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ESE 2021

UPSC ENGINEERING SERVICES EXAMINATION

Preliminary Examination

Mechanical Engineering

Topicwise **Objective** Solved Questions

Volume-II

Topicwise Presentation | ***Thoroughly Revised and Updated***

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ESE-2021 : Preliminary Examination
Mechanical Engineering : Volume-2 | Topicwise Objective Solved Questions : (1995-2020)

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Director's Message

B. Singh (Ex. IES)

Engineering is one of the most chosen graduating field. Taking engineering is usually a matter of interest but this eventually develops into "purpose of being an engineer" when you choose engineering services as a carrier option.

Train goes in tunnel we don't panic but sit still and trust the engineer, even we don't doubt on signalling system, we don't think twice crossing over a bridge reducing our travel time; every engineer has a purpose in his department which when coupled with his unique talent provides service to mankind.

I believe *"the educator must realize in the potential power of his pupil and he must employ all his art, in seeking to bring his pupil to experience this power"*. To support dreams of every engineer and to make efficient use of capabilities of aspirant, MADE EASY team has put sincere efforts in compiling all the previous years' ESE-Pre questions with accurate and detailed explanation. The objective of this book is to facilitate every aspirant in ESE preparation and so, questions are segregated chapterwise and topicwise to enable the student to do topicwise preparation and strengthen the concept as and when they are read.

I would like to acknowledge efforts of entire MADE EASY team who worked hard to solve previous years' papers with accuracy and I hope this book will stand up to the expectations of aspirants and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

B. Singh (Ex. IES)
CMD, MADE EASY Group

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■■■■

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]**

5.6 Consider the following statements regarding a centrifugal clutch

1. It need not be unloaded before engagement.
2. It enables the prime mover to start up under no-load conditions.
3. It picks up the load gradually with the increase in speed.
4. It will not slip to the point of destruction.
5. It is very useful when the power unit has a low starting torque.

Which of these are the advantages of a centrifugal clutch?

(a) 1, 2 and 4 (b) 1, 3 and 5

(c) 2, 3 and 5 (d) 1, 3, 4 and 5

[ESE : 2000]

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

List-I	List-II
A. Single-plate friction clutch	**1.** Scooters
B. Multi-plate friction clutch	**2.** Rolling mills
C. Centrifugal clutch	**3.** Trucks
D. Jaw clutch	**4.** Mopeds

Codes:

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

[ESE : 2000]

5.8 Consider the following types of stresses in respect of a hoisting rope during acceleration of load
1. Direct stress due to weight hoisted and weight of the rope.
2. Bending stressed due to bending of rope over the sheave.
3. Stresses due to initial tightening.
4. Acceleration stresses.

Which of these are the correct types of stresses induced in a hoisting rope during acceleration of load?
(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 2 and 4 (d) 1, 3 and 4
[ESE : 2000]

5.9 In a multiple disc clutch in n_1 and n_2 are the number of discs on the driving and driven shafts, respectively, the number of pairs of contact surfaces will be
(a) $n_1 + n_2$ (b) $n_1 + n_2 - 1$
(c) $n_1 + n_2 + 1$ (d) $\frac{n_1 + n_2}{2}$
[ESE : 2001]

5.10 In a plate clutch axial force is 4 kN. The inside radius of contact surface is 50mm and the outside radius is 100 mm. For uniform pressure the mean radius of friction surface will be
(a) 78 mm (b) 60 mm
(c) 75 mm (d) 80 mm **[ESE : 2001]**

5.11 In the multiple disc clutch, if there are 6 discs on the driving shaft and 5 discs on the driven shaft, then the number of pairs of contact surfaces will be equal to
(a) 11 (b) 12
(c) 10 (d) 22 **[ESE : 2001]**

5.12 A 6 × 19 rope implies that there are
(a) 6 wires in each strand and 19 strands in the rope.
(b) 6 strands and 19 wires in each strand.
(c) 6 large diameter wires and 19 small diameter wires.
(d) 19 large diameter wires and 6 small diameter wires. **[ESE : 2001]**

5.13 Which one of the following is not a friction clutch?
(a) Disc or plate clutch
(b) Cone clutch
(c) Centrifugal clutch
(d) Jaw clutch **[ESE : 2002]**

5.14 A 6 × 19 rope implies that there are
(a) 6 wires in each strand and 19 strands in the rope
(b) 6 strands and 19 wires in each strand
(c) 6 large diameter wires and 19 small diameter wires
(d) 19 large diameter wires and 6 small diameter wires
[ESE : 2003]

