DETAILED SOLUTIONS

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ESE 2023 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 22

Full Syllabus Test 6 : Paper-II

1. (b)	26. (a)	51. (a)	76. (a)	101. (d)	126. (d)
2. (c)	27. (d)	52. (d)	77. (c)	102. (c)	127. (b)
3. (d)	28. (c)	53. (d)	78. (b)	103. (d)	128. (c)
4. (b)	29. (a)	54. (c)	79. (b)	104. (d)	129. (b)
5. (b)	30. (c)	55. (a)	80. (d)	105. (b)	130. (a)
6. (b)	31. (a)	56. (d)	81. (d)	106. (c)	131. (d)
7. (d)	32. (d)	57. (c)	82. (b)	107. (c)	132. (c)
8. (b)	33. (a)	58. (d)	83. (b)	108. (c)	133. (b)
9. (d)	34. (d)	59. (c)	84. (c)	109. (c)	134. (d)
10. (b)	35. (a)	60. (b)	85. (b)	110. (b)	135. (d)
11. (b)	36. (d)	61. (a)	86. (d)	111. (c)	136. (d)
12. (b)	37. (c)	62. (b)	87. (a)	112. (b)	137. (b)
13. (b)	38. (d)	63. (a)	88. (d)	113. (d)	138. (c)
14. (d)	39. (a)	64. (c)	89. (b)	114. (b)	139. (d)
15. (d)	40. (d)	65. (b)	90. (c)	115. (c)	140. (c)
16. (b)	41. (b)	66. (d)	91. (d)	116. (a)	141. (a)
17. (b)	42. (d)	67. (c)	92. (d)	117. (d)	142. (d)
18. (a)	43. (a)	68. (a)	93. (c)	118. (b)	143. (c)
19. (d)	44. (c)	69. (b)	94. (b)	119. (d)	144. (c)
20. (a)	45. (b)	70. (b)	95. (c)	120. (b)	145. (b)
21. (c)	46. (d)	71. (b)	96. (b)	121. (d)	146. (a)
22. (c)	47. (b)	72. (a)	97. (b)	122. (d)	147. (a)
23. (b)	48. (c)	73. (a)	98. (b)	123. (b)	148. (b)
24. (b)	49. (c)	74. (c)	99. (c)	124. (b)	149. (d)
25. (d)	50. (d)	75. (c)	100. (d)	125. (c)	150. (c)

DETAILED EXPLANATIONS

1. (b)

Given : T_L = –9°C = 264 K, T_H = 24°C = 297 K

$$(COP)_{actual} = \frac{1}{4}(COP)_{ideal} = \frac{1}{4}\left(\frac{T_L}{T_H - T_L}\right)$$

$$= \frac{1}{4} \times \left(\frac{264}{297 - 264}\right)$$

or $$\frac{R.C.}{\dot{p}} = \frac{1}{4} \times \frac{264}{33}$$

∴ $$\dot{p} = \frac{4 \times 33 \times 20}{264} = 10 \text{ kW}$$

2. (c)

Since, $$1 + (COP)_{ref} = \frac{1}{\eta_E}$$

or $$(COP)_{ref} = \frac{1}{0.6} - 1 = \frac{2}{3}$$

∴ $$HRR = 1 + \frac{1}{(COP)_{ref}} = 1 + \frac{1}{\frac{2}{3}}$$

$$HRR = 2.5$$

5. (b)

For an adiabatic nozzle,

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$$

$$C_p \times T_1 + \frac{V_1^2}{2} = C_p \times T_2 + \frac{V_2^2}{2}$$

∴ $$C_p(T_2 - T_1) = \frac{V_1^2 - V_2^2}{2000}$$

$$1 \times (T_2 - 600) = \frac{25^2 - 120^2}{2000}$$

∴ $$T_2 - 600 = -6.88$$

∴ $$T_2 = 593.11 \text{ K}$$

6. (b)

Energy balance gives, $$\dot{E}_{lost} = hA(T_b - T_0)$$

∴ $$700 - 660 = 0.2 \times 10 \times (T_b - 300)$$

$$40 = 2 \times (T_b - 300)$$

$$\therefore \quad T_b = 300 + 20 = 320 \text{ K}$$

$$\therefore \quad \text{Irreversibility, } I_{\text{G.B.}} = T_0 \times \left(\frac{Q}{T_b}\right)$$

$$I_{\text{G.B.}} = 300 \times \frac{40}{320} = 37.5 \text{ kW}$$

8. (b)

Planck's equation is the basis of all other radiation equation, and is given by

$$E(T, \lambda) = \frac{2\pi C_1}{\lambda^5 \left(e^{C_2/\lambda T} - 1\right)}$$

9. (d)

$$\text{Shape factor, } f_{ij} \propto \frac{A}{l^2}$$

More will be the surface area and lower the distance between the surface. Shape factor will be more.

10. (b)

Cooling depends on the temperature difference of body and surrounding. More will be the difference the lesser will be time to cool the body. Initially the cooling will be faster, as this difference of temperature will reduce, the time taken to cool further will increase for same temperature reduction.

11. (b)

$$\text{Nu} = 0.52\ (\text{Gr.Pr})^{0.25}$$

$$\frac{hD}{k_f} = 0.52\left[\frac{g\beta\Delta TD^3}{\nu^2}.\frac{\mu c_p}{k}\right]^{0.25}$$

$$\Rightarrow \quad h \propto D^{0.75}.\ D^{-1}$$

$$\Rightarrow \quad h \propto \frac{1}{D^{0.25}}$$

$$\Rightarrow \quad \frac{h_2}{h_1} = \left(\frac{D_1}{D_2}\right)^{0.25}$$

$$\Rightarrow \quad h_2 = \left(\frac{5}{10}\right)^{0.25} \times 6000 = \left(\frac{1}{2}\right)^{\frac{1}{4}} \times 6000$$

$$\Rightarrow \quad h_2 = 5045.37 \text{ kJ/m}^2\text{-hr-K}$$

12. (b)

$$(\text{Pr})^{1/3} = \frac{\delta}{\delta_t}$$

13. (b)

