B. Track No. 5	**2.** Numerals
C. Track No. 6 & 7	**3.** End of block
D. Track No. 8	**4.** Block number
	5. Parity check

Codes:

	A	B	C	D
(a)	2	5	1	3
(b)	1	4	2	5
(c)	2	4	1	3
(d)	1	5	2	3

[ESE : 1997]

6.8 Which of the following are valid statements for point to point motion of the tool in APT language?
1. GO TO/...........
2. GO DLTA/........
3. GO/TO,............
Select the correct answer using the codes given below:
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3
[ESE : 1997]

6.9 In tape preparation for an NC machine tool the code S 624 would represent spindle speeds of
(a) 624 rpm, 240 rpm and 2346 rpm
(b) 624 rpm and 240 rpm
(c) 624 rpm and 246 rpm
(d) 240 rpm and 246 rpm
[ESE : 1998]

6.10 Which of the following are the rules of programming NC machine tools in APT language?
1. Only capital letters are used
2. A period is placed at the end of each statement
3. Insertion of space does not affect the APT word.
Select the correct answer using the codes given below:
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1 alone
[ESE : 1998]

6.11 Transfer machines can be defined as
(a) Material processing machines
(b) Material handling machines
(c) Material processing and material handling machines
(d) Component feeders for automatic assembly
[ESE : 1999]

6.12 Consider the following statements regarding numerically controlled machine tools
1. They reduce non-productive time
2. They reduce fixturing
3. They reduce maintenance cost
Which of these statements are correct?
(a) 1, 2, and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3
[ESE : 1999]

■■■■

Answers NC, CNC, DNC, APT, Automation

6.1 (a) 6.2 (d) 6.3 (c) 6.4 (a) 6.5 (a) 6.6 (b) 6.7 (a) 6.8 (a) 6.9 (d)
6.10 (d) 6.11 (c) 6.12 (c)

Explanations NC, CNC, DNC, APT, Automation

6.2 (d)

Numerical control machine has the advantages of:
1. Processing of parts frequently in small lots (flexibility of design)
2. Reduction in use of jig and fixture.
3. High accuracy and reduced human error.
4. Improved productivity.

6.3 (c)

GO DLTA/dx, dy, dz
This is an incremental instruction used to make movement of the tool in specified direction from current position.
Example:
GO DLTA/0, 0, –50
Means feed drill 50 mm into work.
GO FWD is an intermediates movement command.

6.5 (a)

Post processor is a sort of simulation activity in which after programming the execution of tool in simulated on computer screen.
Machining centre is always associated with tool magazine.

6.8 (a)

GO/symble for geometric expression is a general format of contouring motion statements.
Example:
GO/TO, LIN1, TO, CIR 2

Mean tool movement touching the surface of LIN1 onwards touching the counter of CIR 2.

Point to Point Motion: are represented in following form:

TO/symbol of geometry

Example:

GO TO/PT1

This statement is used to position the cutter above required position for example locating drill above hole to be drilled.

GO DLTA/dx, dy, dz

This is an incremental instruction used to make movement of the tool in specified direction from current position.

6.11 (c)

Transfer machines are used to move the workpiece from one station to another in machine to enable various operation to be performed on the part. Workpiece are transferred by several methods:

1. Rails along which the parts, usually placed on pallets, are pushed or pulled by various mechanism
2. Rotary indexing tables
3. Overhead conveyors.

■■■■

7 Non-conventional Machining Process

7.1 Which one of the following processes does not cause tool wear?
(a) Ultrasonic machining
(b) Electrochemical machining
(c) Electric discharge machining
(d) Anode mechanical machining [ESE : 1997]

7.2 Match **List-I** (Machining process) with **List-II** (Associated medium) and select the correct answer using the codes given below the lists:

	List-I		**List-II**
A.	Ultrasonic machining	**1.**	Kerosene
B.	EDM	**2.**	Abrasive slurry
C.	ECM	**3.**	Vacuum
D.	EBM	**4.**	Salt solution

Codes:

	A	B	C	D
(a)	2	3	4	1
(b)	2	1	4	3
(c)	4	1	2	3
(d)	4	3	2	1

[ESE : 1998]

7.3 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Die sinking
B. Deburring
C. Fine hole drilling (thin materials)
D. Cutting/sharpening hard materials

List-II
1. Abrasive jet machining
2. Laser beam machining
3. EDM
4. Ultrasonic machining
5. Electrochemical grinding

Codes:

	A	B	C	D
(a)	3	5	4	1
(b)	2	4	1	3
(c)	3	1	2	5
(d)	4	5	1	3

[ESE : 1999]

■■■■

Answers Non-conventional Machining Process

7.1 (b) **7.2** (b) **7.3** (c)

Explanations Non-conventional Machining Process

7.1 (b)

Electrochemical machining does not cause tool wear.

7.2 (b)

Ultrasonic machining – Abrasive slurry
EOM – Kerosene
ECM – Salt solution
EBM – Vacuum

7.3 (c)

Die sinking – EDM
Deburring – Abrasive jet machine
Tiny hole drilling (thin materials) – Laser beam machine
Cutting/Sharpening hard materials – Electochemical grinding

■■■■

8 Powder Metallurgy

8.1 Which of the following components can be manufactured by powder metallurgy methods?
1. Carbide tool tips
2. Bearings
3. Filters
4. brake linings

Select the correct answer using the codes given below:
(a) 1, 3 and 4 (b) 2 and 3
(c) 1, 2 and 4 (d) 1, 2, 3 and 4

[ESE : 1997]

8.2 In powder metallurgy, the operation carried out to improve the bearing property of a bush is called
(a) Infiltration (b) Impregnation
(c) Plating (d) Heat treatment

[ESE : 1998]

8.3 Consider the following processes for the manufacture of gears
1. Casting
2. Powder metallurgy
3. Machining from bar stock
4. Closed die forging

The correct sequence in increasing order of bending strength of gear teeth is
(a) 1, 2, 3, 4 (b) 1, 2, 4, 3
(c) 2, 1, 4, 3 (d) 2, 1, 3, 4

[ESE : 1999]

8.4 **Assertion (A):** In atomization process of manufacture of metal powder, the molten metal is forced through a small orifice and broken up by a stream of compressed air.
Reason (R): The metallic powder obtained by atomization process is quite resistant to oxidation.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

8.5 The correct sequence of the given processes in manufacturing by powder metallurgy is
(a) Blending, compacting, sintering and sizing
(b) Blending, compacting, sizing and sintering
(c) Compacting, sizing, blending and sintering
(d) Compacting, blending, sizing and sintering

[ESE : 1999]

■■■■

Answers Powder Metallurgy

8.1 (d) 8.2 (b) 8.3 (a) 8.4 (c) 8.5 (a)

Explanations Powder Metallurgy

8.1 (d)

Typical products made by powder-metallurgy technique range from tiny balls for ball-point pens, to gears, cams, and bushing to cutting tools, to porous products, such as filters and oil-impregnated bearing, to a varity of automotive components such as piston ring, value guides, connecting rods, and hydraulic pistons.

8.2 (b)

Bearings...... Impregnation

8.3 (a)

The bending strength of gear will be minimum for casting of process and strongest for produced by close die forging.

8.4 (c)

In atomization process, forcing the molten metal through a nozzle into a stream of air or nozzle. In the atomization, they usually carry a layer of oxide over them, which means they are more prone to the oxidation.

8.5 (a)

Blending → Compacting → Sintering → Sizing.

Sizing: It consist of placing the sintered part in a die & made to correct dimension & repressing the same to bring it to the required size. It also takes care of certain distortion which might have occurred during sintering.

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UNIT

VI

Industrial Engineering and Maintenance Engg.

Syllabus

Production planning and Control, Inventory control and operations research - CPM-PERT. Failure concepts and characteristics-Reliability, Failure analysis, Machine Vibration, Data acquisition, Fault Detection, Vibration Monitoring, Field Balancing of Rotors, Noise Monitoring, Wear and Debris Analysis, Signature Analysis, NDT Techniques in Condition Monitoring.

