DETAILED SOLUTIONS

MADE EASY

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ESE 2023 : Prelims Exam
CLASSROOM TEST SERIES
MECHANICAL ENGINEERING
Test 18

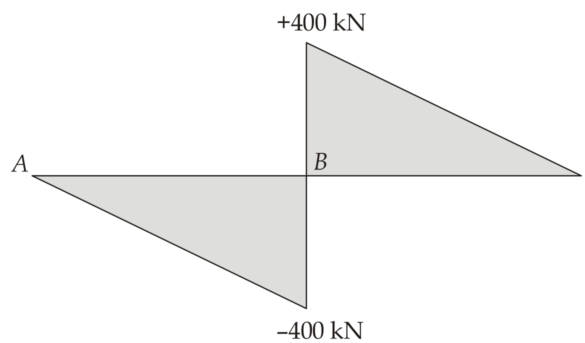
Full Syllabus Test 2 : Paper-II

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

DETAILED EXPLANATIONS

1. (b)

The shear force diagram of the beam can be drawn as



Since, the given cross-section is rectangular.

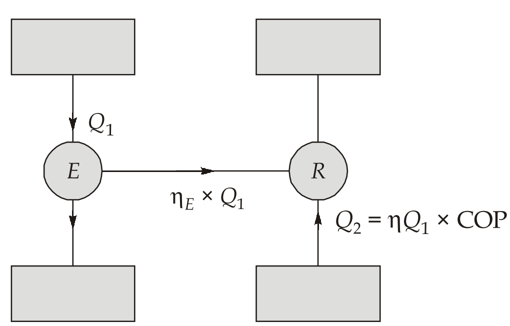
$$\tau_{max} = 1.5\tau_{av}$$

$$= 1.5\frac{F}{\text{Area}}$$

$$= 1.5 \times \frac{400 \times 10^3}{0.4 \times 0.15} = 10 \text{ MPa}$$

2. (d)

Given : $\eta = 0.6$, COP = 4, $Q_2 = 1$ kJ



∴ Heat input to the engine is given by,

$$Q_1 = \frac{Q_2}{\eta_E \times COP}$$

$$Q_1 = \frac{1}{0.6 \times 4} = 0.41 \text{ kJ}$$

3. (b)

$$(\text{COP})_{\text{rev}} = \frac{T_2}{T_1 - T_2} = \frac{243}{324 - 243} = 3$$

$$\eta_{\text{ref}} = \frac{COP}{(COP)_{rev}}$$

$$\therefore \quad COP = 0.8 \times 3 = 2.4$$

$$\therefore \quad W = \frac{Q_2}{COP} = \frac{2.4}{2.4} = 1 \text{ kW}$$

4. (d)

$$(\dot{m}C)_{\min} = 4 \times 4 = 16 \text{ kJ/K}$$

$$Q_{\max} = (\dot{m}C)_{\min}\left(t_{h_1} - t_{c_1}\right)$$

$$= 16 \times (90 - 10) = 1280 \text{ kJ}$$

$$Q_{oil} = 8 \times 2.5\left(90 - t_{h_2}\right) = 20\left(90 - t_{h_2}\right)$$

$$20\left(90 - t_{h_2}\right) = 1280$$

$$t_{h_2} = 26°C$$

5. (a)

The thickness of the film (δ) increases in the flow direction x because of continued condensation at the liquid-vapour interface.

The heat transfer from the vapour to the plate must occur through the film, which offers resistance to heat transfer. Thicker the film, larger is the thermal resistance and lower heat transfer rates.

6. (c)

$$\bar{h}_x = \frac{1}{x}\int_0^x h_x dx$$

$$\bar{h}_x = \frac{1}{x}\int_0^x x^{-\frac{1}{3}} dx$$

$$\bar{h}_x = \frac{1}{x}\frac{3}{2}x^{\frac{2}{3}} = \frac{3}{2}x^{-\frac{1}{3}}$$

$$\bar{h}_x = \frac{3}{2}x^{-\frac{1}{3}}$$

$$\frac{\bar{h}_x}{h_x} = \frac{3x^{-\frac{1}{3}}}{2x^{-\frac{1}{3}}} = \frac{3}{2}$$

7. (d)

$$\overline{Nu} = \frac{\bar{h}L_c}{k} \propto \left(\frac{\mu c_p}{k}\right)^{\frac{1}{3}}$$

$$\Rightarrow \quad \bar{h} \propto k^{\frac{2}{3}}$$

$$\bar{h} \propto (c_p)^{\frac{1}{3}}$$

$$\bar{h} \propto (U_\infty)^{\frac{4}{5}}$$

$$\bar{h} \propto \frac{1}{(L)^{\frac{1}{5}}}$$

8. (d)

$$\frac{q_{with\,shield}}{q_{without\,shield}} = \frac{1}{n+1}$$

$$q_{with\ shield} = \frac{1}{4} q_{without\ shield}$$

$$\%\text{reduction in heat transfer} = \frac{q_{without\,shields} - q_{with\,shield}}{q_{without\,shield}} \times 100$$

$$= \left(1 - \frac{1}{4}\right) \times 100$$

$$= \frac{3}{4} \times 100 = 75\%$$

9. (b)