Balancing energy,

$$(mc_p)_c [T_{ce} - T_{ci}] = (mc_p)_h [T_{hi} - T_{he}]$$

$$C_c[110 - 30] = C_h[180 - 160]$$

$$C_c 80 = 20C_h$$

$$\text{Capacity ratio} = \frac{C_c}{C_h} = 0.25$$

15. (d)

$$Q_{in} = Q_{rej}$$

$$UA(T_{amb} - T_{room}) = (COP)_R \times \dot{w}$$

$$150 \times 20(320 - 300) = \frac{300}{20} \times \dot{w}$$

$$\frac{150 \times 20 \times 20 \times 20}{300} = \dot{w}$$

$$\dot{w} = 4000 \text{ W} = 4 \text{ kW}$$

16. (b)

VARS systems are environment friendly as they run on low grade energy i.e. heat. They have lower COP as compared to VCRS.

17. (b)

In large refrigeration plants, secondary refrigerants are used for carrying refrigeration from the plant room to the space where it is usually applied, instead of directly obtaining it by the evaporating refrigerant at the place of application. This is done in order to reduce the quantity of the refrigeration charge in the system and to reduce pressure losses in lines.

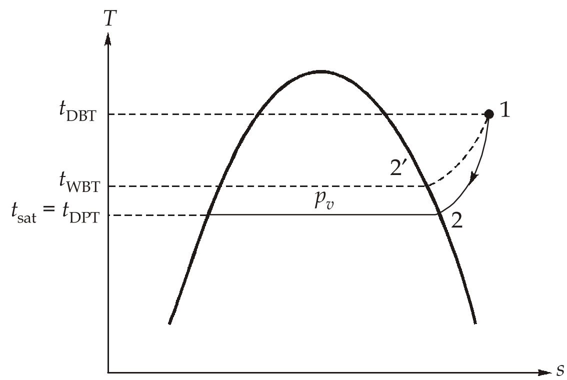
20. (a)

$$P_v = \frac{P \times \omega}{(0.622 + \omega)} = \frac{90 \times 0.004}{0.622 + 0.004}$$

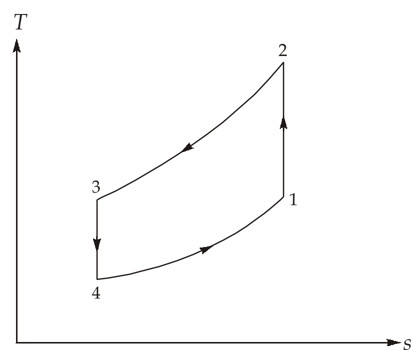
$$= 0.58 \text{ kPa}$$

$$\phi = \frac{0.58}{2.34} = 24.8\%$$

21. (c)



22. (c)



For isentropic compression and expansion,

$$\frac{T_2}{T_1} = \frac{T_3}{T_4}$$

$$T_2 = \frac{300}{200} \times 248 = 372 \text{ K}$$

$$w_{net} = c_p(T_2 - T_1) - c_p(T_3 - T_4)$$

$$= 1 \times (372 - 248) - 1 \times (300 - 200)$$

$$= 124 - 100 = 24 \text{ kJ/kg}$$

23. (b)

According to Trouton's law, for all substances

$$\frac{M h_{fg}}{T} = \text{Constant}$$

where, M = Molecular weight; h_{fg} = Latent heat of vaporization; T = Absolute boiling temperature

Since for a given application, the required evaporator temperature (i.e. its boiling temperature) would be same for each refrigerant,

$$Mh_{fg} = \text{Constant}$$

Thus, the refrigerant with lower molecular weight will have higher latent heat of vaporization.

24. (b)

$$C_F = 4a(1 - a)$$

$$\frac{d(C_F)}{da} = 4 - 8a = 0$$

$$a = \frac{1}{2}$$

26. (a)

$$I_{\text{ext.}} = I_{sc}\left[1 + 0.033\cos\left(\frac{360n}{365}\right)\right]$$

$$n = 365$$

$$I_{\text{ext.}} = 1367 \times [1 + 0.033] = 1412 \text{ W/m}^2$$

27. (d)

$$\frac{I_b'}{I_b} = \frac{\cos\theta_i}{\cos\theta_z}$$

$$\frac{I_b'}{I_b} = \frac{\cos 30°}{\cos 60°}$$

$$I_b' = \sqrt{3} \times I_b = \sqrt{3} \times 500$$

$$= 866 \text{ W/m}^2$$

28. (c)

Austenite FCC structure is formed when temperature is between 910°C and 1400°C.

29. (a)

The crystal structure of martensite is body centered tetragonal.

30. (c)

$$\text{Efficiency, } \eta = 1 - \frac{Q_{\text{rej}}}{Q_{\text{supp}}} = 1 - \frac{200}{500} = 0.6 \text{ or } 60\%$$

32. (d)

- Process annealing is carried out to remove effect of cold working and it to soften it for further plastic deformation.
- Since it is a subcritical annealing, cooling rate is of little importance.

35. (a)

Flowability of moulding sand first decreases and then increases if the water content is increased.

36. (d)

Assembly must have transition fit and H7/k6 is a transition fit.

37. (c)

Conditions that promote Chevron cracking are

- higher die angles.
- low extrusion ratios.
- impurities in work material.

38. (d)

By increasing back rake angle, chip flow will become easier hence drag between chip and tool will reduce.

39. (a)

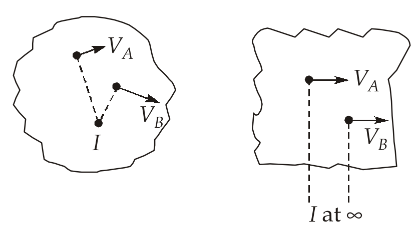
- The movement of jaws in their slots is not independent.
- It can not hold square bar.

