DETAILED SOLUTIONS

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UPPSC AE 2019
ASSISTANT ENGINEER

MECHANICAL ENGINEERING

Test 1

Part Syllabus Test

Engineering Mechanics + Mechanics of Solids

ANSWER KEY

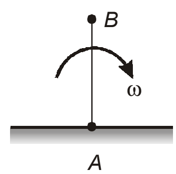
1.	(a)	**11.**	(a)	**21.**	(d)	**31.**	(b)	**41.**	(d)
2.	(b)	**12.**	(b)	**22.**	(a)	**32.**	(b)	**42.**	(d)
3.	(c)	**13.**	(a)	**23.**	(c)	**33.**	(d)	**43.**	(d)
4.	(c)	**14.**	(b)	**24.**	(b)	**34.**	(b)	**44.**	(c)
5.	(b)	**15.**	(a)	**25.**	(b)	**35.**	(a)	**45.**	(d)
6.	(c)	**16.**	(b)	**26.**	(a)	**36.**	(c)	**46.**	(a)
7.	(d)	**17.**	(c)	**27.**	(c)	**37.**	(a)	**47.**	(d)
8.	(a)	**18.**	(a)	**28.**	(c)	**38.**	(b)	**48.**	(d)
9.	(d)	**19.**	(c)	**29.**	(b)	**39.**	(a)	**49.**	**(a)**
10.	(a)	**20.**	(b)	**30.**	(a)	**40.**	(b)	**50.**	(a)

DETAILED EXPLANATIONS

1. (a)

Since body is moving rightward, friction force will be in leftward direction. Weight is always acted in vertical downward direction.

2. (b)



$$V_B - V_A = \omega \cdot AB$$

3. (c)

When resultant is equal to P,

$$P = \sqrt{P^2 + P^2 + 2P.P\cos\theta}$$

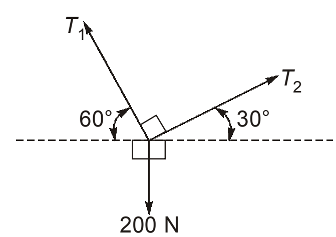
$$P^2 = P^2 + P^2 + 2P^2\cos\theta$$

$$\cos\theta = -\frac{1}{2} = -0.5$$

$$\theta = \mathbf{120°}$$

4. (c)

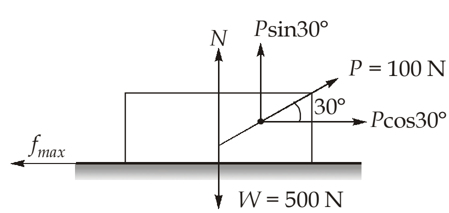
Using Lami's Theorem,



$$\frac{T_1}{\sin(90° + 30°)} = \frac{T_2}{\sin(90° + 60°)}$$

$$\frac{T_1}{T_2} = \frac{\sin 120}{\sin 150} = 1.732$$

6. (c)



Normal reaction, N = 500 – P sin30°

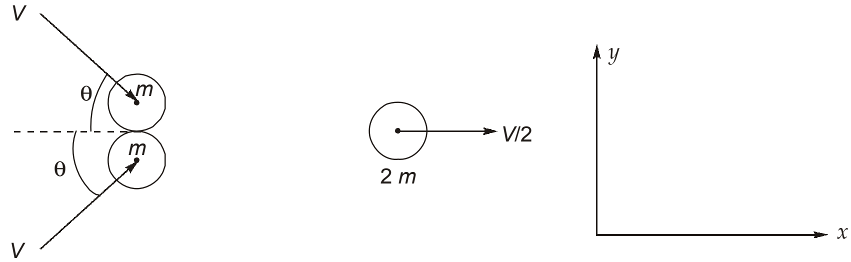
= 500 – 100 × 0.5 = 450 N

Maximum frictional force, $f_{max.}$ = μN = 0.3 × 450 = 135 N

But Traction force, F = 100 cos30° = 86.6 N

So the frictional force = 86.6 N

7. (d)