Contents

1 Forecasting

1.1 Which one of the following methods can be used for forecasting the sales potential of a new product?
(a) Time series analysis
(b) Jury of Executive Opinion method
(c) Sales Force Composite method
(d) Direct Survey method

[ESE : 1995]

1.2 Given
T = underlying trend
C = cyclic variations within the trend
S = seasonal variation within the trend and
R = residual, remaining or random variation, as per the time series analysis of sales forecasting, the demand will be a function of:
(a) T and C (b) R and S
(c) T, C and S (d) T, C, S and R

[ESE : 1997]

1.3 A company intends to use exponential smoothing technique for making a forecast for one of its products. The previous year's forecast has been 78 units and the actual demand for the corresponding period turned out to be 73 units. If the value of the smoothening constant α is 0.2, the forecast for the next period will be:
(a) 73 units (b) 75 units
(c) 77 units (d) 78 units

[ESE : 1999]

■■■■

Answers Forecasting

1.1 (d) **1.2** (d) **1.3** (c)

Explanations Forecasting

1.1 (d)

Opinion survey method is relatively simple and practical method for forcasting demands and especially for new products.

1.2 (d)

As per the time series analysis of sales forecasting the demand will be a function of
1. Trend
2. Cyclic fluctuations
3. Seasonal variation
4. Random variation

1.3 (c)

$$F_n = \alpha y_{n-1} + (1-\alpha)F_{n-1}$$
$$= (0.2)(73) + (1-0.2)\,78 = 14.6 + 62.4$$
$$= 77$$

■■■■

2 Inventory, Control and Break Even Analysis

2.1 Consider the following factors:

1. Adequate incentive
2. Ease of administration
3. Flexibility
4. Guaranteed basic pay
5. Higher wages
6. Simplicity

Among these, the factors which are to be considered while developing a good wage incentive plan would include

(a) 1, 2, 3 and 5 (b) 2, 3, 4 and 5
(c) 1, 2, 4 and 6 (d) 1, 2, 5 and 6

[ESE : 1995]

2.2 Production cost refers to prime cost plus

(a) factory overheads
(b) factory and administration overheads
(c) factory, administration and sales overheads
(d) factory, administration and sales overheads and profit

[ESE : 1995]

2.3 For a small scale industry, the fixed cost per month is Rs. 5000/-. The variable cost per product is Rs. 20/- and sales price is Rs. 30/- per piece. The break-even production per month will be

(a) 300 (b) 460
(c) 500 (d) 10000

[ESE : 1995]

2.4 Classifying items in *A*, *B* and *C* categories for selective control in inventory management is done by arranging items in the decreasing order of

(a) total inventory costs
(b) item value
(c) annual usage value
(d) item demand

[ESE : 1995]

2.5 Consider the following statements:

1. *ABC* analysis is based on Pareto's principle.
2. FIFO and LIFO policies can be used for material valuation in materials management.
3. Simulation can be used for inventory control.
4. EOQ (Economic Order Quantity) formula ignores variations in demand pattern.

Which of these statements is/are correct?

(a) 1 only (b) 1 and 3
(c) 2, 3 and 4 (d) 1, 2, 3 and 4

[ESE : 1995]

2.6 In inventory control theory, the Economic Order Quantity (EOQ) is

(a) average level of inventory
(b) optimum lot size
(c) lot size corresponding to break-even analysis
(d) capacity of a warehouse

[ESE : 1995]

2.7 Given that E = Earnings, R = Rate per hour, T = worked in hours, S = Standard time on the basis of date in hours. Rowan wage incentive plan is:

(a) $E = RT + \left(\frac{S-T}{S}\right)$

(b) $E = RT + (S-T)^R$

(c) $E = RT + 0.4\,(S-T)^R$

(d) $E = RT + \left(\frac{S-T}{S}\right)RT$

[ESE : 1996]

2.8 Given that, θ = procurement cost per order, D = number of units demanded per year, H = holding cost per unit year, i = rate of interest, p = purchase price per unit. The procurement quantity per order (Q) is given by

(a) $Q = \frac{2.\theta.D}{H+iP}$ (b) $Q = \sqrt{\frac{2.\theta.D}{iH+P}}$

(c) $Q = \sqrt{\frac{2.\theta.D}{H+iP}}$ (d) $Q = \sqrt{\frac{2.\theta}{D(H+iP)}}$

[ESE : 1996]

2.9 Two alternative methods can produce a product first method has a fixed cost of Rs. 2000/- and variable cost of Rs. 20/- piece. The second method has fixed cost of Rs. 1500/- and a variable cost of Rs. 30/-. The break even quantity between the two alternatives is:

(a) 25 (b) 50
(c) 75 (d) 100

[ESE : 1996]

2.10 Consider the data given in the following table:

Period	Demand	Production Plan Regular Prod.	Overtime Prod.	Others
1	500	500	––	––
2	650	650	––	––
3	800	650	150	––
4	900	650	150	?

Give the fact that production in regular and overtime is limited to 650 and 150 respectively, the balance demand of 100 units in the 4th period can be met by:

(a) Using overtime in period 2
(b) Using regular production in period 1
(c) Subcontracting
(d) Using any of the steps indicated in (A), (B) and (C)

[ESE : 1997]

2.11 M/s. ABC and Co. is planning to use the most competitive manufacturing process to produce an ultramodern sports shoe. They can use a fully automatic robot-controlled plant with an investment of Rs. 100 million; alternately they can go in for a cellular manufacturing that has a fixed cost of Rs. 80 million. There is yet another choice of traditional manufacture that needs an investment of Rs. 75 million only. The fully automatic plant can turn out a shoe at a unit variable cost of Rs. 25 per unit, whereas the cellular and the job shop layout would lead to a variable cost of Rs. 40 and Rs. 50 respectively. The break even analysis shows that the break even quantities using automatic plant Vs. traditional plant are in the ratio of 1 : 2. The per unit revenue used in the break even calculation is:

(a) Rs. 75 (b) Rs. 87
(c) Rs. 57 (d) Rs. 55

[ESE : 1997]

2.12 Process I requires 20 units of fixed cost and 3 units of variable costs per piece, while process II required 50 units of fixed costs and 1 unit of variable cost per piece. For a company producing 10 pieces per day:

(a) Process I should be chosen
(b) Process II should be chosen
(c) Either of the two processes should be chosen
(d) A combination of the process I and process II should be chosen

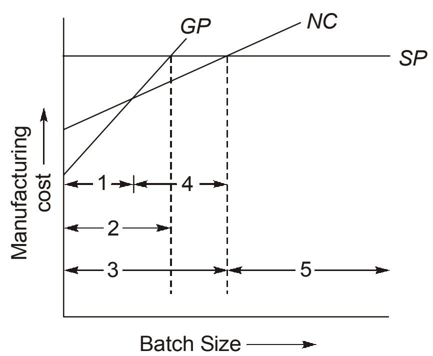
[ESE : 1997]

2.13 Annual demand for a product costing Rs. 100 per piece is 900. Ordering cost per order is Rs. 100 and inventory holding cost is Rs. 2 per unit per year. The economic lot size is

(a) 200 (b) 300
(c) 400 (d) 500

[ESE : 1997]

2.14 Based on the given graph, the economic range of batch sizes to be preferred for general purpose machine (GP), NC machine (NC) and special purpose (SP) will be:

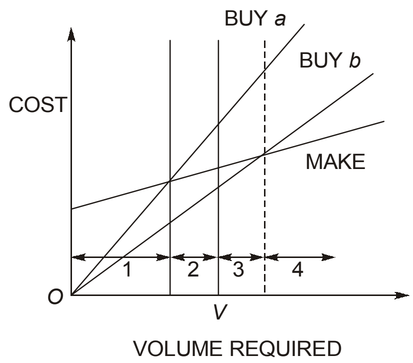


Codes:

	GP	NC	SP
A.	2	5	4
B.	1	4	5
C.	3	2	4
D.	1	4	2

[ESE : 1997]

2.15 Details of cost for make or buy decision are shown in the below graph. A discount is offered for volume of purchase above 'V'. Which one of the following ranges would lead to the economic decision?