By summation rule,

$$F_{11} + F_{12} + F_{13} + F_{14} = 1$$

$$0.2 + 0.3 + 0.3 + F_{14} = 1$$

$$F_{14} = 0.2$$

By reciprocity theorem,

$$F_{41}A_4 = A_1F_{14}$$

$$F_{41} = \frac{A_1}{A_4}F_{14} = \frac{4}{2} \times 0.2$$

$$= 0.40$$

10. (b)

$$T_1 = 127 + 273 = 400 \text{ K}$$

$$T_2 = 527 + 273 = 800 \text{ K}$$

$$\frac{E_1}{E_2} = \frac{\sigma T_1^4}{\sigma T_2^4} = \left(\frac{T_1}{T_2}\right)^4$$

$$\frac{E_1}{E_2} = \frac{1}{16}$$

11. (d)

$$\in = \frac{Q_{fin}}{Q_{wo,fin}} = \frac{\sqrt{hpkA}\theta_0}{hA\theta_0}$$

$$= \sqrt{\frac{pk}{hA}}$$

Effectiveness is directly proportional to the square root of thermal conductivity.

12. (b)

Dimensionless form of temperature distribution in a solid cylinder with internal heat generation is given by $\frac{t - t_w}{t_{max} - t_w} = 1 - \left(\frac{r}{R}\right)^2$

13. (d)

For same heat transfer,

$$R_1 = R_2$$

$$\Rightarrow \quad \frac{r_2 - r_1}{4\pi k r_1 r_2} = \frac{r_2 - r_1}{kA_m}$$

$$\Rightarrow \quad A_m = 4\pi r_1 r_2$$

$$\Rightarrow \quad 4\pi R_m^2 = 4\pi r_1 r_2$$

$$\Rightarrow \quad R_m = \sqrt{r_1 r_2}$$

14. (b)

$$\omega = 0.622\frac{p_v}{p_a}$$

Parts by mass of water vapour

$$\frac{m_v}{m} = \frac{\omega}{1+\omega} = \frac{0.622\frac{p_v}{p_a}}{1 + 0.622\frac{p_v}{p_a}}$$

$$= \frac{0.622 p_v}{p_a + 0.622 p_v}$$

15. (c)

Thermodynamic WBT is known as temperature of adiabatic saturation. Both measurable WBT and thermodynamic WBT values are different for a gaseaous mixture with water vapour.

16. (c)

Water has a high normal boiling point (100°C). So, it is a low pressure refrigerant.

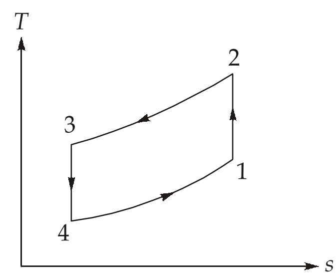
17. (d)

$$\text{ERSH} = \text{RSH} + (\text{OASH})$$
$$= 35 + 0.05 \times (55 - 30)$$
$$= 35 + 0.05 \times (25)$$
$$= 36.25 \text{ kW}$$

19. (d)

Hermetic compressors are sealed. So, their maintenance is not easy.

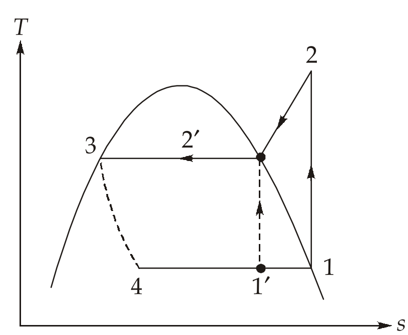
20. (b)



$$T_1 = \frac{T_2 \times T_4}{T_3} = \frac{600 \times 300}{400} = 450 \text{ K}$$

$$\text{R.C.} = \dot{m}c_p(T_1 - T_4)$$
$$= 0.5 \times 1 \times 150 = 75 \text{ kW}$$
$$= 21.4 \text{ TR}$$

21. (c)



$$w_1 = \frac{2 \times 3.5}{\text{COP}} = \frac{2 \times 3.5}{5} = \frac{7}{5} \text{kW}$$

$$\text{R.C.}_2 = 2 \times 3.5 - 2 = 5 \text{ kW}$$

$$w_2 = \frac{5}{\text{COP}} = \frac{5}{5+1} = \frac{5}{6} \text{kW}$$

$$w_1 - w_2 = \frac{7}{5} - \frac{5}{6} = 0.56 \text{ kW}$$

22. (d)

Bulb of a thermostatic expansion valve is fixed at the outlet of evaporator.