5.15 Which one of the following is the correct expression for the torque transmitted by a conical clutch of outer radius R, inner radius r and semi-cone angle α assuming uniform pressure? (Where W = total axial load and μ = coefficient of friction)
(a) $\frac{\mu W(R+r)}{2\sin\alpha}$ (b) $\frac{\mu W(R+r)}{3\sin\alpha}$
(c) $\frac{2\mu W(R^3 - r^3)}{3\sin\alpha(R^2 - r^2)}$ (d) $\frac{3\mu W(R^3 - r^3)}{4\sin\alpha(R^2 - r^2)}$
[ESE : 2004]

5.16 In a 6 × 20 wire rope, No. 6 indicates the
(a) diameter of the wire rope in mm
(b) number of strands in the wire rope
(c) number of wires
(d) gauge number of the wire **[ESE : 2007]**

5.17 In case of a multiple disc clutch, if n_1 is the number of discs on the driving shaft and n_2 is the number of discs on the driven shaft, then what is the number of pairs of contact surfaces?
(a) $n_1 + n_2$ (b) $n_1 + n_2 - 1$
(c) $n_1 + n_2 + 1$ (d) $n_1 + 2n_2$
[ESE : 2008]

5.18 An elevator weighing 10000 N attains an upward velocity of 4 m/s in 2 seconds with uniform acceleration. Then what is the tension in the wire rope ?
(a) 8000 N (b) 5000 N
(c) 2500 N (d) 12000 N
[ESE : 2009]

5.19 In a multiple-disc clutch, the axial intensity of pressure is not to exceed 0.2 MPa. The inner radius of the discs is 100 mm and is half the outer radius. The axial force per pair of contact surfaces in N is
(a) 2000π (b) 3000π
(c) 4000π (d) 6000π
[ESE : 2010]

5.20 **Assertion (A):** In design of friction clutches the torque transmission capacity is predicted from the condition of uniform rate of wear of friction plate.

Reason (R): With the use of hard materials for the friction lining there is always perfect geometrical fit between two surfaces and hence pressure distribution over the contact zone is not uniform.

(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 : 2010]**

5.21 In wire ropes which one of the following statements is correct?

(a) Bending stress is directly proportional to the wire diameter and inversely proportional to the sheave diameter
(b) Both fatigue and wear are due to the tensile stress on the wire bearing against the sheave
(c) Bending stress is inversely proportional to the wires diameter and directly proportional to sheave diameter
(d) Both fatigue and wear are due to shear stress on the wires bearing against the sheave

[ESE : 2011]

5.22 If their are n_1 discs on the driving shaft and n_2 discs on the driven shaft in a multi-plate clutch, then the number of pairs of contact surfaces is

(a) $n_1 + n_2$ (b) $n_1 + n_2 - 1$
(c) $n_1 + n_2 - 2$ (d) $n_1 + n_2 + 1$

[ESE : 2011]

5.23 A rope has been designated as 6 × 19. The numbers 6 and 19 respectively stand for

(a) Rope diameter and the number of wires
(b) Rope diameter and the number of strands
(c) Number of strands and the number of wires
(d) Number of wires and the number of strands

[ESE : 2011]

5.24 The effect of increasing the stiffness of springs of centrifugal clutch is

(a) The decrease of engagement speed
(b) The increase of engagement speed
(c) The increase of frictional force at maximum speed
(d) None of the above **[ESE : 2012]**

5.25 A multi-disc clutch employs 3 steel and 2 bronze discs having outer diameter of 300 mm and inner diameter of 175 mm. If the coefficient of friction is 0.25 and axial force on each pair of surfaces is 5 kN, then the torque transmitted (assuming uniform wear) is

(a) 416.6 Nm (b) 887.5 Nm
(c) 1093.75 Nm (d) 593.75 Nm

[ESE : 2014]

5.26 A truncated conical pivot bearing has semi-cone angle α and the two radii are r_1 and r_2 respectively with $r_1 > r_2$. The coefficient of friction between the sliding surfaces is μ for an axial thrust load of W kN, the reduction in torque due to friction (assuming uniform rate of wear) is

(a) $\mu W (r_1 + r_2)\ \text{cosec}\ \alpha$

(b) $\frac{1}{2}\mu W (r_1 + r_2)\,\text{cosec}\ \alpha$

(c) $\frac{3}{2}\mu W\left[\frac{(r_1)^3 - (r_2)^3}{3}\right]\text{cosec}\ \alpha$

(d) $\frac{2}{3}\mu W\left[\frac{(r_1)^3 - (r_2)^3}{3}\right]\text{cosec}\ \alpha$

[ESE : 2014]

5.27 Consider that a wire rope is subjected to the following stresses

1. Direct stress on account of axial force
2. Bending stress
3. Stress due to acceleration of the moving mass

Which of the above are correct?