	Buy *a*, *b*	Make
(a)	1 and 2	3 and 4
(b)	1 and 3	2 and 4
(c)	2 and 4	1 and 3
(d)	1 and 4	2 and 3

[ESE : 1998]

2.16 Which of the following cost elements are considered while determining the Economic Lot Size for purchase?

1. Inventory carrying cost
2. Procurement cost
3. Set up cost

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3 [ESE : 1998]

2.17 A manufacturer's master product schedule of product is given below:

Period Planned	Week-1	Week-2	Week-3
Planned Production	50	100	100
	Week-4	Week-5	Week-6
	100	150	50

Each product requires a purchased component *A* in its sub-assembly. Before the start of week-1, there are 400 components of type *A* in stock. The lead time to procure this component is 2 weeks and the order quantity is 400. Number of components *A* per product is only one. The manufacturer should place the order for:

(a) 400 components in week-1
(b) 400 components in week-3
(c) 200 components in week-1 and 200 components in week-3
(d) 400 components in week-5 [ESE : 1999]

2.18 A dealer sells a radio set at Rs. 900 and makes 80% profit on his investment. If he can sell it at Rs. 200 more, his profit as percentage of investment will be:

(a) 160 (b) 180
(c) 100 (d) 120 [ESE : 1999]

2.19 Consider the following costs:

1. Cost of inspection and return of goods
2. Cost of obsolescence
3. Cost of scrap
4. Cost of insurance
5. Cost of negotiation with suppliers

Which of these costs are related to inventory carrying cost?

(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 2, 3 and 4 (d) 2, 4 and 5

[ESE : 1999]

■■■■

Answers Inventory, Control and Break Even Analysis

2.1 (c) 2.2 (a) 2.3 (c) 2.4 (c) 2.5 (d) 2.6 (b) 2.7 (d) 2.8 (c) 2.9 (b)
2.10 (b) 2.11 (*) 2.12 (a) 2.13 (b) 2.14 (b) 2.15 (a) 2.16 (b) 2.17 (b) 2.18 (d)
2.19 (c)

Explanations Inventory, Control and Break Even Analysis

2.1 (c)

Good wage incentive plans have
1. Adequate incentive
2. Ease of administration
3. Guaranteed basic pay
4. Simplicity

2.2 (a)

Prime cost = Direct material cost + Direct labour cost + direct expenses

Production cost = Prime cost + factory overhead

2.3 (c)

$C_F + C_V x = C_p x$

$$\therefore \quad x = \frac{C_F}{(C_P - C_V)}$$

$$= \frac{5000}{(30-20)} = \frac{5000}{10} = 500$$

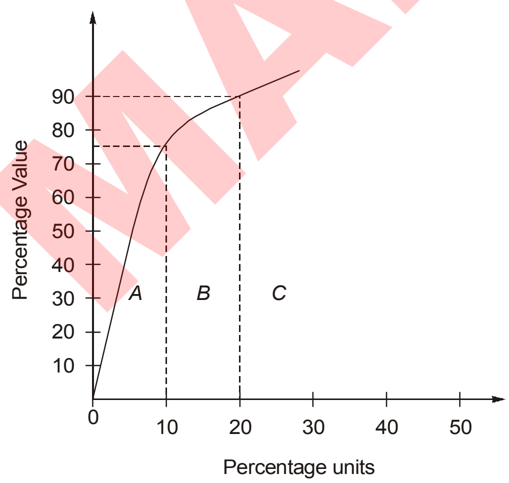
where

C_F = fixed cost

$$C_V = \frac{\text{Variable cost}}{\text{Product}}$$

$$C_P = \frac{\text{Sales cost}}{\text{Product}}$$

2.4 (c)



2.6 (b)

Economic Order Quantity (*EOQ*) is that size of order which minimizes total annual cost of carrying inventory and cost of ordering under the assumed conditions of certainty and that annual demands.

2.7 (d)

In Rowan plan wage of a worker is given by:

$$E = RT + \left(\frac{S-T}{S}\right)RT$$

2.8 (c)

Procurement quantity per order will be the *EOQ* = $\sqrt{\dfrac{2\theta D}{H+ip}}$

2.9 (b)

$2000 + 20x = 1500 + 30x$

$30x - 20x = 2000 - 1500$

$10\,x = 500$

$\therefore \quad x = 50$

2.10 (b)

In the 4th period since regular production is limited to 650 and overtime is limited to 150, the balance demand of 100 units in the 4th period can be met by using regular production in period 1.

$\because$ Demand is only 500 but production capacity in regular period can be increased to 600 to meet the demand.

2.11 (*)

Let the sale cos *t* be C_s

Let break even quantity for fully automatic plant is 'x' & break even quantity, for traditional plant is 'y'.

$100 \times 10^6 + 25\,x = C_s\,x$ ...(i)

$75 \times 10^6 + 50\,y = C_s\,y$ ....(ii)

$$\because \quad \frac{x}{y} = \frac{1}{2}$$

or $\quad y = 2x$

Dividing equation (i) by (ii)

$$\text{or} \quad \frac{100 \times 10^6 + 25x}{75 \times 10^6 + 50(2x)} = \frac{x}{2x} \text{ (since } y = 2x)$$

or $\{(100 \times 10^6) + 25x\}\, 2 = 75 \times 10^6 \times 100x$

or $200 \times 10^6 + 50x = 75 \times 10^6 + 100x$

or $50x = 125 \times 10^6$

$\therefore \quad x = 25 \times 10^5$

$(C_s - 25) \times 25 \times 10^5 = 100 \times 10^6$

$C_s - 25 = 40$

$\therefore \quad C_s = 40 + 25 = \mathbf{65}$

2.12 (a)

For process I: $C_F + C_V x = 20 + 3 \times 10 = 50$

Process II: $C_F + C_V x = 50 + 1 \times 10 = 60$

$\because$ Total cost for process I is less than II

$\therefore$ Process I is chosen

2.13 (b)

A = Annual consumption in rupees

C_0 = Cost of placing an order

i = Inventory carring cost per unit per year

$$EOQ = \sqrt{\frac{2 \times A \times C_0}{i}} = \sqrt{\frac{2 \times 900 \times 100}{2}} = \mathbf{300}$$

2.16 (b)

Following cost elements are considered while determining the economic lot size

1. Inventory carrying cost
2. Ordering cost or procurement cost

The set up cost does not comes into play while purchasing.

2.17 (b)

Order quantity=400 Lead time = 2 week		Week 1	2	3	4	5	6
Planned Production		50	100	100	100	150	50
Receipts						(400)	
Avaialbe on hands	400	350	250	150	50	300	250
Planned order Release				(400)			

The manufacture should place the order for 400 component in week-3.

