ANSWER KEY

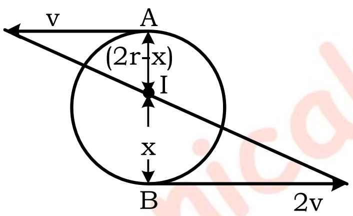
1.	(D)	13.	(C)	25.	(0.15 - 0.17)	37.	(20.70 - 20.76)	49.	0.67	61.	(A)
2.	(B)	14.	(C)	26.	(265-268)	38.	(65.0 - 69.0)	50.	(0.12 - 0.126)	62.	(A)
3.	(B)	15.	(C)	27.	(B)	39.	0	51.	366 to 370	63.	(C)
4.	(C)	16.	(B)	28.	52.806	40.	(D)	52.	(C)	64.	(B)
5.	(B)	17.	(A)	29.	2.67 (2.5 to 3)	41.	2.	53.	59 to 60 W	65.	(C)
6.	(C)	18.	(B)	30.	10.096 (9to 11m)	42.	0.8125	54.	0		
7.	(C)	19.	(B)	31.	6.08 (6.1 - 6.2)	43.	14.5 - 15.5	55.	(1.62 - 1.68)		
8.	(B)	20.	(D)	32.	(B)	44.	(C)	56.	(D)		
9.	(B)	21.	(D)	33.	(C)	45.	3.0 - 3.3	57.	$\left(\frac{10\pi}{13}\right)$		
10.	(B)	22.	50 (49-51) N/mm²	34.	(A)	46.	(A)	58.	(B)		
11.	(B)	23.	(B)	35.	(C)	47.	(0.56 - 0.58)	59.	(A)		
12.	1.154 (1.150-1.160)	24.	(D)	36.	(A)	48.	22.25 (22 to 23)	60.	(D)		

SOLUTIONS

1. (D)

2. (B)
Upto proportionality limit stress is linearly proportional to strain. Therefore Hooke's law is perfectly valid

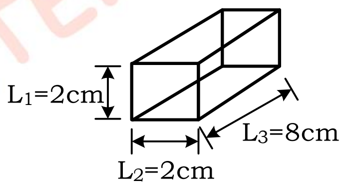
3. (B)



$$\frac{v}{2r-x}=\frac{2v}{x}$$
$$x=4r-2x$$
$$3x=4r\Rightarrow x=\frac{4}{3}r$$
$$\therefore\quad \omega=\frac{2v}{x}=\frac{2v}{\frac{4}{3}r}=\frac{6v}{4r}=\frac{3v}{2r}$$

4. (C)
Equations of streamlines is given as
$$\frac{dx}{u}=\frac{dy}{v}$$
$$\frac{dx}{ax}=\frac{dy}{-ay}$$
$$\frac{dx}{x}=\frac{dy}{-y}$$
Integrating
$$\log x=-\log y+c$$
$xy=c$, rectangular hyperbola

5. (B)



$$L_C=\frac{\text{volume}}{\text{Surface Area}}=\frac{L_1L_2L_3}{2(L_1L_2+L_2L_3+L_3L_1)}$$
$$L_C=4.44\times10^{-3}\,m$$
Biot Number
$$Bi=\frac{hL_C}{K}=\frac{55\times4.44\times10^{-3}}{50}$$
$$=4.88\times10^{-3}=0.049$$

6. (C)
$$F_H=\rho.g\times\bar{h}\times A_{proj}$$
$$F_H=1000\times9.81\times\frac{20}{2}\times20\times1$$
$$F_H=1.962\times10^{6}\,N$$

7. (C)
$$\frac{X}{\left(\frac{F_0}{K}\right)}=\frac{1}{\sqrt{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2+\left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$
At resonance $\omega=\omega_n$
$$\frac{X}{\left(\frac{F_0}{K}\right)}=\frac{1}{2\xi}=20$$
$$\Rightarrow\quad \xi=0.025$$