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

[ESE : 2014]

5.28 **Assertion (A):** Centrifugal clutches are designed to provide automatic and smooth engagement of load to driving member.

Reason (R): Since the operating centrifugal force is a function of square of angular velocity, the friction torque for accelerating a load is also a function of square of speed of driving member.

(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 : 2015]**

5.29 In case of design of friction clutches, uniform rate of wear theory is used over uniform pressure. The reasons may be the following :

1. It gives higher frictional torque.
2. It gives lower frictional torque.
3. The intensity of pressure is maximum at the inner radius and minimum at the outer radius of the friction or contact surfaces.
4. This concept is prevalent for running and old clutches.

Which of the above reasons are correct?

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

[ESE : 2016]

Direction: Each of the following items consists of two statements, one labelled as the **'Statement (I)'** and the other as **'Statement (II)'.** You are to examine these two statements carefully and select the answers to these items using the codes given below:

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.

5.30 **Statement (I) :** The linear speed of the belt in a belt drive is controlled by the tensile strength of the material of the driven pulley (larger in diameter).

Statement (II) : The rotating pulley rim is subjected to tensile hoop stress. **[ESE : 2016]**

5.31 **Statement (I) :** Regarding the power transmitted by a clutch, greater the speed, lower the torque to be transmitted for fixed power rating.

Statement (II) : The clutch is placed on the low-speed side to transmit larger torque.

[ESE : 2017]

5.32 To avoid self-engagement in cone clutch, its semi-cone angle is always kept

(a) smaller than the angle of static friction
(b) equal to the angle of static friction
(c) greater than the angle of static friction
(d) half of the angle of static friction

[ESE : 2019]

5.33 A solid cast iron disk, 1 m in diameter and 0.2 m thick, is used as a flywheel. It is rotating at 350 rpm. It is brought to rest in 1.5 sec by means of a brake. If the mass density of cast iron is 7200 kg/m^3, the torque exerted by the brake will be nearly

(a) 3.5 kNm (b) 4.5 kNm
(c) 5.3 kNm (d) 6.3 kNm **[ESE : 2020]**

5.34 The torque transmitting capacity of friction clutches can be increased by

(a) Use of friction material with a lower coefficient of friction
(b) Decreasing the mean radius of the friction disk
(c) Increasing the mean radius of the friction disk.
(d) Decreasing the plate pressure **[ESE : 2020]**

■■■■

Answers Brakes, Clutches and Ropes

5.1 (a)	5.2 (b)	5.3 (c)	5.4 (c)	5.5 (b)	5.6 (c)	5.7 (d)	5.8 (c)	5.9 (b)	
5.10 (a)	5.11 (c)	5.12 (b)	5.13 (d)	5.14 (b)	5.15 (c)	5.16 (b)	5.17 (b)	5.18 (d)	
5.19 (c)	5.20 (c)	5.21 (a)	5.22 (b)	5.23 (c)	5.24 (b)	5.25 (d)	5.26 (b)	5.27 (d)	
5.28 (b)	5.29 (a)	5.30 (a)	5.31 (b)	5.32 (c)	5.33 (a)	5.34 (c)			

Explanations Brakes, Clutches and Ropes

5.1 (a)

Because during normal operation acceleration avoided. So direct stress and bending stress accounted.

5.2 (b)

$$\left(\begin{matrix}\text{mass of rope + mass of weight}\\ \text{to be raised be raised}\end{matrix}\right) \times \text{accl}^n$$

= inertia force acting as additional load

5.3 (c)

$n_1 = 6, \quad n_2 = 5$

$N = n_1 + n_2 - 1 = 6 + 5 - 1 = \mathbf{10}$

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.

5.6 (c)

Centrifugal clutch will have slip as it is example of friction clutch.

It has to be unloaded before engagement.

$$F_c = m\omega^2 r$$

5.7 (d)

Mopeds have centrifugal clutch as one initially paddles up to achieve the speed so that shoes touch the rim it picks up the load gradually with increased in speed.

Multi plate clutch is used in cars as there is less space to accommodate plates and multiple plate clutch are always wet type lubrication done to dissipate the heat. Single plate clutches in truck.

5.8 (c)

Only stress due to initial tightening not considered.