2.18 (d)

$$\text{S.P.} = \text{C.P.} + \frac{\text{C.P.} \times \text{Profit}}{100}$$

$$\text{C.P} = \frac{900 \times (100)}{(100 + 80)} = 500$$

S.P if he sells at 200 more = 900 + 200 = 1100

$$\therefore \text{ Profit (in \%)} = \frac{1100 - 500}{500} \times 100 = \mathbf{120\%}$$

2.19 (c)

Inventory carrying costs are:

(i) Invested capital cost

(ii) Record keeping and administrative cost

(iii) Handling cost

(iv) Storage cost

(v) Depreciation, Deterioration and obsolescence cost

(vi) Purchase price or production costs

(vii) Taxes and insurance costs

■■■■

3 Linear Programming

3.1 Which one of the following subroutines does a computer implementations linear programming by the simplex method use?
(a) Finding a root of a polynomial
(b) Finding the determinant of a matrix
(c) Finding the Eigen values of a matrix
(d) Solving a system of linear equations
[ESE : 1996]

3.2 Consider the following linear programming problem:
Max. $Z = 2A + 3B$, subject to $A + B \leq 10$, $4A + 6B \leq 30$, $2A + B \leq 17$, $A, B \geq 0$
What can one say about the solution?
(a) It may contain alternative optima
(b) The solution will be unbounded
(c) The solution will be degenerate
(d) It cannot be solved by simplex method
[ESE : 1997]

3.3 A variable which has no physical meaning, but is used to obtain an initial basic feasible solution to the linear programming problem is referred to as:
(a) Basic variable
(b) Non-basic variable
(c) Artificial variable
(d) Basis
[ESE : 1998]

3.4 In the solution of a linear programming problem by simplex method, if during an iteration, all ratios of right-hand side b_i to the coefficients of entering variable a are found to be negative, it implies that the problem has:
(a) Infinite number of solutions
(b) Infeasible solution
(c) Degeneracy
(d) Unbound solution
[ESE : 1999]

3.5 Consider the following statements regarding the characteristics of the standard form of a linear programming problem:
1. All the constraints are expressed in the form of equations.
2. The right-hand side of each constraint equation is non-negative.
3. All the decision variables are non-negative.

Which of these statements are correct?
(a) 1, 2 and 3
(b) 1 and 2
(c) 2 and 3
(d) 1 and 3 **[ESE : 1999]**

Answers Linear Programming

3.1 (d) **3.2** (a) **3.3** (c) **3.4** (d) **3.5** (a)

Explanations Linear Programming

3.1 (d)

Simplex method is used to solve a system of linear equations.

3.2 (a)

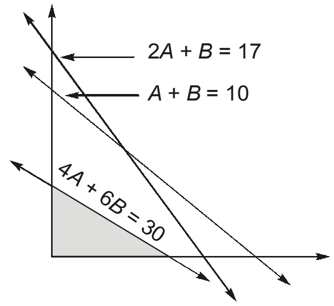
$Z = 2A + 3B$

$A + B \leq 10 \qquad \frac{A}{10} + \frac{B}{10} \leq 1$

$4A + 6B \leq 30 \qquad \frac{A}{7.5} + \frac{B}{5} \leq 1$

$2A + B \leq 17 \qquad \frac{A}{8.5} + \frac{B}{17} \leq 1$

$A, B \geq 0$



$Z(7.5,0) = 15$
$Z(0,5) = 15$

Maximum value of objective function = 15
and it has alternative optimal solutions because of same constraint as objective function.

3.3 (c)

Artificial variable is used to obtain on initial basic feasible solution to the linear programming problem.

3.4 (d)

All ratio of right hand side to the coefficients of entering variable are found to be negative. It implies that the problem has unbounded solution.

3.5 (a)

Characteristics of the standard form of a LPP.

1. All the constraints are expressed in the form of equations.
2. The RHS of each constraint equation is non-negative.
3. All the decision variables are non-negative.

■■■■

4 PERT and CPM

4.1 Which of the following are the guidelines for the construction of a network diagram?

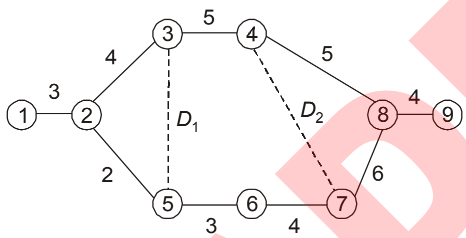
1. Each activity is represented by one and only one arrow in the network
2. Two activities can be identified by the same beginning and end events
3. Dangling must be avoided in a network diagram
4. Dummy activity consumes no time or resource

Select the correct answer the codes given below:

(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 1, 2 and 4 (d) 2, 3 and 4

[ESE : 1996]

4.2 In the network shown below the critical path is along:



(a) 1–2–3–4–8–9 (b) 1–2–3–5–6–7–8–9
(c) 1–2–3–4–7–8–9 (d) 1–2–5–6–7–8–9

[ESE : 1996]

4.3 **Assertion (A):** Generally PERT is preferred over CPM for the purpose of project evaluation.

Reason (R): PERT is based on the approach of multiple time estimates for each activity.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1996]

4.4 In a PERT network, expected project duration is found to be 36 days from the start of the project. The variance is four days. The probability that the project will be completed in 36 days is:

(a) zero (b) 34%
(c) 50% (d) 84% [ESE : 1997]

4.5 The variance (V_1) for critical path
$a \rightarrow b$ = 4 time units, $b \rightarrow c$ = 16 time units, $c \rightarrow d$ = 4 time units, $d \rightarrow e$ = 1 time unit.
The standard deviation of the critical path $a \rightarrow e$ is:

(a) 3 (b) 4
(c) 5 (d) 6 [ESE : 1997]

4.6 Estimated time T_C and variance of the activities 'V' on the critical path in a PERT network are given in the following table:

Activity	T_C (days)	V (days)
a	17	4
b	15	4
g	8	1

The probability of completing the project in 43 days is:

(a) 15.6% (b) 50.0%
(c) 81.4% (d) 90.0% [ESE : 1998]

4.7 The earliest occurrence time for event '1' is 8 weeks and the latest occurrence time for event '1' is 26 weeks. The earliest occurrence time for event '2' is 32 weeks and the latest occurrence time for event '2' is 37 weeks. If the activity time is 11 weeks, then the total float will be:

(a) 11 (b) 13
(c) 18 (d) 24 [ESE : 1998]

4.8 Time estimates of an activity in a PERT network are:
Optimistic time t_0 = 9 days; pessimistic time t_p = 21 days and most likely time t_m = 15 days.
The approximates probability of completion of this activity in 13 days is:

(a) 16% (b) 34%
(c) 50% (d) 84% [ESE : 1999]

Answers PERT and CPM

4.1 (b) 4.2 (b) 4.3 (a) 4.4 (c) 4.5 (c) 4.6 (c) 4.7 (c) 4.8 (a)

Explanations PERT and CPM

4.1 (b)

Rules for drawing Network Diagram:

(i) Each activity is represented by one and only one arrow in the network.

(ii) No two activity can be identified by the same end events.

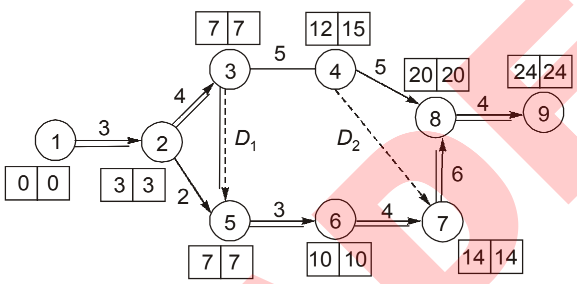
(iii) In order to ensure the correct precedence relationship in the arrow diagram, following question must be checked whenever any activity is added to network.

(a) What activity must be completed immediately before this activity can start?

(b) What activity must follow this activity?

(c) What activity must occur simultaneously with this activity?

4.2 (b)



$TF = LST = EST$

Activities	Duration	*EST*	*LST*	*EFT*	*LFT*	Total Float	Remark
1 – 2	3	0	0		3	0	
2 – 3	4	3	3		7	0	
3 – 4	5	7	10		15	3	
2 – 5	2	3	5		7	2	
4 – 8	5	12	15		20	3	
5 – 6	3	7	7		10	0	
6 – 7	4	10	10		14	0	
7 – 8	6	14	14		20	0	
8 – 9	4	20	20		24	0	
4 – 7	0	12	14		14	2	
3 – 5	0	7	7		7	0	

Therefore critical path

1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9

and total project duration

= 3 + 4 + 3 + 4 + 6 + 4 = 24

4.3 (a)

Project management has evolved two analytical technique for planning, scheduling and controlling of projects. These are the Critical Path Method (CPM) and the project evaluation and Review Technique (PERT).