8. (B)
As $r=2cm,\quad F=14\,N$
$r=6cm,\quad F=38\,N$

$F = mr + C$

$14 = m \times 2 + C$

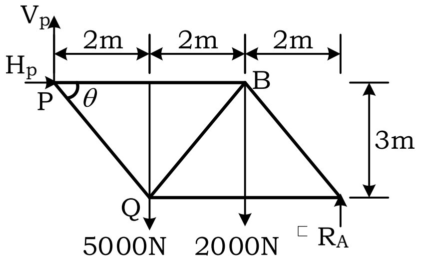
$38 = m \times 6 + C$

$4m = 24$

$\therefore \quad m = 6, C = 2$

$\therefore \quad F = 6r + 2(\text{unstable})$

9. (B)



$\Sigma F_x = 0$

$Hp = 0 \quad \ldots(i)$

$\Sigma Fy = 0$

$V_P + 5000 + 2000 - R_A = 0 \quad \ldots(ii)$

(assume V_P acts downward direction since we don't know, $\Sigma M_{@P} = 0$)

$5000 \times 2 + 2000 \times 4 - R_A \times 6 = 0$

$\therefore \quad R_A = \dfrac{18000}{6} = 3000\,N(\text{upward}) \quad \ldots(iii)$

$\therefore$ substitute (3) in (2)

$V_P + 5000 + 2000 - 3000 = 0$

$\therefore \quad V_P = -4000\,N$

$= 4000\,N(\text{upward})$

Here we assumed V_P as downward. i.e., why we got V_P as negative

$\therefore$ our assumption is wrong. The direction of V_P is upward

Take the joint, P

$\Sigma F_y = 0$

$V_P = R_{pq} \sin\theta$

(Assume R_{PQ} in downward direction)

$4000 = R_{PQ} \times \dfrac{3}{\sqrt{3}}$

$\therefore \quad R_{PQ} = 4807.4\,m(\text{downward})$

R_{PQ} is the positive value obtained hence in case of R_{PQ} our assumption about direction is correct.

10. (B)

At limiting condition biot number is 0.1.

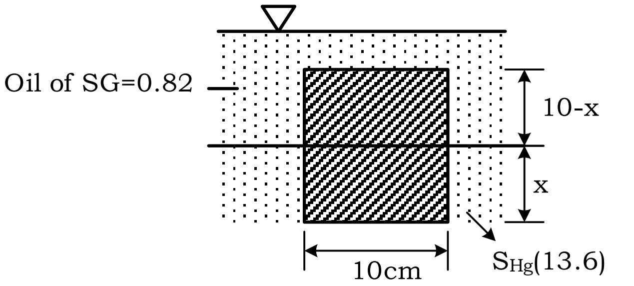
Hence $\ln(T - T_\infty / T_0 - T_\infty) = -bi \times F_o$

$l_n(60 - 300/30 - 300) = l_n(24/27) = l_n(0.88888) = -0.1177$

At limiting condition, biot no. $= 0.1$

Hence $F_o = 1.177$

11. (B)



Weight of the body = Buoyancy force on two liquids

$7.85 \times g \times 10^3 =$

$g\left[13.6 \times x \times 100 + \left[0.82 \times (10 - x) \times 100\right]\right]$

$\Rightarrow \quad x = 5.5\,cm$

12. 1.154 (1.150-1.160)

Energy at the top = mgh

Energy at the bottom $= \dfrac{1}{2}mV^2 + \dfrac{1}{2}I\omega^2$

$= \dfrac{1}{2}mV^2 + \dfrac{1}{2}\dfrac{1}{2}mR^2\left(\dfrac{V}{R}\right)^2$

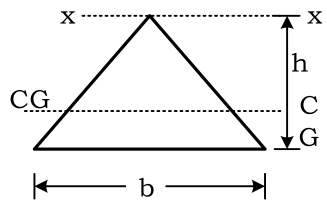
$= \dfrac{3}{4}mV^2$

$mgh = \dfrac{3}{4}mV^2$

$\Rightarrow \quad V = \sqrt{\dfrac{4}{3}gh} = 1.154\sqrt{gh}$

13. (C)

Moment of inertia of triangle about base is



$I_b = \dfrac{bh^3}{12}$

$I_b = I_G + Ay^2$

$I_G = I_b - Ay^2 = \dfrac{bh^3}{12} - \left[\dfrac{bh}{2} \times \left(\dfrac{h}{3}\right)^2\right]$