Effective stress during acceleration of load

$= f_b + f_d + f_a$

1. $f_d = \dfrac{(w + w_r)}{A}$ (Direct stress due to weight hoisted)
2. Bending stress $\sigma_b = \dfrac{E \cdot d_w}{D} = f_b$
3. Acceleration stress $\left(\dfrac{w + w_r}{g}\right)\dfrac{a}{A} = f_a$

a = Acceleration, w = Load lifted

W_r = Weight of the rope

5.9 (b)

Number of pair of contacting surface $= n_1 + n_2 - 1$

5.10 (a)

$$r_m = \frac{2}{3}\left[\frac{r_0^3 - r_1^3}{r_0^2 - r_i^2}\right] = \frac{2}{3}\left[\frac{100^3 - 50^3}{100^2 - 50^2}\right] = 77.77$$

$\approx \mathbf{78\ mm}$

5.11 (c)

$n = n_1 + n_2 - 1 = 6 + 5 - 1 = \mathbf{10}$

5.12 (b)

$$\underset{\substack{\downarrow \\ \text{Diameter of} \\ \text{rope wire}}}{35} \times \underset{\substack{\downarrow \\ \text{Number of} \\ \text{Strand}}}{6} \times \underset{\substack{\downarrow \\ \text{Number of rope} \\ \text{in each Strand}}}{19}$$

5.13 (d)

Jaw clutch is example of positive clutch whereas others are example of friction clutches.

Jaw clutch has no slip, so no heat generation but accompanied with shock. It is very difficult to engage them at high speed.

5.14 (b)

$$\underset{\substack{\downarrow \\ \text{Diameter of} \\ \text{rope wire}}}{35} \times \underset{\substack{\downarrow \\ \text{Number of} \\ \text{Strand}}}{6} \times \underset{\substack{\downarrow \\ \text{Number of rope} \\ \text{in each Strand}}}{19}$$

5.15 (c)

$T = \dfrac{2\mu w(R^3 - r^3)}{3\sin\alpha(R^2 - r^2)}$ where α is semicone angle.

5.17 (b)

In case of a multiple disc clutch, if n_1 is the number of discs on the driving shaft and n_2 is the number of discs on the driven shaft, then number of pairs of contact surfaces $= n_1 + n_2 - 1$

5.18 (d)

Let $g = 10\ m/s^2$

Mass of elevator = 1000 kg

$$\text{Upward acceleration} = \frac{4}{2} = 2\ m/s^2$$

Tension in the rope $= m(g + a)$

$= 1000\ (10 + 2) =$ **12000 N**

5.19 (c)

For multi-disc clutch

Axial intensity of pressure, $p = 0.2$ MPa

$R_i = 100$ mm; $R_0 = 200$ mm

According to UWT,

$$F = p \times 2\pi r_i (r_0 - r_i)$$
$$= 0.2 \times 2\pi \times 100 \times (200 - 100)$$
$$= 4000\pi\ N$$

5.21 (a)

In wire ropes, bending stress is directly proportional to wire diameter and inversely proportional to sheave diameter. Wire ropes sheave are made of either cast iron or mild steel.

5.22 (b)

For multidisc clutch, if n_1 is the number of disc on driving shaft and n_2 is the number of disc on driven shaft than number of pairs of contact surface = $n_1 + n_2 - 1$.

Application : Scooter's

5.24 (b)

When the load is released from clutch lever, it again engages with the shaft. As the stiffness of spring will increases, the restoring force on clutch will increase and hence velocity of engagement will be more.

5.25 (d)

Number of active surfaces,

$$n = n_b + n_s - 1 = 2 + 3 - 1 = 4$$

$D = 300$ mm, $d = 175$ mm, $\mu = 0.25$,

$W_a = 5$ kN

$$T = n\mu W_a R_m$$

$$= 0.25 \times 4 \times 5000 \times \frac{(300 + 175)}{4} \times 10^{-3}$$

$=$ **593.75 Nm**

5.31 (b)

Although UPSC has given correct answer (c)

Power = torque $(\uparrow) \times \omega(\downarrow)$

5.32 (c)

To avoid self locking semi-cone angle should be greater than angle of static friction.

5.33 (a)

Mass, $m = \rho V$

$$= \rho \frac{\pi}{4} D^2 \times t$$

$$= 7200 \times \frac{\pi}{4} \times (1)^2 \times 0.2$$

$$m = 1130.97\ kg$$

$$I = \frac{mR^2}{2} = 141.37\ kg\text{–}m^2$$

$$T_{braking} = I \times \alpha$$

$$\omega_f = \omega_i + \alpha t$$

$$0 = \frac{2\pi N_i}{60} + \alpha t$$

$$\alpha = \frac{2\pi \times 350}{60 \times 1.5} = -24.43\ rad/s^2$$

$$T_{braking} = 3454\ Nm = 3.45\ kNm$$

5.34 (c)

Torque, $T_f \uparrow = \mu W R_{eff} \uparrow$

(where, R_{eff} = mean radius of friction disk)

■■■■