40. (d)

$$f_m = f_t \times z \times N = 0.2 \times 16 \times 60 = 192 \text{ mm/min}$$

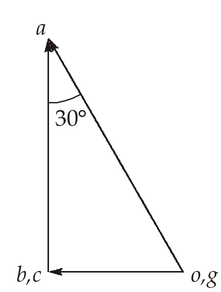
$$\text{MRR} = f_m wd = 192 \times 100 \times 5 = 96000 \text{ mm}^3\text{/min}$$

41. (b)



So, I centre can lie outside the body.

42. (d)



$$V_{ao} = \omega r = \frac{2\pi \times 180}{60} \times 15 = 90\pi \text{ cm/s}$$

$$V_{cg} = V_{ao} \sin 30° = 90\pi \times 0.5 = 45\pi \text{ cm/s}$$

45. **(b)**

In deltoid linkage, equal links are adjacent to each other and when longest link is fixed then crank rocker mechanism is obtained.

46. **(d)**

Other name of snap action mechanism is toggle mechanism.

47. **(b)**

$$\Delta E = \left(1 - \frac{t}{2s}\right)E_s = \left(1 - \frac{18}{180}\right)20000$$

$$= 18000 \text{ Nm}$$

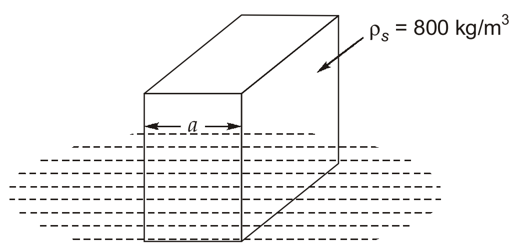
48. **(c)**

$$F_{un} = (1 - C)mr\omega^2\cos\theta$$

$$= \frac{1}{2} \times 20 \times 0.1 \times 20^2 \times \cos 60°$$

$$= 200 \text{ N}$$

49. **(c)**



$$m\ddot{x} + \rho A g x = 0$$

$$\rho_s \times a^3 \ddot{x} + \rho a^2 g x = 0$$

$$\omega_n = \sqrt{\frac{\rho a^2 g}{\rho_s a^3}} = \sqrt{\frac{1000 \times 0.098^2 \times 9.8}{800 \times 0.098^3}}$$

$$= 11.3 \text{ rad/s}$$

50. **(d)**

$$c_c = 2\xi\sqrt{k_t I} = 2\xi\sqrt{8.1 \times 10^5 \times 0.04}$$

$$= 2 \times 0.2 \times 900 \times 0.2$$

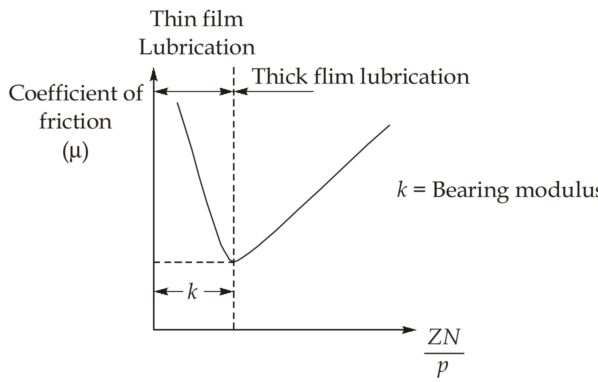
$$= 72 \text{ Nm-sec/rad}$$

51. (a)

$$h = \left(\frac{b}{a}\right)(r_2 - r_1)$$

$$= \left(\frac{40}{50}\right)(70 - 50) = 16 \text{ mm}$$

53. (d)



54. (c)

As the size of component increases the probability that a flow exist somewhere in component increases. Thus endurance limit reduces with increasing size of component.

55. (a)

$$k = \frac{Gd^4}{8D^3n}$$

$$= \frac{80 \times 10^3 \times 8^4}{8 \times 40^3 \times 8} = 80 \text{ N/mm}$$

56. (d)

$$\sigma_{mean} = \frac{150 + 100}{2} = 120 \text{ MPa}$$

$$\sigma_{amp} = \frac{150 - 100}{2} = 25 \text{ MPa}$$

As per Goodman criterion,

$$\frac{125}{500} + \frac{25}{225} = \frac{1}{N}$$

$$N = 2.77$$

57. (c)

In transverse fillet weld,

$$P_{st} = 0.828\, hl\tau$$

In parallel fillet weld,

$$P_{sp} = 0.707\, hl\tau$$

$$\frac{p_{st}}{p_{sp}} = \frac{0.828}{0.707} = 1.17$$

58. (d)

$$L_{90} = \left(\frac{C}{W}\right)^3 \times 10^6 \text{rev}$$

$$= \left(\frac{56}{7}\right)^3 \times 10^6 = 512 \times 10^6 \text{rev}$$

$$L_{50} = 5 \times 512 = 2560 \times 10^6 \text{ rev}$$

60. (b)

$$Q = \frac{2T_G}{T_G + T_P} = \frac{2 \times 400}{400 + 100} = 1.6$$

$$k = 0.16\left(\frac{BHN}{100}\right)^2 = 0.16 \times \left(\frac{300}{100}\right)^2 = 1.44$$

$$P_w = D_p bQk$$

$$P_w = 100 \times 50 \times 1.6 \times 1.44$$

$$= 11520 \text{ N}$$

62. (b)

$$N_t = \frac{\text{Sum of task times}}{\text{Cycle time}}$$

$$= \frac{17 + 16 + 13 + 15}{18} = \frac{61}{18} = 3.4$$

63. (a)

Machine utilization is reduced in group layout as compared to product layout.