$= \dfrac{bh^3}{12} - \dfrac{bh^3}{18}$

$I_G = \dfrac{bh^3}{36}$

$I_x = I_G + Ay^2$

$I_x = \dfrac{bh^3}{36} + \left[\left(\dfrac{bh}{2}\right) \times \left(\dfrac{2h}{3}\right)^2\right]$

$= \dfrac{bh^3}{36} + \dfrac{2bh^3}{9}$

$$I_{XX} = \frac{bh^3}{4}$$

14. (C)

Applying equilibrium conditions

$\Sigma F_x = 0 \Rightarrow 100 - 200 + P - 150 = 0$

$\therefore \quad P = 250\,kN$

15. (C)

$$L\left[te^{-2t}\sin\sqrt{2}t\right]$$

$$L\left[\sin\sqrt{2}t\right] = \frac{\sqrt{2}}{\left(S^2+2\right)}$$

$$L\left(t\sin\sqrt{2}t\right) = \frac{-d}{ds}\left\{\frac{\sqrt{2}}{S^2+2}\right\} = \left(-\sqrt{2}\right)\left\{\frac{-1.25}{\left(S^2+2\right)^2}\right\}$$

$$L\left[t\sin\sqrt{2}t\right] = \frac{2\sqrt{2}S}{\left(S^2+2\right)^2}$$

$$L\left[e^{-2t}t\sin\sqrt{2}t\right] = \frac{2\sqrt{2}\left(S+2\right)}{\left(\left(S+2\right)^2+2\right)^2}$$

16. (B)

$$St = \frac{Nu}{(\text{Re})(\text{Pr})}$$

$$\text{Pr} = \frac{Nu}{\text{Re}\times St}$$

$$= \frac{400}{40\times 0.5} = \frac{400}{20} = 20$$

17. (A)

Radiosity $= J = E + \rho G$

$J = 32 + 0.6(93)$

$J = 87.8\,W - m^{-2}$

18. (B)

19. (B)

$$NTU = \frac{U.A}{C_{\min}} = \frac{60\times 25}{1000} = 1.5$$

$$\in = \frac{N}{N+1} = \frac{1.5}{2.5} = 0.6$$

20. (D)

21. (D)

22. (50 N/mm²).

Using Bending equation;

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

$$\therefore \quad \sigma = \frac{E}{R}.y$$

$$\Rightarrow \quad \sigma_{\max} = \frac{E}{R}, y_{\max}$$

$$= \frac{2\times 10^5}{20\times 10^3}\times 5 = 50\,N/mm^2$$ **Ans.**

23. (B)

24. (D)

25. (0.15, 0.17)

$V_a = \left(\omega_1 - \omega_2\right).r$

$= \left(4.2 - (-3.8)\right)\times 20\times 10^{-3} = 0.16\,m/s$

Two marks questions

26. (__)

27. (B)

Given

$\vec{V} = 2xy\hat{i} - y^2\hat{j} = 4(x,y)\hat{i} + \upsilon(x,y)\hat{j}$

$\Rightarrow \quad 4 = 2xy$ & $\upsilon = -y^2$

$\therefore$ The equation of streamlines is given by,

$$\frac{dx}{u} = \frac{dy}{\upsilon}$$

$$\Rightarrow \quad \frac{dx}{2xy} = \frac{dy}{-y^2}$$

$$\Rightarrow \quad \frac{dx}{2x} = \frac{dy}{-y}$$

$$\Rightarrow \quad \frac{1}{2}\ln x = -\ln y + \ln c$$

$$\Rightarrow \quad \ln x = -2\ln y + 2\ln c$$

$$\Rightarrow \quad \ln\left(x.y^2\right) = \ln c$$

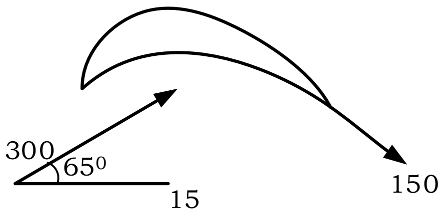
$$\Rightarrow \quad x.y^2 = \text{constant}$$

28. (52.806)