CPM – Activity Oriented

PERT – Event Oriented

4.4 (c)

Standard deviation (s.d):

$$\sqrt{var} = \sqrt{4} = 2$$

$$Z = \frac{X - \bar{X}}{\sigma} = \frac{36 - 36}{2} = 0$$

$$P(0) = 0.5$$

∴ the probability that the project will be completed in 36 days is 50%

4.5 (c)

Standard deviation of critical path $a \to e$ is

$$= \sqrt{4 + 16 + 4 + 1} = \sqrt{25} = \mathbf{5}$$

4.6 (c)

$$\text{S.d} = \sqrt{4 + 4 + 1} = 3$$

$$Z = \frac{X - \bar{X}}{\sigma} = \frac{43 - 40}{3} = 1$$

$$P(1) = \mathbf{0.8413}$$

4.7 (c)

E_i	E_j		L_i	L_j
8	32		26	37

Total float $= (L_j - E_i) - d_{ij}$

∵ $L_j = 37$

$E_i = 8$

$d_{ij} = 11$

$T.F = 37 - 8 - 11 = \mathbf{18}$

4.8 (a)

$$t_{\text{expected}} = \frac{t_0 + 4t_m + t_p}{6} = \frac{9 + (4 \times 15) + 21}{6} = 15$$

$$S.D = \frac{(b - a)}{6} = \frac{21 - 9}{6} = 2$$

$$Z = \frac{x - \bar{x}}{\sigma} = \frac{13 - 15}{2} = -1$$

$p(-1) = 0.1586 \simeq \mathbf{0.16}$

■■■■

5 Queuing Theory

5.1 **Assertion (A):** In a queueing model, the assumption of exponential distribution with only one parameter family for service times is found to be unduly restrictive.

Reason (R): This is partly because the exponential distribution has the property that smaller service times are inherently less probable than large service time.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1995]

5.2 If the arrival rate of units is l and the service rate is μ for a waiting line system having 'm' number of service stations, then the probability of a service unit being turned out in time interval $(t, t + \Delta t)$ is

(a) Zero (b) $\mu.\Delta t$
(c) $m.\mu.\Delta t$ (d) $n.\mu.\Delta t$

[ESE : 1996]

5.3 Consider two queueing disciplines in a single server queue. Case 1 has a first come first served discipline and case 2 has a last come first served discipline. If the average waiting times in the two cases are W_1 and W_2 respectively, then which one of the following inferences would be true?

(a) $W_1 > W_2$
(b) $W_1 < W_2$
(c) $W_1 = W_2$
(d) Data insufficient to draw any tangible inference [ESE : 1997]

5.4 In a single server queue customers are served at a rate of μ. If W and W_q represent the mean waiting time in the system and mean waiting time in the queue respectively, then W will be equal to

(a) $W_q - \mu$ (b) $W_q + \mu$
(c) $W_q + 1/\mu$ (d) $W_q - 1/\mu$

[ESE : 1997]

5.5 For a $M/M/1 : \infty/FCFS$ queue, the mean arrival rate is equal to 10 per hour and the mean service rate is 15 per hour. The expected queue length is

(a) 1.33 (b) 1.53
(c) 2.75 (d) 3.20

[ESE : 1998]

5.6 An operations consultant for an automatic car wash wishes to plan for enough capacity to handle 60 cars per hour. Each car will have wash time to 2 minutes, but there is to be a 20% allowance for setup, delays and payment transactions. The installation capacity of car wash stalls should be:

(a) 3 (b) 4
(c) 5 (d) 6 [ESE : 1999]

5.7 The average time between two arrivals of customers at a counter in a ready-made garment store is 4 min. The average time of the counter clerk to serve the customer is 3 min. The arrivals are distributed as per Poisson distribution and the services are as per the exponential distribution. The probability that a customer arriving at the counter will have to wait, is:

(a) Zero (b) 0.25
(c) 0.50 (d) 0.75 [ESE : 1999]

■■■■

Answers **Queuing Theory**

5.1	(c)	5.2	(a)	5.3	(c)	5.4	(c)	5.5	(a)	5.6	(a)	5.7	(d)

Explanations Queuing Theory

5.3 (c)

Average waiting time in the system in both the cases will be

μ = Service rate;
λ = Arrival rate

$$W_q = \frac{1}{(\mu - \lambda)}$$

5.4 (c)

$$W = \frac{L_S}{\lambda} = \frac{1}{\lambda}\left(\frac{\rho}{1-\rho}\right)$$

$$W_q = \frac{L_q}{\lambda} = \frac{1}{\lambda}\left(\frac{\rho^2}{1-\rho}\right)$$

$$\because\ W = \frac{L_S}{\lambda} = \frac{L_q + \rho}{\lambda} = \frac{L_q}{\lambda} + \frac{\rho}{\lambda}$$

$$= \frac{L_q}{\lambda} + \frac{\lambda}{\mu \times \lambda} = \frac{L_q}{\lambda} + \frac{1}{\mu}$$

$$= W_q + \frac{1}{\mu}$$

5.5 (a)

λ = 10 (Arrival rate); μ = 15 (Service rate)

$$\rho = \frac{10}{15} = \frac{2}{3}$$

Length of queue

$$L_q = \frac{\rho^2}{1-\rho} = \frac{\left(\frac{2}{3}\right)^2}{1-\frac{2}{3}} = \frac{\frac{4}{9}}{\frac{1}{3}} = 1.33$$

5.6 (a)

Time required to wash one car is $2 \times 1.2 = 2.4$ mins. Number of cars washed in 1 hr in 1 stall

$$= \frac{60}{2.4} = 25$$

$$\therefore \text{ Number of stalls} = \frac{60}{25} = 2.4 \simeq 3$$

5.7 (d)

$$\lambda = \text{Number of arrivals/hour} = \frac{60}{4} = 15$$

μ = Number of customers serviced/hour

$$= \frac{60}{3} = 20$$

Probability that customer will have to wait

$$= \frac{15}{20} = 0.75$$

■■■■

6 Scheduling, Line Balancing, Product Development, MRP, Process Planning and Control Plant Layout

6.1 Which of the following charts are used for plant layout design?
1. Operation process chart
2. Man machine chart
3. Correlation chart
4. Travel chart

Select the correct answer using the codes given below:
(a) 1, 2, 3 and 4 (b) 1, 2 and 4
(c) 1, 3 and 4 (d) 2 and 3

[ESE : 1995]

6.2 In manufacturing management, the term "Dispatching" is used to describe
(a) dispatch of sales order
(b) dispatch of factory mail
(c) dispatch of finished product to the user
(d) dispatch of work orders through shop floor

[ESE : 1995]

6.3 Which of the following factors are to be considered for production scheduling?
1. Sales forecast 2. Component design
3. Route Sheet 4. Time standards

Select the correct answer using the codes given below:
Codes:
(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 1, 3 and 4 (d) 2, 3 and 4

[ESE : 1995]

6.4 A device for lifting or lowering objects suspended from a hook at the end of a retractable chain or cable is called
(a) hoist (b) jib crane
(c) chain conveyor (d) elevator

[ESE : 1995]

6.5 **Assertion (A):** Product layout is more amenable to automation than process layout.
Reason (R): The work to be performed on the product is the determining factor in the positioning of the manufacturing equipment in product layout.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

6.6 Which of the following are the principles of material handling?
1. Keep all handling to the minimum.
2. Move as few pieces as possible in one unit.
3. Move the heaviest weight to the least distance.
4. Select only efficient handling equipment.