65. (b)

For laminar flow in a horizontal pipe, the volume flow is given by

$$Q_{\text{laminar}} = \frac{\pi d^4}{128\mu}\left(\frac{\Delta P}{L}\right)$$

Since, ΔP, L and μ are same in small pipes, we can write,

$$\frac{Q_1}{Q_2} = \frac{d_1^4}{d_2^4}$$

$$\Rightarrow \quad \frac{4Q_2}{Q_2} = \frac{24^4}{d_2^4}$$

$$\Rightarrow \quad 4 = \frac{24^4}{d_2^4}$$

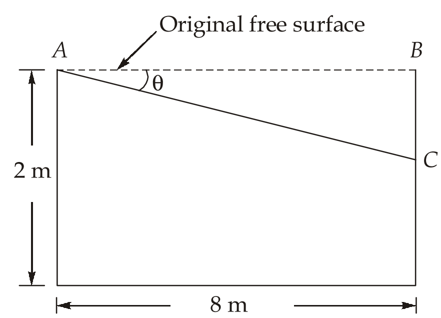
$$\Rightarrow \quad d_2 = \frac{24}{4^{1/4}} = \frac{24}{\sqrt{2}} = 12\sqrt{2} \text{ mm}$$

66. (d)

$$-40 \times 10^3 + 800 \times 10 \times h = 0$$

$$\therefore \quad h = \frac{40 \times 1000}{800 \times 10} = 5 \text{ m}$$

67. (c)



$$\tan\theta = \frac{a}{g} = \frac{2}{10} = 0.2$$

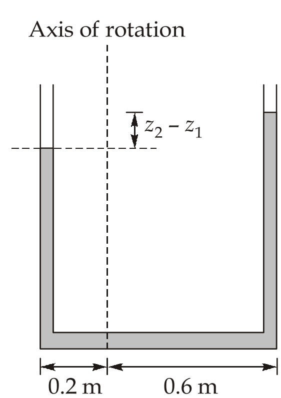
$$\text{Drop in surface} = 8\tan\theta = 8 \times 0.2 = 1.6 \text{ m}$$

$$\text{Volume of oil spilled} = 3 \times \text{Area of } ABC$$

$$= 3 \times \frac{1}{2} \times 1.6 \times 8 = 19.2 \text{ m}^3$$

68. (a)

The difference in elevation of the free surfaces in the two legs is given by



$$(z_2 - z_1) = \frac{\omega^2}{2g}\left(x_2^2 - x_1^2\right) \quad \text{...(i)}$$

where, $\omega = \frac{2\pi N}{60} = \frac{2 \times 22 \times 105}{7 \times 60} = 11$ rad/s

Putting the value of ω in equation (i)

$$\Rightarrow \quad z_2 - z_1 = \frac{\omega^2}{2g}\left(x_2^2 - x_1^2\right)$$

$$\Rightarrow \quad z_2 - z_1 = \frac{121}{20}\left(0.6^2 - 0.2^2\right)$$

$$\Rightarrow \quad z_2 - z_1 = \frac{121}{20} \times 0.32 = 1.94 \text{ m}$$

70. (b)

The drag coefficient for a laminar flow is given by,

$$C_D = \frac{1.328}{\text{Re}_L^{1/2}} \text{ or } C_D \propto L^{-1/2}$$

Thus, drag force F

$$F = \frac{\text{Constant}}{\sqrt{L}} \times L^2$$

$$\therefore \quad F_{\text{I}} = \frac{\text{Constant}}{\sqrt{L}} \times L^2$$

$$\therefore \quad F_{\text{II}} = \frac{\text{Constant}}{\sqrt{2L}} \times 4L^2$$

$$\therefore \quad \frac{F_{\text{I}}}{F_{\text{II}}} = \frac{L^2}{\sqrt{L}} \times \frac{\sqrt{2L}}{4L^2}$$

$$= \left(\frac{1}{4}\right) \times \sqrt{2} = \frac{1}{2\sqrt{2}}$$

71. (b)

$$u = 2y^2 + z^2$$
$$v = x^2 + z^2$$
$$w = 2x + y$$

$$\therefore \quad \omega_x = \frac{1}{2}\left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\right) = \frac{1}{2}(1 - 2z)$$

$$= \frac{1}{2}(1 - 2 \times 4) = -3.5$$

$$\therefore \quad \omega_y = \frac{1}{2}\left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}\right) = \frac{1}{2}(2z - 2)$$

$$= \frac{1}{2} \times (2 \times 4 - 2) = 3$$

$$\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$$

$$= \frac{1}{2}(2x - 4y) = \frac{1}{2}(4 - 12) = -4$$

72. (a)

For free vortex,

$$v_1 r_1 = v_2 r_2$$

$$\Rightarrow \quad 10 \times 0.1 = v_2 \times 0.2$$

$$\Rightarrow \quad v_2 = 5 \text{ m/s}$$

Also,
$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$\Rightarrow \quad 200 \times 10^3 + \frac{1}{2} \times 1000 \times 10^2 = P_2 + \frac{1}{2} \times 1000 \times 25$$

$$\Rightarrow \quad 200000 + 50000 = P_2 + 12500$$

$$\Rightarrow \quad P_2 = 237500 \text{ Pa} = 237.5 \text{ kPa}$$

73. (a)

The EGL is always a distance $\frac{V^2}{2g}$ above the HGL. These two curves approach each other as the velocity decreases and they diverge as the velocity increases. The height of the HGL decreases as the velocity increases, and vice versa.

74. (c)

For the flow of fluids through pipes only viscous and inertia forces are predominant, Reynolds model law is the criterion for similarity.

$$\left(\frac{VD}{\nu}\right)_m = \left(\frac{VD}{\nu}\right)_p$$

$$\Rightarrow \quad \frac{10 \times 200}{1.2 \times 10^{-6}} = \frac{V \times 100}{3.6 \times 10^{-6}}$$

$$\Rightarrow \quad V = \frac{10 \times 200 \times 3}{100} = 60 \text{ m/s}$$

75. (c)

Assuming datum to be passing through the lower point, we have

$$h_1 - h_2 = \left(\frac{P_1}{\rho g} + 0\right) - \left(\frac{P_2}{\rho g} + 40 \sin 30°\right)$$

$$= \left(\frac{800 \times 10^3}{10000}\right) - \left(\frac{500 \times 10^3}{10000} + 20\right)$$

$$= 80 - 70 = 10 \text{ m}$$

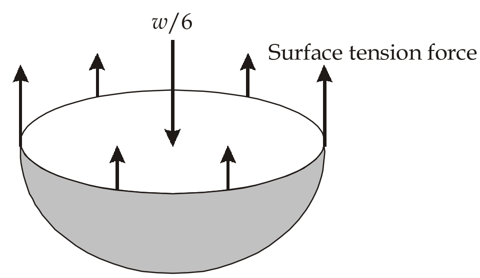
$\therefore$ Average shear stress at wall of the pipe is given by,

$$\tau = (\rho g)\left(-\frac{\partial h}{\partial x}\right)\times\frac{R}{2}$$

$$\tau = (10000)\left(\frac{10}{40}\right)\times 0.025$$

$$\tau = 62.5 \text{ N/m}^2$$

76. (a)



The figure shows one of the legs of the insect landing upon the water surface.