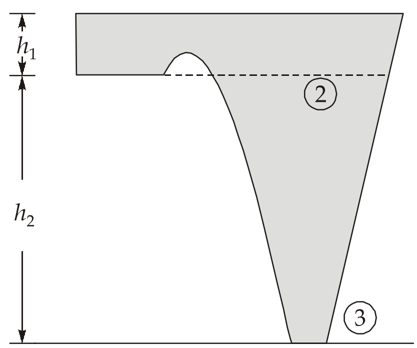
23. (a)

$$(\text{COP})_{\text{system}} = \frac{\text{COP}_1 \times \text{COP}_2}{\text{COP}_1 + \text{COP}_2 + 1} = \frac{5 \times 4}{5 + 4 + 1} = 2$$

25. (c)

This process uses loose granulated flux to cover the joint so it is not possible to carry out welding in any position other than flat or down hand position.

26. (d)



It has been found in practice that a straight tapered sprue is able to effectively reduce the air aspiration as well as increase the flow rate compared to a parallel sprue.

To avoid air aspiration, the ratio of cross-sectional area at point (3), A_3 to cross-sectional area at point (2), A_2 is

$$\frac{A_3}{A_2} = \sqrt{1 - \frac{h_2}{h_1 + h_2}}$$

It suggests that ideal profile of sprue should be parabolic.

27. (a)

Plane strain condition is applied to cases where strain along one direction is zero.

28. (a)

$$\text{Table feed, } f = 0.3 \times 100 \times 12 = 360 \text{ mm/min}$$

$$\text{Necessary approach} = \sqrt{d(D-d)} = \sqrt{25(170-25)} = 60.2 \text{ mm}$$

$$\text{Time of machining} = \frac{L + A}{f} = \frac{120 + 60.2}{360} = 30 \text{ seconds}$$

29. (b)

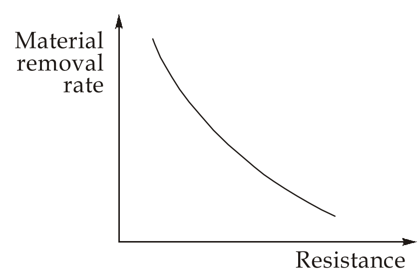
$$r = \frac{V_s}{V \sin\phi}$$

$$= \frac{198}{200 \times 0.3} = 3.3$$

30. (c)

In AC welding, polarity continuously changes hence effect of arc blow can be nullified.
By reducing current strength, magnetic field gets reduced hence arc blow reduces.

31. (b)



32. (d)

Canned cycle is used in operations such as drilling, boring, reaming etc.
In case of drilling, the tool has to positioned a little above hole in rapid position, then moved to desired depth with a given feed rate, then tool has to return to top of hole. Thus, for multiple holes 3 NC blocks has to be written. So by using Canned cycle program, length will decrease as it will perform all these motions without repeating same information for each hole.

33. (b)

$$CR = \frac{\text{Path of contact}}{\pi m \times \cos\phi}$$

$$POC = 1.4 \times \pi \times 8 \times 0.94 = 33.07 \text{ mm}$$

34. (a)

Instantaneous axis passes through instantaneous centre and is perpendicular to plane of motion.

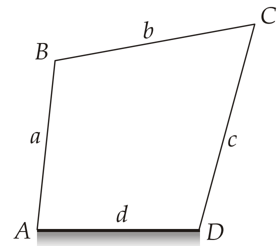
35. (b)

$$COI = \frac{f}{(m+M)g} = \frac{f}{30 \times 10} = 0.06$$

$$f = 18 \text{ N}$$

36. (a)

In Grashof's linkage by knowing shortest link, type of mechanism can be identified.



$$a + d < b + c \quad \text{...(i)}$$

$$d + c < a + b \quad \text{...(ii)}$$

Add (i) and (ii),

$\Rightarrow$ $$2d < 2b$$

and $$d < b$$

$$b + d < c + a \quad \text{...(iii)}$$

Add (i) and (iii),

We get

$$2d < 2c$$

or $$d < c$$

Add (ii) and (iii),

We get

$$2d < 2a$$

or $$d < a$$

Thus d is shortest link and is fixed so it is a crank-crank mechanism.