Select the correct answer using the codes given below:
(a) 1, 2, 3 and 4 (b) 1, 3 and 4
(c) 1, 2 and 3 (d) 2 and 4

[ESE : 1996]

6.7 Consider the following aspects:
1. Speed 2. Decision making
3. Accuracy 4. Cost savings

Use of computers hold substantial advantages over manual methods in the case of
(a) 1, 2 and 3 (b) 2 and 4
(c) 1, 3 and 4 (d) 1, 2, 3 and 4

[ESE : 1996]

6.8 The routing function in a production system design is concerned with:
(a) Manpower utilization
(b) Machine unitization
(c) Quality assurance of the product
(d) Optimizing material flow through the plan

[ESE : 1996]

6.9 Match **List-I** (Type of Products) with **List-II** (Type of layout) and select the correct answer using the codes given below the lists:

List-I

A. Ball bearings
B. Tools and gauges
C. Large boilers
D. Motor cycle assembly

List-II

1. Process layout
2. Product layout
3. Combination of product and process layout
4. Fixed position layout

Codes:

	A	B	C	D
(a)	1	3	4	2
(b)	3	1	4	2
(c)	1	2	4	3
(d)	3	1	2	4

[ESE : 1996]

6.10 Consider the following sets of tasks to complete the assembly of an engineering component:

Task	Time (in seconds)	Precedence
a	10	––
b	20	––
c	15	*a*
d	5	*b*
e	30	*c*
f	15	*e*
g	5	*d*

The expected production rate is 3000 units per shift of 8 hour duration. The minimal number workstations that are needed to achieve this production level is:

(a) 4 (b) 8
(c) 10 (d) 11 [ESE : 1997]

6.11 A production line is said to be balanced when

(a) there are equal number of machines at each work station
(b) there are equal number of operators at each work station
(c) the waiting time for service at each station is the same
(d) the operation time at each station is the same

[ESE : 1997]

6.12 There are two machines M_1 and M_2 which process jobs *A*, *B*, *C*, *D*, *E* and *F*. The processing sequence for these jobs is M_1 followed by M_2. Consider the following data in this regard:

Process time required in minutes

Jobs	*A*	*B*	*C*	*D*	*E*	*F*
M_1	4	7	3	12	11	9
M_2	11	7	10	8	10	13

The processing sequence of jobs that would minimize the make span is:

(a) *C-A-B-F-E-D* (b) *C-A-B-D-E-F*
(c) *C-A-D-B-F-E* (d) *E-F-D-B-A-C*

[ESE : 1997]

6.13 Match **List-I** (Methods) with **List-II** (Problems) and select the correct answer using the codes given below the lists:

List-I

A. Moving average
B. Line balancing
C. Economic batch size
D. Johnson algorithm

List-II

1. Assembly
2. Purchase
3. Forecasting
4. Sequencing

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	1	3	4	2
(c)	3	1	4	2
(d)	3	1	2	4

[ESE : 1998]

6.14 Consider the following statements:

Dispatching

1. Is the action of operations, planning and control
2. Releases work to the operating divisions.
3. Conveys instructions to the shop floor

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1998]

6.15 Which of the following are the benefits of assembly line balancing?

1. It minimizes the in-process inventory.
2. It reduces the work content.

3. It smoothens the production flow.
4. It maintains the required rate of output.

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 3 and 4 (d) 1, 2 and 4

[ESE : 1998]

6.16 The characteristic life-cycle of a product consists of four periods. The rate of consumption increases rapidly at the beginning of the:

(a) Incubation period (b) Growth period
(c) Maturity period (d) Decline period

[ESE : 1998]

6.17 Which of the following input data are needed for MRP?

1. Master production schedule
2. Inventory position
3. Machine capacity
4. Bill of materials

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 2 and 4 (d) 1, 3 and 4

[ESE : 1998]

6.18 Which of the following correctly explains process capability?

(a) Maximum capacity of the machine
(b) Mean value of the measured variable
(c) Lead time of the process
(d) Maximum deviation of the measured variables of the components [ESE : 1998]

6.19 Which one of the following statements is correct in relation to production, planning and control?

(a) Expediting initiates the execution of production plans, whereas despatching maintains them and sees them through to their successful completion
(b) Despatching initiates the execution of production plans, whereas expediting maintains them and sees them through to their successful completion
(c) Both despatching and expediting initiate the execution of production plans
(d) Both despatching and expediting maintain the production plans and see them through to their successful completion [ESE : 1999]

■■■■

Answers Scheduling, Line Balancing, Product Development, MRP, Process Planning and Control Plant Layout

6.1 (b)	6.2 (d)	6.3 (d)	6.4 (a)	6.5 (a)	6.6 (b)	6.7 (b)	6.8 (d)	6.9 (c)
6.10 (a)	6.11 (d)	6.12 (a)	6.13 (d)	6.14 (a)	6.15 (c)	6.16 (b)	6.17 (c)	6.18 (d)
6.19 (b)								

Explanations Scheduling, Line Balancing, Product Development, MRP, Process Planning and Control Plant Layout

6.1 (b)

Tools and techniques of plant layout

1. Process charts (operation and flow)
2. Travel chart
3. Diagram (flow diagram, string diagrams)
4. REL (relationship chart)
5. Templates
6. Scaled models

6.2 (d)

Dispatching basically is the physical delivery of orders and instructions to all the persons who are involved in actual production and other supporting activities.

6.3 (d)

Factors considered for product scheduling.

1. Component design
2. Route sheet
3. Time standards

6.4 (a)

- Conveyors primarily perform the movement of uniform loads between fixed points.
- Cranes are overhead devices capable of moving materials vertically and laterally in area of limited length and width and height.
- Hoists are used for loading and unloading of heavy objects and they are also used for raising and lowering heavy and long objects.

6.6 (b)

Principle of material handling:

1. Keep all handling to the minimum
2. Move the heaviest weight to the least distance.
3. Select only efficient handling equipment.
4. Increase quantity, size, weight of load handled.

6.9 (c)

It is difficult to move large boilers from point hence it has fixed position layout. Assembly work always has product layout. Tools and gauges are not mass manufactured and need a lot of variations, process layout is used. For ball bearing a combination of product and process layout is used.

6.10 (a)

$$n_{min} = \frac{\text{Total work content}}{\text{Cycle time}}$$

Where total work content,

$$= 10 + 20 + 15 + 5 + 30 + 15 + 5$$
$$= 100$$

Time = Largest station time

$$\therefore \quad n_{min} = \frac{100}{30} = 3.3 \approx 4$$

6.11 (d)

A production line is said to be balanced when the operation time at each station is the same.

6.12 (a)

Examine the column for processing time on machine M_1 and M_2 and find the smallest value [min (M_1, M_2)] and allocate on extreme side if M_2 is smallest otherwise on extreme left side in sequence.

M_1 → M_2

C	A	B	F	E	D

6.13 (d)

Moving average	Forecasting
Line balancing	Assembly
Economic batch size	Purchase
Johnson algorithm	Sequencing

6.14 (a)

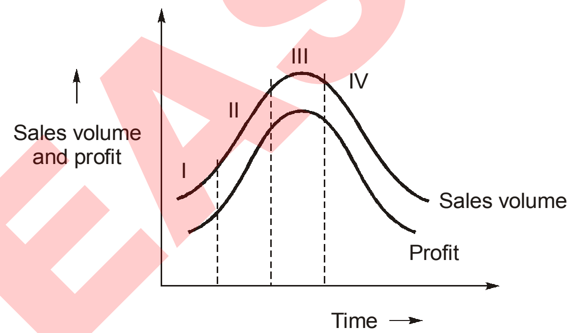
Dispatching basically is the physical delivery of orders and instructions to all the persons who are involved in actual production and other supporting activities when schedule plan and production orders are ready, it is the responsibility of the dispatching section to trigger the flow of information and instructions, the issue of materials, issue of tools and production aids etc. to all the concerned personnel. Dispatching are nothing but the internal courier in an industry.

6.15 (c)

Advantages of assembly line balancing

1. It minimizes the in-process inventory.
2. It smoothens the production flow.
3. It maintains the required rate of output.