Specific work $= \left(V_{W_1} - V_{W_2}\right)\times V$

$= \left[300\sin 65 - (-80.15)\right]\times 150$

$= 52.806\,KJ/kg$



$\because$ Axial velocity is same at entry exit

$\therefore 300\cos 65^0 = 150\cos\theta_2$

$\therefore \quad \theta_2 = 32.3$

$\therefore \quad V_{w_2} = 150\sin 32.3$

$V_{w_2} = 80.174$

29. (2.66)

$$U = \frac{1}{4m}\left(\frac{dp}{dx}\right)\left(R^2 - r^2\right)$$

$$U_1 x = k/2 = \frac{1}{4m}\left(\frac{dp}{dx}\right)\left(R^2 - (R/2)^2\right)$$

$$U_1 = \frac{1}{4m}.\frac{dp}{dx}.\left(\frac{3}{4}R^2\right)$$

$$\Rightarrow \quad \frac{dp}{x} = \frac{16\mu.U_1}{3R^2}$$

& will shear stress

$$\tau_w = \frac{R}{2}\cdot\frac{dp}{dx}$$

$$\therefore \quad \tau_w = \frac{R}{2}\times\frac{16\mu.U_1}{3R^2} = \frac{8}{3}.M.\frac{U_1}{R}$$

$$\therefore \quad K = \frac{8}{3} = 2.66$$

30 (10.096 m)

Given $D = 5\,mm = 0.005\,m;$

$\theta = 2\pi\,rad;$

$\tau = 42\,MN/m^2;$

$C = 27\,GN/m^2$

Let, $l =$ Length of the aluminum wire.

Torque transmitted by the wire,

$$T = \tau.\frac{\pi}{16}D^3 = 42\times10^6\times\frac{\pi}{16}\times(0.005)^3\ Nm = 1.031\,Nm$$

Polar moment of inertia of a circular section,

$$I_p = \frac{\pi}{32}\times D^4 = \frac{\pi}{32}(0.005)^4 = 6.136\times10^{-11}m^4$$

We know that,

$$\frac{T}{l_P} = \frac{C\theta}{l}$$

$$\frac{1.031}{6.136\times10^{-11}} = \frac{27\times10^9\times2\pi}{l}$$

Or, $l = \frac{27\times10^9\times2\pi\times6.136\times10^{-11}}{1.031} = 10.096\,m$

(Ans.)

31. [6.08 (6.1 to 6.2)]

Let, $R_A =$ Reaction at roller A,

$R_{DV} =$ Vertically component of the reaction at the hinged support D, and

$R_{DH} =$ Horizontal component of the reaction at the hinged support D.

Obviously $R_{Dh} = 2\sqrt{3}kN(\rightarrow)$

In order to determine R_A, takings moments about D, we get

$$R_A\times6 + 2\times1 = 1\times2\times\left(\frac{2}{2}+2+2\right)+2+4\times2$$

$$6R_A + 2 = 10 + 2 + 8$$

Or, $R_A = 3\,kN$

Also, $R_A + R_{DV} = (1\times2)+4+2 = 8$

Or, $R_{DV} = 5\,kN(\uparrow)$

$\therefore$ Reaction at $D, R_D = \sqrt{\left(R_{DV}^2 + R_{DH}^2\right)}$

$= \sqrt{5^2 + \left(2\sqrt{3}\right)^2}$

$= 6.08\,kN$

32. (B)

$$T - 65 = \frac{15-65}{10-0}[x-0]$$

$$T = 65 - \frac{50}{10}x$$

$$T = 65 - 5x$$

$$x = 5m$$

$$T = 65 - 25 = 40°C$$

33. (C)

$$\vec{V} = \left(-x^2+3y\right)i + (2xy)j$$

$u = -x^2 + 3y \quad , \quad v = 2xy$

$\frac{\partial u}{\partial x} = -2x \quad , \quad \frac{\partial v}{\partial x} = 2y$

$\frac{\partial u}{\partial y} = 3 \quad , \quad \frac{\partial v}{\partial y} = 2x$

at (1,-1)

$u = -4\ ,\ v = -2\ ,\ \frac{\partial u}{\partial x} = -2\ ,\ \frac{\partial u}{\partial y} = 3\ ,\ \frac{\partial v}{\partial x} = -2\ ,\ \frac{\partial v}{\partial y} = 2$