Therefore, $$T\times 2\pi r = \frac{w}{6}$$

$\Rightarrow$ $$w = 12\,T\pi r$$

77. (c)

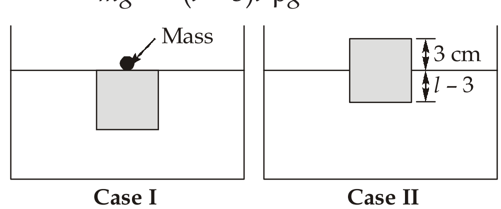
Let m be the mass of the cube,

For case I

$$(m+300)g = l^3\rho g \quad \text{...(i)}$$

For case II,

$$mg = (l-3)l^2\rho g \quad \text{...(ii)}$$



Subtracting (ii) from (i), we get

$$300 = l^3\rho - [(l-3)l^2\rho]$$

$\Rightarrow$ $$300 = l^3\rho - l^3\rho + 3l^2\rho$$

$\Rightarrow$ $$300 = 3l^2\rho$$

$\Rightarrow$ $$l^2 = 100$$

$\Rightarrow$ $$l = 10 \text{ cm}$$

78. (b)

Since,
$$\frac{P_1}{D_1^2 H_1^{3/2}} = \frac{P_2}{D_2^2 H_2^{3/2}}$$

$$\Rightarrow \quad \frac{50}{D_1^2 \times 25^{3/2}} = \frac{60}{D_2^2 \times 36^{3/2}}$$

$$\Rightarrow \quad \frac{50}{D_1^2 \times 125} = \frac{60}{D_2^2 \times 216}$$

$$\Rightarrow \quad \left(\frac{D_2}{D_1}\right)^2 = \frac{60}{216} \times \frac{125}{50} = \frac{25}{36}$$

$$\therefore \quad \text{Scale ratio, } \frac{D_2}{D_1} = \frac{5}{6} = 0.83$$

Also,
$$\frac{N_1 D_1}{\sqrt{H_1}} = \frac{N_2 D_2}{\sqrt{H_2}}$$

$$\Rightarrow \quad \frac{200 \times D_1}{\sqrt{25}} = \frac{N_2 \times D_2}{\sqrt{36}}$$

$$\Rightarrow \quad \frac{200}{5} \times D_1 = \frac{N_2 \times D_2}{6}$$

$$\Rightarrow \quad N_2 = \frac{(40) \times 6 \times 6}{5} = 288 \text{ rpm}$$

79. (b)

$$Q_{\text{th}} = \frac{ALN}{60}$$

$$= \left(\frac{22}{7 \times 4}\right) \times \frac{(0.4)^2}{60} \times 56 \times \frac{100}{100} = 11.73 \text{ L/s}$$

$$\%\text{slip} = \frac{Q_{th} - Q_a}{Q_{th}} \times 100$$

$$= \frac{11.73 - 11}{11.73} \times 100$$

$$= 6.22\%$$

80. (d)

Ideal power produced by one turbine is

$$W_{\text{ideal}} = \rho Q g H$$
$$= 1000 \times 10 \times 20 \times 300$$
$$= 60 \text{ MW}$$
$$W_{\text{actual}} = \eta_{\text{turbine}} \times \eta_{\text{generation}} \times W_{\text{deal}}$$
$$= 0.95 \times 0.9 \times 60$$
$$= 51.3 \text{ MW}$$
$$\text{Total power produced} = 10 \times 51.3 = 513 \text{ MW}$$

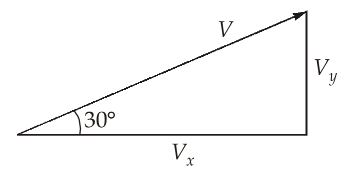
81. (d)

$$k_u = \frac{U}{\sqrt{2gH}}$$

$$\Rightarrow \quad U = k_u\sqrt{2gH} = 0.4\sqrt{2\times 10\times 1280}$$
$$= 0.4 \times 160 = 64 \text{ m/s}$$

82. (b)

Velocity 3 second before and 3 second after the highest point will be same in magnitude but opposite in direction.



$$\therefore \quad V_y = 3 \times 10 = 30 \text{ m/s}$$

$$\therefore \quad \frac{V_y}{V_x} = \frac{V_y}{\tan 30°} = \frac{30}{1/\sqrt{3}} = 30\sqrt{3} \text{ m/s}$$

∴ At highest point, velocity will be in horizontal direction only.

$$\therefore \quad V_x = 30\sqrt{3} \text{ m/s}$$

83. (b)

For minimum number of jumps, the range must be maximum,

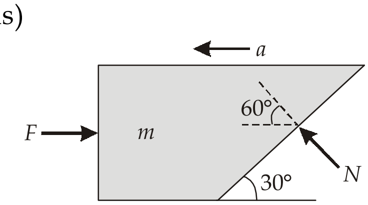
$$R_{max} = \frac{U^2}{g} = \frac{25}{10} = 2.5 \text{ m}$$

$$\therefore \quad \text{Therefore, number of jumps} = \frac{\text{Distance}}{R_{max}} = \frac{20}{2.5} = 8$$

84. (c)

Acceleration of the two mass system is,

$$a = \frac{F_{net}}{3m} = \frac{3F - F}{3m} = \frac{2F}{3m} \text{(leftwards)}$$