6.16 (b)



I. Introduction stage
II. Growth stage rate of consumption increases rapidly.
III. Maturity stage
IV. Declining stage

6.17 (c)

The inputs to the MRP system are:

(i) Master production schedule
(ii) Inventory status file
(iii) Bill of materials (BOM)

6.18 (d)

Process capability study is carried out to measure the ability of the process to meet the specified tolerances. It may be defined as the minimum spread of a specific measurement variation which will include 99.7% of the measurement from the given process.

6.19 (b)

Dispatching executes planning function and insures that the plans are properly implemented. It is concerned with getting the work started. Expediting takes action if the progress reporting indicates a deviation of the plan from the originally set targets.

7 Transportation and Assignment

7.1 Match **List-I** (OR technique) with **List-II** (Application) and select the correct answer using the codes given below the lists:

List-I

A. Linear programming
B. Transportation
C. Assignment
D. Queueing

List-II

1. Warehouse location decision
2. Machine allocation decision
3. Product mix decision
4. Project management decision
5. Number of servers decision

Codes:

	A	B	C	D
(a)	1	2	3	5
(b)	3	1	2	5
(c)	1	3	4	5
(d)	3	2	1	4

[ESE : 1995]

7.2 The solution in a transportation model (of dimension $m \times n$) is said to be degenerate if it has
(a) exactly $(m + n - 1)$ allocations
(b) fewer than $(m + n - 1)$ allocations
(c) more than $(m + n - 1)$ allocations
(d) $(m \times n)$ allocations [ESE : 1995]

7.3 A solution is not a basic feasible solution in a transportation problem if after allocations:
(a) There is no closed loop
(b) There is a closed loop
(c) Total number of allocations is one less than the sum of number of sources and destinations
(d) There is degeneracy

[ESE : 1996]

7.4 **Assertion (A):** Transportation problem can be solved by VAM heuristic much faster as compared to the solution through linear programming method.

Reason (R): VAM heuristic gives an approximate solution. It is checked for optimality test. If it is optimal, the algorithm stops there. If it is not an optimal solution, then improved solutions are found out through very few iterations till optimality is reached.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1996]

7.5 When there are 'm' rows and 'n' columns in a transportation problem, degeneracy is said to occur when the number of allocations is
(a) Less than $(m + n - 1)$
(b) Greater than $(m + n - 1)$
(c) Equal to $(m - n - 1)$
(d) less than $(m - n - 1)$ [ESE : 1997]

7.6 Match **List-I** (Methods) with **List-II** (Applications) and select the correct answer using the codes given below the lists:

List-I

A. Break even analysis
B. Transportation problem
C. Assignment problem
D. Decision tree

List-II

1. To provide different facility at different locations
2. To take action from among the paths with uncertainty
3. To choose between different methods of manufacture
4. To determine the location of the additional plant

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	3	4	1	2
(c)	3	4	2	1
(d)	4	3	2	1

[ESE : 1998]

7.7 In a transportation problem, the materials are transported from 3 plants to 5 warehouses. The basic feasible solution must contain exactly, which one of the following allocated cells?
(a) 3 (b) 5
(c) 7 (d) 8 [ESE : 1998]

7.8 The assignment algorithm is applicable to which of the following combined situations for the purpose of improving productivity?
1. Identification of the sales force-market.
2. Scheduling of operator-machine.
3. Fixing machine-location

Select the correct answer using the codes given below:
(a) 1, 2 and 3 (b) 1 and 3
(c) 2 and 3 (d) 1 and 2
[ESE : 1998]

7.9 In a transportation problem North-West corner rule would yield:
(a) An optimum solution
(b) An initial feasible solution
(c) A Vogel's approximate solution
(d) A minimum cost solution [ESE : 1999]

Answers Transportation and Assignment

7.1 (b) 7.2 (b) 7.3 (b) 7.4 (a) 7.5 (a) 7.6 (b) 7.7 (c) 7.8 (c) 7.9 (b)

Explanations Transportation and Assignment

7.1 (b)

Linear programming	Product mix decision
Transportation	Warehouse location decision
Assignment	Machine allocation decision
Queueing	Number of servers decision

7.2 (b)

In a TP, if the number of non-negative independent allocations is less than $m + n - 1$, there exists a degeneracy.

7.3 (b)

A basic feasible solution will contain $m + n - 1$ independent non-zero allocations and the indication of independence of a set of individual positive allocations is that we can't form a closed loop by joining positive allocations by horizontal and vertical lines only.

7.4 (a)

VAM gives an approximate solution which can be optimal. If not optimal then very few iterations are required till optimality is reached.

7.5 (a)

Degeneracy arises when number of allocation is less than $m + n - 1$

7.6 (b)

(a) Break even analysis: To choose between different methods of manufacture
(b) Transportation problem: To determine the location of the additional plant
(c) Assignment problem: To provide different facility at different locations.
(d) Decision tree: To take action from among the paths with uncertainty

7.7 (c)

Degeneracy arises when number of allocation are less than 3 + 5 – 1 = 7

7.9 (b)

The solution of a transportation problem can be obtained in two stages namely initial solution and optimum solution. Initial solution can be obtained by using one of the three methods:
(i) North west corner rule
(ii) Least cost method
(iii) Vogel's approximation method (VAM)

8 Work Study and Work Measurement

8.1 In time study, the rating factor is applied to determine
(a) standard time of a job
(b) merit rating of the worker
(c) fixation of incentive rate
(d) normal time of job [ESE : 1995]

8.2 Work study is mainly aimed at
(a) determining the most efficient method of performing a job
(b) establishing the minimum time of completion of job
(c) developing the standard method and standard time of a job
(d) economizing the motions involved on the part of the worker while performing a job.
[ESE : 1995]

8.3 Match **List-I** (Object) with **List-II** (Tool) and select the correct answer:

List-I
A. Improving utilization of supervisory staff
B. Improving plant layout
C. Improving work place layout
D. Improving highly repetitive hand movements

List-II
1. Micromotion study
2. Work sampling
3. Flow process chamber
4. Chronocyclegraph

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	3	2	1	4
(c)	2	3	4	1
(d)	3	2	4	1

[ESE : 1996]

8.4 Determination of standard time in complex job system is best done through:
(a) Stop watch time study
(b) Analysis of micromotions
(c) Group timing techniques
(d) Analysis of standard date system
[ESE : 1996]

8.5 Procedure of modifying work content to given more meaning and enjoyment to the job by involving employees in planning, organization and control of their work, is termed as:
(a) Job enlargement (b) Job enrichment
(c) Job rotation (d) Job evaluation
[ESE : 1996]

8.6 Consider the following conditions:
1. Minimum wages should be guaranteed
2. Providing incentive to group efficiency performance
3. A differential price rate should exist
4. All standards should be based on optimum standard of production

Those essential for an incentive plan include
(a) 1 and 4 (b) 1 and 2
(c) 3 and 4 (d) 2 and 3 [ESE : 1996]

8.7 Match **List-I** (Topic) with **List-II** (Method of solving) and select the correct answer using the codes given below the lists:

List-I
A. Forecasting
B. Linear programming
C. Wage incentive
D. Work measurement

List-II
1. North-West corner method
2. Rowan plan
3. Method of penalty
4. Time series analysis
5. Work factor system

Codes:

	A	B	C	D
(a)	4	3	1	5
(b)	4	1	5	3
(c)	4	3	2	5
(d)	3	1	2	4

[ESE : 1997]

8.8 Match **List-I** (Charts) with **List-II** (Details) and select the correct answer using the codes given below the lists:

List-I

A. Multiple activity chart
B. SIMO chart
C. String diagram
D. MTM

List-II

1. Work factor system
2. Movement of material
3. Motion analysis
4. Working and idle time of two or more men/ machines

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	3	4	2	1
(c)	4	3	2	1
(d)	3	4	1	2