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \left[(-4)\times(-2)+(-2)\times3\right]$$

$$a_x = 8 - 6 = 2$$

$$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = \left[(-4)\times(-2)+(-2)\times2\right]$$

$$a_y = 8 - 4 = 4$$

$$a = \sqrt{a_x{}^2 + a_y{}^2} = \sqrt{2^2+4^2} = 2\sqrt{5}$$

34. (A)

35. (C)

36. A

37. (20.70 to 20.76)

38. (65.0 to 69.0)

39. (0)

40. (D)

41. (2.33)

42 (0.8125)

43. (14.5 to 15.5)

44. (C)

We know, $x = \frac{F}{k - m\omega^2}$

$F = x\left(k - m\omega^2\right)$

Given, $x = 1\,mm = 10^{-3}m, k = 100\,N/m,$
$m = 1kg, \omega = 20\,rad/\sec$

$\therefore \quad F = 10^{-3}\left(100 - 1\times20^2\right)$

$= -0.3N(-ve)$ indicates out of phase,

$\therefore \quad F = 0.3\,N$

45. (3.0 to 3.3)

46. (A)

47. (0.56 to 0.58)

48. (22.25)

$\upsilon_{oil} = 1\times10^{-5} m^2/s \quad \alpha = 0.5m \quad V = 10m/s$

$\upsilon_{water} = 0.89\times10^{-6} m^2/s \quad d = 0.02m$

Satisfy the dynamic similarities ÷

$\therefore \quad \text{Re}_1 = \text{Re}_2 = \dfrac{10\times0.5}{10^{-5}} = \dfrac{V\times0.2}{0.89\times10^{-6}}$

$V = 22.15m/s$

49. (0.67)

Mass out flux through (cd) $= \rho b\times\delta_t\times Vo$

$= \rho\times b$ (displacement thickness) $\times Vo$

$$= \rho\times b\left[\int_o^\delta\left\{1-\left(2\left(\frac{y}{\delta}\right)-\left(\frac{y}{\delta}\right)^2\right)\right\}dy\right]\times V_0$$

$$= \rho\times b\times Vo\left(\delta-\delta+\frac{\delta}{3}\right) = \rho\times b\times\frac{\delta}{3}\times Vo$$

$$mas\dot{s}(bd) = \rho\times b\times\delta\times Vo - \frac{\rho\times b\times\delta\times Vo}{3}$$

$$= \frac{2\times\rho\times b\times\delta\times Vo}{3}$$

$$mas\dot{s}(ab) = \rho\times b\times\delta\times Vo$$

$$\text{ratio of } \frac{\dot{m}(bd)}{\dot{m}(ab)} = \frac{2\times\rho\times A\times\frac{Vo}{3}}{\rho\times A\times V_0} = 0.67$$

50. (0.12 – 0.126)

Modulus of resilience = Area under the $\sigma-\in$ curve till the yield point

So, $MOR = \frac{1}{2}\times2\times14 = 14$

Modulus of toughness = Area under $\sigma-\in$ curve till the fracture point

$$MOT = \frac{1}{2}\times2\times14+\frac{1}{2}\times4\times(20+14)+\frac{1}{2}\times2\times(20+12)$$

$$MOT = 14+68+32 = 114$$

So, $\dfrac{MOR}{MOT} = \dfrac{14}{114} = 0.1228$

51. (368.345)

Applying Bernoulli equation between points A & C

$$\frac{P_A}{\rho g}+\frac{V_A^2}{2g}+Z_A = \frac{P_c}{\rho g}+\frac{V_c^2}{2g}+Z_c$$

$$\frac{(18)^2}{2g}+21 = \frac{V_c^2}{2g}$$

$V_c = 27.129m/s$

Applying continuity equation between B&C

$A_B V_B = A_C V_C$

$D_B^2 V_B = D_C^2\times V_C$

$(225)^2\times V_B = (75)^2\times27.129$

$V_B = 3.014m/s$

Applying Bernoulli equation between B&C

$$\frac{P_B}{\rho g}+\frac{V_B^2}{2g}+Z_B = \frac{P_C}{\rho g}+\frac{V_C^2}{2g}+Z_C$$