Momentum will be conserved in x-direction,

Let θ be the angle of velocity of each mass from x-direction as shown in figure. As after collision velocity component in perpendicular direction of velocity of objects is zero, for conservation of momentum along 'y' direction, angle of inclination of both the object w.r.t the x-axis is equal.

$$mV\cos\theta + mV\cos\theta = 2m \times \frac{V}{2}$$

$$2\cos\theta = 1$$

$$\cos\theta = \frac{1}{2}$$

$$\theta = 60°$$

So $\quad$ the total angle $= 2\theta = 120°$

8. (a)

$$\text{K.E.} = \frac{1}{2}I\omega^2 + \frac{1}{2}mV^2$$

$$= \frac{1}{2}\left(\frac{2}{5}mr^2\right)\omega^2 + \frac{1}{2}mV^2$$

$$\text{K.E.} = \frac{1}{5}m\omega^2 r^2 + \frac{1}{2}mV^2 = \frac{7}{10}mV^2$$

9. (d)

Let, s is the distance travelled by pet,

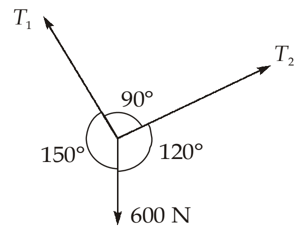
Average velocity of pet, $\quad V_P = \frac{s}{45}$

Velocity of conveyor, $\quad V_C = \frac{s}{30}$

Combined velocity, $\quad V_{P,C} = \frac{s}{30} + \frac{s}{45} = \frac{s}{18}$

$$t = \frac{s}{s/18} = 18 \text{ seconds}$$

11. (a)



By Lami's Theorem,

$$\frac{T_1}{\sin 120°} = \frac{T_2}{\sin 150°} = \frac{600}{\sin 90°}$$

$\therefore$ $T_1 = 600 \sin 120°$

$= 519.31 \simeq 520$ N

and $T_2 = 600 \sin 150°$

$T_2 = 300$ N

12. (b)

$$\bar{x} = \frac{A_1x_1 - A_2x_2}{A_1 - A_2} = \frac{(2a)^2 \times 0 - a^2 \times a/2}{3a^2} = -\frac{a^3}{2} \times \frac{1}{3a^2} = -\frac{a}{6}$$

13. (a)

It can be visualized that with increase in angle w.r.t. horizontal floor, normal reaction at floor will increase frictional force (μN), hence ladder will be in equilibrium.

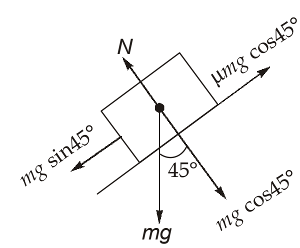
14. (b)

Let mass of body is

F_{net} along the slope $= mg \sin 45° - 0.5mg \cos 45°$

$= 0.5 \times mg \cos 45°$

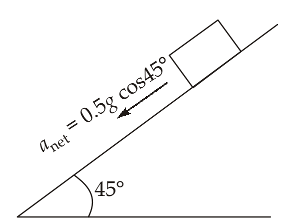
$$a = \frac{F_{net}}{m} = 0.5g \cos 45°$$



$v^2 = u^2 + 2as,$

$u = 0$ (given)

$$s = \frac{v^2}{2a} = \frac{v^2}{2 \times 0.5g \cos 45°}$$



$$s = \frac{400}{2 \times 0.5 \times 9.81 \times \cos 45°} = 57.66 \approx 58 \text{ m}$$

16. (b)

$$\vec{s} = \vec{u}t + \frac{1}{2}\vec{a}t^2$$

$$\vec{s} = (2\hat{i} + 3\hat{j})2 + \frac{1}{2}(4i + 2\hat{j})(2)^2$$

$$= (12\hat{i} + 10\hat{j})\text{ m}$$

17. (c)

$$\frac{UTS}{BPS} = \frac{P_U / A_U}{P_U / A_B} = \frac{P_U}{P_B} \times \frac{A_B}{A_U} = \frac{150}{70} \times \frac{\frac{\pi}{4} \times 1^2}{\frac{\pi}{4} \times 2^2} = 0.53$$

18. (a)

$$\text{Strain energy, } U = \int_0^L \frac{P^2}{2AE} dx$$

$$P_x = \text{Weight} = \gamma.A.x$$

$$U = \int_0^L \frac{\gamma^2 A^2 x^2}{2AE} dx = \frac{\gamma^2 A^2 L^3}{6AE} = \frac{\gamma^2 AL^3}{6E}$$

19. (c)

Stress is given by $\tau = \frac{T}{J}r$. The hollow shaft have larger value of J and as such can bear larger torques while maintaining shear stress within limits.