[ESE : 1998]

8.9 The type of layout suitable for use of the concept, principles and approaches of 'group technology' is
(a) Product layout
(b) Job-shop layout
(c) Fixed position layout
(d) Cellular layout **[ESE : 1999]**

8.10 The standard time of an operation has been calculated as 10 min. The worker was rated at 80%. If the relaxation and other allowances were 25%, then the observed time would be:
(a) 12.5 min (b) 10 min
(c) 8 min (d) 6.5 min **[ESE : 1999]**

8.11 MTM is a work measurement technique by
(a) Stopwatch study
(b) Work sampling study
(c) Predetermined motion time system
(d) Past data comparison **[ESE : 1999]**

8.12 Given
E = Earning in time T_a
T_a = Actual time of work
T_s = Standard time set to complete the task
R = Rate per unit time

if $E = R.T_a + \frac{R}{2}(T_s - T_a)$, then the graph between bonus earned and time saved is a:
(a) Straight line (b) Convex curve
(c) Concave curve (d) Parabola
[ESE : 1999]

8.13 A process of discovering and identifying the pertinent information relating to the nature of a specific job is called
(a) Job identification (b) Job description
(c) Job analysis (d) Job classification
[ESE : 1999]

■■■■

Answers Work Study and Work Measurement

8.1 (d) **8.2** (c) **8.3** (c) **8.4** (d) **8.5** (a) **8.6** (a) **8.7** (c) **8.8** (c) **8.9** (d)
8.10 (b) **8.11** (c) **8.12** (a) **8.13** (c)

Explanations Work Study and Work Measurement

8.1 (d)

A rating factor is a factor by which the observed time is multiplied in order to adjust for differences in operator's performance.
Normal time = observed time × performance rating factor.

8.2 (c)

Work study investigates work done in an organization and it aims at finding the best and most efficient way of using available resources. It may be divided as
(i) Method study (ii) Time study

8.3 (c)

A. Improving utilization of supervisory staff → work sampling.
B. Improving plant layout → flow process chamber.
C. Improving work place layout → chronocycle graph.
D. Improving highly repetitive hand movements → micromotion study.

8.5 (a)

Job enlargement occurs along two dimensions, vertical and horizontal. Vertical means the worker is involved with greater ability, responsibility, skill and autonomy required from job holders as in planning, organizing and inspecting his own work.

8.6 (a)

Essential for an incentive plan

1. Minimum wages should be guaranteed.
2. All standards should be based on optimum standard of production.

8.7 (c)

A. Forecasting–Time Series analysis
B. Linear Programming–Method of penalty
C. Wage incentive–Rowan Plan
D. Work measurement–Work factor system

8.8 (c)

Multiple activity chart: working and idle time of two or more men/machines.
SIMO chart: Motion analysis.
String diagram: Movement of material
MTM: Work factor system.

8.9 (d)

Group technology has become an increasingly popular concept in manufacturing that is designed to take advantages of mass production layout and technique in smaller batch production system and cellular layout is used in G.T.

8.10 (b)

Standard time = 10 mins
Normal time = 0.8 × 10 = 8 mins
Observed

$$= \text{Normal time}\left(1+\frac{\%\text{ Allowances}}{100}\right)$$

$$= 8\left(1+\frac{25}{100}\right) = 8 \times 1.25 = \textbf{10 minutes}$$

8.11 (c)

MTM (Method-time measurement) is based on use of standard time for work elements that have been predetermined from long period of observation and analysis.

8.12 (a)

$$E = RT_a + \frac{R}{2}(T_s - T_a)$$

Graph between bonus earned and time saved is a straight line.

8.13 (c)

The correct option is (c) i.e., job analysis.
The step involved in job evaluation are:

Job analysis determine detailed facts about the job
↓
Job desctiption describe clearly the requirement of job
↓
Job classification determine the relative worth of job
↓
Wages determination compare job with predetermined job and arrive at suitable wage strucure
↓
Evaluate performance based on job description and specification

Job analysis: Job analysis is the process of determining the facts relating to the jobs. It involves a systematic examination of the job to find out (1) Nature of tasks performed by the worker, (2) Purpose or objective of the tasks, (3) Working condition under which the tasks are carried.

■■■■

9 Value Engineering

9.1 In value engineering important consideration is given to
(a) cost reduction (b) profit maximization
(c) function concept (d) customer satisfaction
[ESE : 1995]

9.2 Value is usually considered as a relationship between
(a) Utility and cost
(b) Profit and cost
(c) Psychology and reliability
(d) Appearance and utility **[ESE : 1996]**

9.3 Aluminium tie pin and gold tie pin, both serve the purpose of keeping the tie in position. But the gold pin has significance due to:
(a) Exchange value (b) Use value
(c) Esteem value (d) Cost value
[ESE : 1996]

9.4 If one state occurred four times in hundred observations while using the work-sampling technique, then the precision of the study using a 95% confidence level will be:
(a) 90% (b) 92%
(c) 95% (d) 98% **[ESE : 1997]**

9.5 Consider the following basic steps involved in value analysis:
1. Create 2. Blast 3. Refine
The correct sequence of these steps is
(a) 1, 2, 3 (b) 3, 1, 2
(c) 1, 3, 2 (d) 2, 1, 3 **[ESE : 1997]**

9.6 **Assertion (A):** In case of control charts for variables, if some points fall outside the control limits, it is concluded that the process is not under control.
Reason (R): It was experimentally proved by Shewhart that averages of four or more consecutive readings from a universe (population) or from a process, when plotted, will form a normal distribution curve.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE : 1999]**

Answers Value Engineering

9.1 (a) **9.2** (a) **9.3** (c) **9.4** (d) **9.5** (d) **9.6** (b)

Explanations Value Engineering

9.1 (a)

Value engineering is the application of the concept of value analysis at the design or pre-manufacture stage of the component parts with a view to cut down the unnecessary cost, without impairing the function or utility of the product.

9.2 (a)

$$\text{Value} = \frac{\text{Function (or utility)}}{\text{Cost}}$$

It can be seen that value of a product can be increased either by increasing its utility with the same cost or decreasing its cost for the same functions.

9.3 (c)

Esteem Value: The properties, features or attractiveness of an object makes its ownership desirable.

Use Value: The properties or qualities which accomplish a use, work or service.

Cost Value: The sum of labour, material and other cost required to produce the object (also called as Economic value).

Exchange Value: The properties or qualities of an object that make it possible to exchange it for something else that one wants.

9.4 (d)

$$P = \frac{4}{100} = 0.04$$

$$P{\cdot}S = k{\cdot}\sigma_p$$

$$\sigma_p = \sqrt{\frac{(1-p)p}{n}} = \sqrt{\frac{0.04 \times 0.96}{100}} = 0.0196$$

$$S = \frac{k\sigma_p}{p} = \frac{2 \times 0.0196}{0.04} = 0.979 \simeq \mathbf{0.98}$$

∴ Confidence factor is 98%

9.5 (d)

Value analysis procedure:

(a) Blast:
- Identity the product
- Collect the relevant informations
- Define the different function

(b) Create:
- Create different alternatives
- Critically evaluate the alternative

(c) Refine:
- Develop the best alternatives
- Implement the alternative

10 Element of Computation and Maintenance

10.1 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
- **A.** Linear programming
- **B.** Dynamic programming
- **C.** 'C' programming
- **D.** Integer programming

List-II
- **1.** Ritchie
- **2.** Dantzing
- **3.** Bell
- **4.** Gomory

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	1	2	3	4
(c)	2	3	1	4
(d)	2	3	4	1

[ESE : 1995]

■■■■

Answers Element of Computation and Maintenance

10.1 (c)

Explanations Element of Computation and Maintenance

10.1 (c)

Linear programming	Dantzing
Dynamic programming	Bell
'C' programming	Ritchie
Integer programming	Gomory

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