FBD of block *A*

For equilibrium,

$$N\cos 60° - F = ma$$

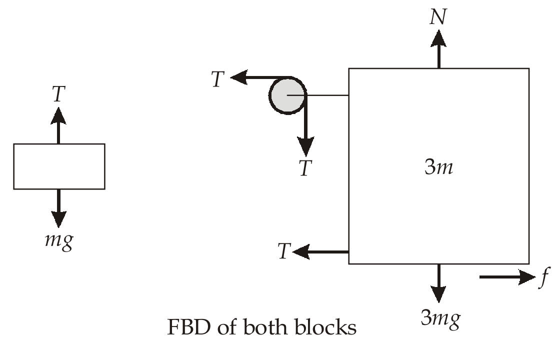
$$\therefore \quad \frac{N}{2} - F = m \times \frac{2F}{3m}$$

$$\therefore \quad \frac{N}{2} - F = \frac{2F}{3}$$

$$\therefore \quad \frac{N}{2} = \frac{5F}{3}$$

$$\Rightarrow \quad N = \frac{10F}{3}$$

85. (b)



FBD of both blocks

In equilibrium,

$$T = mg$$

$\therefore$ $$N = T + 3mg = 4mg$$

$\therefore$ $$f = 2T = 2mg$$

In limiting case,

$$f = f_{max} = \mu N$$

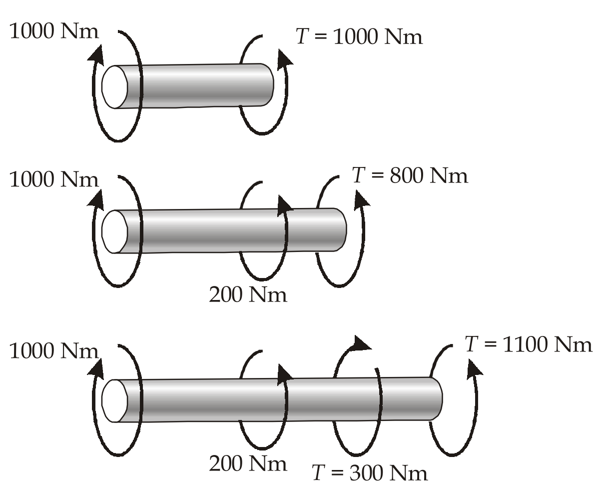
$\Rightarrow$ $$2mg = \mu 4mg$$

$\Rightarrow$ $$\mu = \frac{2mg}{4mg} = 0.5$$

86. (d)

The block will begin to slide when the angle of inclination is greater than the angle of repose. The motion has nothing to do with the mass of the blocks.

87. (a)



Maximum shear stress is given by

$$\tau_{max} = \frac{T_{max} R}{J}$$

$$= \frac{7 \times 1100 \times 0.02 \times 32}{22 \times (2.56 - 0.81)10^{-6}} = \frac{7 \times 1100 \times 0.02 \times 32}{22 \times 1.75 \times 10^{-6}}$$

$$= 128 \times 10^{6} \text{ Pa} = 128 \text{ MPa}$$

88. (d)

Since, it is a composite bar, so elongation in both of them will be same.

$$\Delta_s = \Delta_{al}$$

$$\Rightarrow \quad \frac{\sigma_s L}{E_s} = \frac{\sigma_{al} L}{E_{al}}$$

$$\Rightarrow \quad \frac{\sigma_s}{4E_{al}} = \frac{\sigma_{al}}{E_{al}}$$

$$\Rightarrow \quad \sigma_s = 4\sigma_{al}$$

∴ Now, external force will be resisted by both the bars

$$P = \sigma_s A_s + \sigma_{al} A_{al}$$

$$\Rightarrow \quad 12000 = (4\sigma_{al} + \sigma_{al}) \times 400 \times 10^{-6}$$

$$\Rightarrow \quad \sigma_{al} = \frac{12000}{400 \times 5} \times 10^6 = 6 \text{ MPa}$$

$$\Rightarrow \quad \sigma_s = 4 \times 6 = 24 \text{ MPa}$$

89. (b)

Till proportional limit, the stress is directly proportional to strain and in this region Hooke's law is valid.

90. (c)

Comparing deflections in both bars:

$$\Delta_{steel} = \Delta_{aluminium}$$

$$\Rightarrow \quad \frac{4PL_s}{\pi d_s^2 E_s} = \frac{4PL_{al}}{\pi E_{al} d_1 d_2}$$

$$\Rightarrow \quad \frac{L_s}{d_s^2 E_s} = \frac{L_{al}}{d_1 d_2 E_{al}}$$

$$\Rightarrow \quad \frac{5}{15 \times 15 \times 3} = \frac{10}{50 \times d_2}$$

$$\Rightarrow \quad d_2 = \frac{10 \times 15 \times 15 \times 3}{50 \times 5} = 27 \text{ mm}$$

91. (d)

$$[E] = \frac{[\text{Stress}]}{[\text{Strain}]} = \frac{ML^{-1}T^{-2}}{M^0L^0T^0} = ML^{-1}T^{-2}$$

92. (d)

There is no neck formation of the specimen of a brittle material and the rupture occurs along a perpendicular surface to the load indicating that normal stresses are primarily responsible for failure of brittle materials.

93. (c)

$$\sigma = \frac{W}{A}\left(1+\sqrt{1+\frac{2hAE}{WL}}\right)$$

$$\sigma = \frac{12000}{2400\times10^{-6}}\left(1+\sqrt{1+\frac{2\times40\times10^{-3}\times2400\times10^{-6}\times20\times10^{9}}{12000\times4}}\right)$$

$$\sigma = \frac{12000}{2400\times10^{-6}}\left(1+\sqrt{81}\right)$$

$$\sigma = 50\text{ MPa}$$

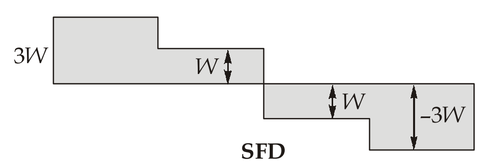
$$\therefore \quad \text{Strain energy stored} = \frac{\sigma^2}{2E}\times\text{Volume}$$

$$= \frac{2500\times10^{12}}{2\times20\times10^{9}}\times2400\times10^{-6}\times4$$

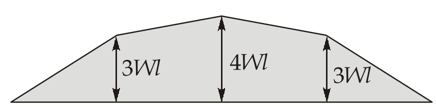
$$= 600\text{ Joules}$$

94. (b)

Since the forces are symmetrically distributed, reactions at the supports will be 3W on each support.