20. (c)

In the area 1 stress is proportional to strain. In the area 2, plastic deformation occurs due to sliding of dislocation. In the area 3, strain hardening occurs due to which the stress keeps on increasing upto the point of UTS. In the area 4, necking occurs that results in decrease in area of the specimen at a localized point/section.

21. (d)

$$\text{Thermal Stress} = \alpha E \Delta t = (12 \times 10^{-6})(200 \times 10^3)(120 - 20) = 240 \text{ MPa}$$

22. (a)

Given, $\sigma_1 = 100$ MPa, $\sigma_2 = 50$ MPa, $S_{yt} = 200$ MPa,

For maximum shear strain energy theory,

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2)^2 + (\sigma_1)^2 \le 2\left(\frac{S_{yt}}{N}\right)^2$$ [Where, N = factor of safety]

$$(100 - 50)^2 + (50)^2 + (100)^2 = 2\left(\frac{200}{N}\right)^2$$

$$\Rightarrow \quad 50^2 + 50^2 + 100^2 = \frac{2 \times (200)^2}{N^2}$$

$$15000 = \frac{2 \times (200)^2}{N^2}$$

$$N = \frac{4}{\sqrt{3}}$$

23. (c)

$$P_e = \frac{\pi^2 E I_{min}}{l_e^2}$$

$$P_e \propto \frac{1}{l_e^2}$$

Here, l_e (Effective length) is minimum for the case when both ends of column are fixed, hence it will carry maximum load.

25. (b)

$$\text{Change in slope } (\Delta\theta) = \frac{\text{Area of bending moment diagram}}{EI}$$

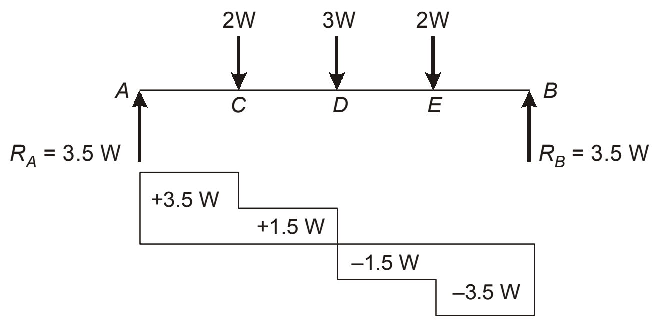
$$\text{Change in deflection}(\Delta y) = \frac{\text{Moment of area of bending moment diagram}}{EI}$$

26. (a)

$$\text{Circumferential strain} = \frac{\delta d}{d} = \frac{Pd}{4tE}(2 - \mu)$$

$$\because \quad \delta d = \frac{Pd^2}{4tE}(2 - \mu)$$

27. (c)



S.F.D.

So maximum shear force is 3.5 W.

28. (c)

$$\sigma_{max} = \sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2}$$

$$\Rightarrow \quad \sigma_1 = \frac{14-10}{2} + \sqrt{\left(\frac{14-(-10)}{2}\right)^2 + (-9)^2}$$

$$\Rightarrow \quad \sigma_1 = 2 + \sqrt{12^2 + 9^2} = 2 + 15 = 17 \text{ MPa}$$

29. (b)

Materials	Independent elastic constants
Isotropic	2
Orthotropic	9
Anisotropic	21

30. (a)

Since Mohr's circle represents transformation of second order tensor. It is also possible for moment of inertia as it is also a second order tensor along with stress and strain.