$$\frac{P_B}{\rho g}+\frac{(3.014)^2}{2\times9.81} = \frac{(27.129)^2}{2\times9.81}+0.5$$

$$\frac{P_B}{\rho g} = 37.548$$

$P_B = 37.548\times9810$

$P_B = 368.345kPa$

52. (C)

$$\frac{hd}{k} = 0.52\left[\frac{\beta g\rho^2 d^3\Delta t}{\mu^2}\right]^{0.25}$$

$$\therefore \quad \frac{h_1}{h_2} = \left(\frac{d_2}{d_1}\right)^{0.25} = \left(\frac{20}{5}\right)^{0.25}$$

$$\therefore \quad h_2 = \frac{6000}{\sqrt{2}} = 3000\sqrt{2}$$

$= 4242W/m^2-K$

53. (59.472 W)

$Nu = 39 = \dfrac{hL}{K}$

$h = \dfrac{39K}{L}$

$h = \dfrac{39\times0.03}{0.15}$

$h_c = 7.8W/m^2K$

$Q_{conv} = 2\left[h_c A(T_o-T_\infty)\right] = 28.08$

$Q_{rad} = 2\left[h_r A(T_s-T_\infty)\right] = 31.39$

$Q_{total} = Q_{conv}+Q_{rad}$

$Q_{total} = 59.472W$

54. (0)

The system is statically balanced as,

$27\times10.5-27\times10.5+W\times7-W\times7 = 0$

Let us check whether the system is dynamically balanced or not.

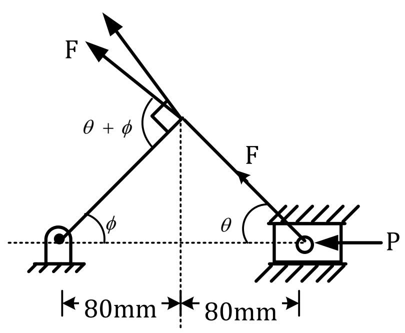
$(27\times10.5\times5.5)-(27\times10.5\times15)$

$+(64.125\times7\times14)-(64.125\times7\times8)$

$= 0$

Hence system is dynamically balanced.

55. (1.62 – 1.68)



Now, $\tan\theta = \tan\phi = \dfrac{55}{80}$

$\Rightarrow \quad \theta = \phi = 34.51^0$

$\Rightarrow \quad F\cos\theta = P$

$$\Rightarrow \quad F = \frac{15}{\cos(34.51)} = 18.203\,kN$$

Now, $F\sin(\theta+\phi)\times r = M$

$$\therefore \quad M = 18.203\sin(2\times 34.51)\times \frac{\sqrt{80^2+55^2}}{1000}$$

$$= 0.016996\times 97.0824 = 1.65\,kNm$$

56. (D)

57. $\left(\frac{10\pi}{13}\right)$

58. (B)

Salary	No. of employees	Cumulative
20000	45	45
30000	25	70
40000	20	90
60000	8	98
150000	2	100

Median $= \frac{100+1}{2} = 50.5$

From cumulative column,

Median salary = 30000

59. (A)

60. (D)

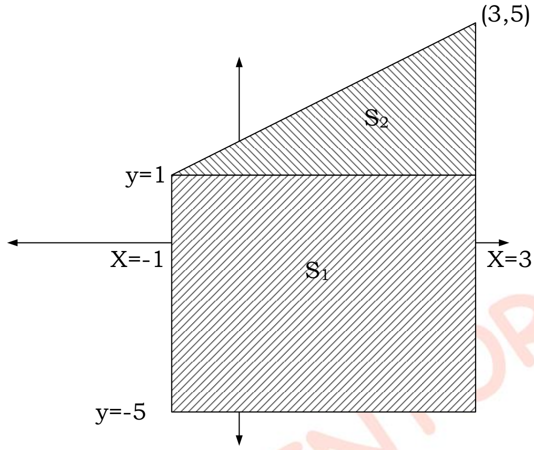
61. (A)

62. (A)

5 0 0 0 0
4 8 8 8 9
1 1 1 1

$sum = 0+0+0+0+8 = 8$

63. (C)



$$S = S_1 + S_2 = 6\times 4 + \frac{1}{2}\times 4\times 4 = 32$$

64. (B)

65. (C)

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