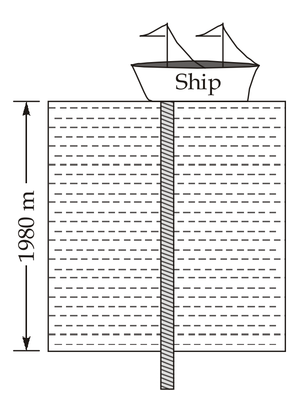
SFD



BMD

$$\therefore \quad \text{Ratio} = \frac{BM_{max}}{SF_{max}} = \frac{4Wl}{3W} = \frac{4l}{3}$$

96. (b)



$$\theta = \frac{TL}{GJ} \Rightarrow T = \frac{\theta GJ}{L}$$

$$\Rightarrow \qquad \tau = \frac{Tr}{J} = \frac{G\theta J}{L} \times \frac{r}{J} = \frac{G\theta r}{L} \qquad \text{...(i)}$$

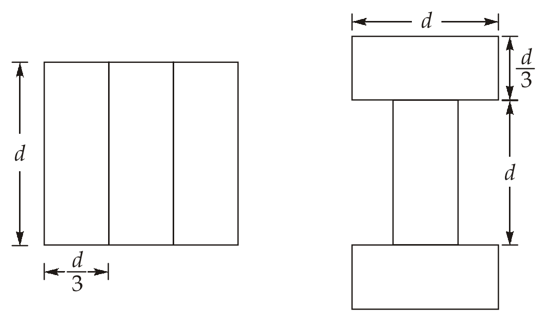
Now, $\theta = 3 \text{ revolution} = 3 \times 2\pi \text{ radians}$

$$= \frac{132}{7} \text{ radians}$$

Putting the given values in equation (i),

$$\tau = \frac{84 \times 10^9 \times 132 \times 0.1}{7 \times 1980} = 80 \text{ MPa}$$

97. (b)



$$I_I = \frac{d^4}{12}$$

$$I_{II} = \frac{\frac{d}{3} \times d^3}{12} + \left\{ \frac{d \times \left(\frac{d}{3}\right)^2}{12} + d \times \frac{d}{3}\left(\frac{2d}{3}\right)^2 \right\} \times 2$$

$$= \frac{d^4}{36} + \left\{ \frac{d^4}{324} + \frac{4d^4}{27} \right\} \times 2$$

$$= \frac{d^4}{36} + \frac{98d^4}{324} = \frac{107d^4}{324}$$

Now, $P_{cr} \propto I$

$$\therefore \qquad \frac{P_I}{P_{II}} = \frac{I_I}{I_{II}} = \frac{1}{12} \times \frac{324}{107} = \frac{27}{107}$$

100. (d)

For water, $T_{c_1} - T_{c_2} = \frac{42}{4.2} = 10°\text{C}$

or $T_{c_2} = 32 - 10 = 22°\text{C}$

$\therefore$ Approach $= T_{c_2} - T_{wbt_1}$

$= 22 - 15 = 7°\text{C}$

and range $= T_{c_1} - T_{c_2} = 32 - 22°\text{C} = 10°\text{C}$

101. (d)

$$1 \text{ atm} = 76 \text{ cm Hg}$$

$$\therefore \quad P_{sat} = 0.056 \text{ bar} = 4.2 \text{ cm Hg}$$

$$P_{abs} = 75.5 - 70 = 5.5 \text{ cm Hg}$$

Vacuum gauge corrected to standard atmosphere = 76 – 5.5 = 70.5 cm Hg

$$\therefore \text{ Vacuum efficiency} = \frac{\text{Vacuum produced by steam at condenser inlet}}{\text{Barometric pressure – Saturation pressure at exhaust steam pressure}}$$

$$\therefore \quad \text{Vacuum efficiency} = \frac{70.5}{76 - 4.2} = 0.9818 \text{ or } 98.18\%$$

$$\simeq 98.2\%$$

102. (c)

Soot blowers are devices that direct a high pressure fluid (steam or water) onto heat transfer surfaces to remove ash or slag deposits.

103. (d)

In pulverized coal firing system, greater surface area per unit mass of coal allows faster combustion reactions because more carbon becomes exposed to heat and oxygen. This reduces the excess air needed to complete combustion. This also reduces the dry exhaust loss through chimney and raises the steam generator efficiency.

105. (b)

In many cases, the power available from the back pressure turbine through which the whole of the heating steam flows is appreciably less than that required in a factory. This may be due to relatively high pressure, or small heating requirements or both. Pass-out turbines are employed in these cases, where a certain quantity of steam is continuously extracted from the turbine at an intermediate stage for heating purposes at the desired temperature and pressure.

108. (c)

- Statement 1 is correct for external irreversibility.
- Large pinch-point temperature difference causes better heat transfer which results in low surface area of boiler.

109. (c)

Specific heat of liquid should be low.