31. (b)

Writing compatibility equation for this case:

$$\theta_{AC} = 0$$

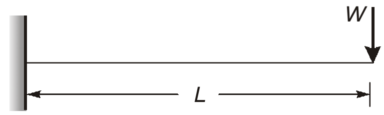
$$\theta_{AB} + \theta_{BC} = 0$$

$$-\frac{T_A a}{GJ} + \frac{T_C b}{GJ} = 0$$

$$T_A a = T_C b$$

$$\frac{T_A}{T_C} = \frac{b}{a}$$

32. (b)



As $\delta_1 = \dfrac{WL^3}{3EI}$

Again when $W_2 = \dfrac{W}{2}$

and $L_2 = 2L,$

$$\Rightarrow \quad \delta_2 = \dfrac{\dfrac{W}{2}\times(2L)^3}{3EI} = \dfrac{4WL^3}{3EI}$$

$$\Rightarrow \quad \delta_2 = 4\delta_1$$

33. (d)

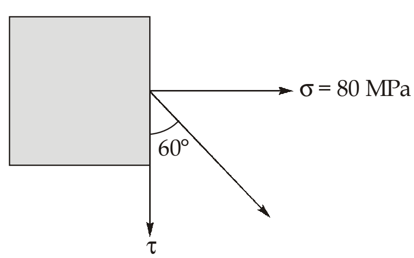
As for thin cylindrical shell, $\sigma_l = \dfrac{PD}{4t}$

and $\sigma_h = \dfrac{PD}{2t}$

$\Rightarrow$ Maximum inplane, shear stress,

$$\tau_{max} = \dfrac{\sigma_h - \sigma_l}{2} = \dfrac{PD}{8t}$$

34. (b)



$$\tan\theta = \dfrac{\sigma}{\tau}$$

$$\Rightarrow \quad \tau = \dfrac{80}{\tan 60^\circ} = 46.18 \text{ MPa}$$

35. (a)

$$\text{Displacement} = \sum(\text{Area under curve}, V - t)$$
$$= (4 \times 2) + (-2 \times 2) + (2 \times 4) = 12 \text{ m}$$

$$\text{Distance} = \sum|\text{Area under curve}, V - t|$$
$$= (4 \times 2) + (2 \times 2) + (2 \times 4) = 20 \text{ m}$$

37. (a)

Thin plate of uniform thickness pertains to plane stress condition. So, stress out of plane would be zero.

39. (a)

$$SF = \frac{d(BM)}{dx}$$

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

$$\frac{dM}{dx} = 0 \quad \Rightarrow \quad M = \text{Constant}$$

Then, BM remains constant.

40. (b)

As,
$$E = \frac{A_1E_1 + A_2E_2}{A_1 + A_2} = \frac{A_1}{A_1 + A_2}E_1 + \frac{A_2}{A_1 + A_2}E_2$$

42. (d)

Poisson's ratio is the negative ratio of lateral strain to the longitudinal strain. It is denoted by μ. When volume change on loading is zero, value of μ is 0.5.

$$\in_V = \frac{(1-2\mu)}{E}(\sigma_x + \sigma_y + \sigma_z)$$

43. (d)

For shaft in torsion, strength depends on polar section modulus,

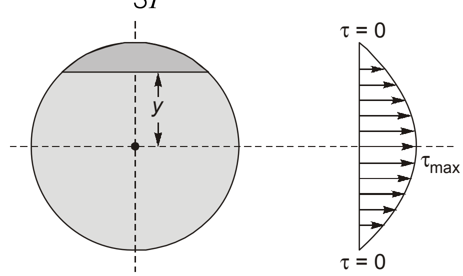
∵ Polar section modulus $Z_p \alpha\, d^3$

∴ Shaft B is 8 times stronger than A.

46. (a)

Shear stress in circular cross-section due to transverse load

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



Variation of τ versus y is a parabolic curve.

47. (d)

I-section have maximum section modulus so bending stress produced in the section will be minimum.

49. (a)

We know that $\alpha_{copper} > \alpha_{steel}$, α → Coefficient of thermal expansion. Copper will try to expand more than steel. Hence, Tensile stress induce in copper and compressive stress induced in steel.

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