110. (b)

$$\text{Heat rate, HR} = 5$$

$$5 = \frac{Q_S}{Q_S - Q_R}$$

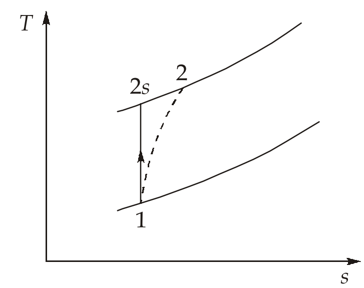
$$5Q_S - 5Q_R = Q_S$$

$$\therefore \quad Q_R = \frac{4Q_S}{5}$$

$$\because \quad Q_S = 2500 \text{ kJ/kg}$$

$$\therefore \quad Q_R = \frac{4 \times 2500}{5} = 2000 \text{ kJ/kg}$$

111. (c)



$$\eta_{isen,c} = \frac{T_2 - T_1}{T_{2s} - T_1}$$

$$\therefore \quad T_2 = T_1 + \frac{T_{2s} - T_1}{\eta_{isen.c}}$$

$$900 = 300 + \frac{T_{2s} - 300}{0.9}$$

$$\therefore \quad T_{2s} = 300 + 600 \times 0.9$$

$$= 840 \text{ K}$$

Now, for isentropic process,

$$\frac{P_2}{P_1} = \left(\frac{T_{2s}}{T_1}\right)^{\frac{\gamma}{\gamma - 1}}$$

$$P_2 = 1 \times \left(\frac{840}{300}\right)^{\frac{1.5}{1.5-1}} = 21.95 \text{ bar} \simeq 22 \text{ bar}$$

112. (b)

$$\text{Mole fraction of } N_2 = 1 - 0.15 - 0.05 = 0.8$$

$$\therefore \quad \text{Partial pressure of } N_2, P_v = 0.8 \times 10 = 8 \text{ bar} = 800 \text{ kPa}$$

114. (b)

$$\text{Solar time} = \text{Watch time} + 4(L_{local} - L_{standard})$$

$$= 1300 + 4(77.5 - 82.5) = 1300 - 20$$

$$= 1240 \text{ hours}$$

$$\therefore \quad \text{Hour angle, } \omega = 15(\text{Solar time} - 1200)$$

$$= 15(1240 - 1200)$$

$$= 15 \times \frac{40}{60} = 10°$$

115. (c)

Spring tides or maximum range is reached when Sun, Moon and Earth in a line.

116. (a)

Using power law,

$$\frac{V_1}{V_2} = \left(\frac{z_1}{z_2}\right)^{\alpha}$$

or

$$\frac{V_1}{5} = \left(\frac{384}{3}\right)^{1/7}$$

$$V_1 = 5 \times (128)^{1/7} = 5 \times 2 = 10 \text{ m/s}$$

121. (d)

Closed loop control system differ from open-loop systems by having a feedback device and an error detector. So, any change in the system is automatically taken care of.

122. (d)

In active transducers, auxiliary sources of power supply are a major part of the output power while input signal supplies only an insignificant portion. They are also known as self-generating transducers. e.g. techogenerators, thermocouples, photovoltaic cells etc.

123. (b)

$$\text{Average resolution} = \frac{16}{800} = 0.02\text{ V}$$

124. (b)

$$\text{Span of thermometer} = 500 - 400 = 100°\text{C}$$

$$\text{Maximum static error} = \frac{\pm 0.5 \times 100}{100} = \pm 0.5°\text{C}$$

125. (c)

In differential amplifiers, the output is proportional to the difference of the two inputs, whereas summing amplifier provides linear sum of input signals.

126. (d)

The sequence valve is used in a pneumatic circuit for switching operations depending upon a preset pressure. The sequence valve opens once its inlet pressure rises above a preset pressure. The signal output is generated only after the required operating pressure has been reached.

127. (b)

We know that,

$$\text{Step angle} = \frac{360°}{\text{Number of steps per revolution}}$$

$$\therefore \quad \text{Number of steps per revolution} = \frac{360°}{15} = 24\text{ steps}$$

$$\therefore \quad \text{Input pulse rate} = \frac{24 \times 600}{60} = 240\text{ pulses/sec}$$

130. (a)

If the anode is smaller in comparison to the cathode, the attack on anode will be more, but if the size of the anode is bigger, then the situation is reversed. A steel bolt in an aluminium plate wherein aluminium becomes anode, anode plate is large in comparison to steel bolt (cathode) and hence attack will be less.

132. (c)

Cartridge brass consist of 30% zinc and 70% copper, it has applications in making cartridge cases, head lamp reflectors, fasteners, springs plumbing accessories.

135. (d)

An economizer is a valve which remains close at normal cruise operation and gets opened to supply rich mixture at full throttle operation, it regulates the additional fuel supply during the full throttle operation.

136. (d)

Major advantages of fuel injection in an SI engine are:

1. Increased volumetric efficiency.
2. Better thermal efficiency.
3. Lower exhaust emissions.
4. High quality fuel distribution.

The use of petrol injection is limited by its high initial cost, complex design and increased maintenance requirements.

137. (b)

Fuel consumed per hour,

$$\dot{m}_f = \text{bsfc} \times \text{B.P.} = 200 \times 10^{-3} \times 150 = 30 \text{ kg/hour}$$

$$\therefore \quad \frac{\dot{m}_f}{\text{Cylinder}} = \frac{30}{6} = 5 \text{ kg/hour}$$

$$\therefore \quad \frac{\dot{m}_f}{\text{Cycle}} = \frac{5/60}{3000/2} = 5.55 \times 10^{-5} \text{ kg}$$

142. (d)

The main advantage of a centrifugal pump is that its discharging capacity is very much greater than that of a reciprocating pump which can handle relatively small quantity of liquids only. A centrifugal pump can be used for lifting highly viscous liquids such as oils, muddy and sewage water, paper pulp, sugar molasses etc.

143. (c)

A submerged body whose center of gravity is directly above the centre of buoyancy is unstable, and any disturbance will cause the body to turn upside down.

144. (c)

Old clutches are designed by uniform wear theory and pressure is maximum at inner radius and minimum at outer radius of friction lining.

145. (b)

Sliding and turning motion in a screw pair are not independent so their degree of freedom is one.

146. (a)

Velocity of sliding is product of sum of angular velocities of mating gears and distance between pitch point and point of contact.

147. (a)

For welding metals of higher thermal conductivity, higher heat input is required. So a shielding gas with ability to withstand higher arc voltage should be used.

148. (b)

Invar has 36% nickel due to which it has low coefficient of thermal expansion.

149. (d)

In stall regulated machines, blades are fixed but twist and thickness are designed in a manner to maintain speed constant.

150. (c)

Isentropic lines become flatter on p-h curve when evaporator pressure is decreased. So effect of decreasing evaporator pressure is more severe.