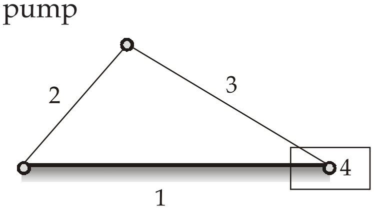
38. (d)

Inversions of four bar chain

1. Crank Rocker mechanism
2. Double Crank mechanism
3. Rocker Rocker mechanism

Inversion of slider crank chain

1. When link 1 is fixed, reciprocating engine.
2. When link 2 is fixed, rotary engine.
3. When link 3 is fixed, oscillating cylinder engine.
4. When link 4 is fixed, hand pump



Inversions of double slider crank chain

1. Oldham's coupling
2. Scotch yoke
3. Elliptical trammel

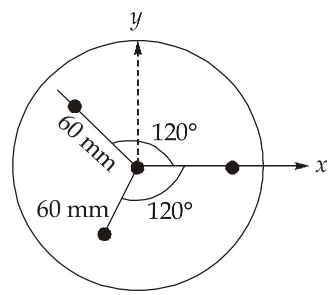
39. (d)

This mechanism is widely used in jacks, clocks, locks etc.

40. (b)

$$C = I w w_p$$
$$10 \times 9.8 \times 0.4 = 10 \times 0.2^2 \times 30 \times w_p$$
$$w_p = 3.27 \text{ rad/s}$$

41. (c)

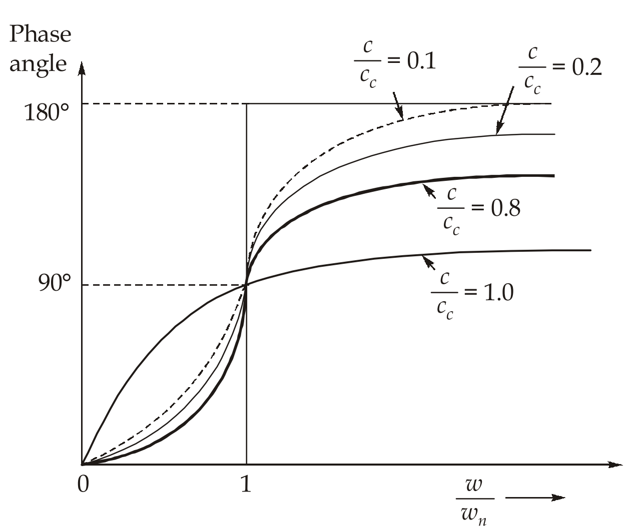


This disc can be balanced by two equal masses of 50g each at a radius of 60 mm.

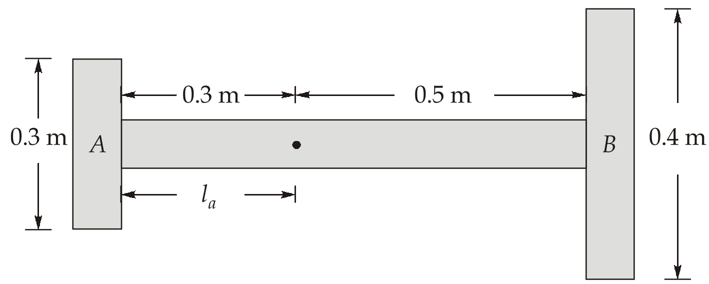
42. (b)

$$a_{max} = \frac{h}{2}\left(\frac{\pi w}{Q_0}\right)^2$$
$$= \frac{0.02}{2}\left(\frac{\pi}{\frac{\pi}{2}} \times 2 \times \frac{22}{7} \times \frac{840}{60}\right)^2$$
$$= 309.76 \text{ m/s}^2$$

43. (d)



44. (d)



$$I_A l_a = I_B l_b$$
$$20 \times 0.5^2 \times 0.3 = m_B \times 0.4^2 \times 0.5$$
$$m = 18.75 \text{ kg}$$

45. (b)

For Proell governor, $$\omega^2 = \frac{a}{e}\left[\frac{g}{h}\left(\frac{m+M}{m}\right)\right]$$

As $\frac{a}{e}$ is less than one so for same lift, speed required in Proell governor is less than that of Porter governor.

46. (d)

$$F = F_P - F_I + W$$
$$= 600 \times 10^3 \times \frac{100}{100^2} - 2 \times 200^2 \times 0.05[\cos 45] + 2 \times 10$$
$$= 6000 - 2828.43 + 20$$
$$= 3191.57$$

49. (d)

The operating temperature in solid oxide fuel cell is in the range of 600°C – 1000°C. Due to high temperature operation, catalyst is not required.

51. (b)

Heat energy required for cooking, $E = 50 \times 1700 = 85000$ kJ/day

$$\text{Actual energy required, } Q_{act} = \frac{85000}{0.8} = 106250 \text{ kJ/day}$$

$$\therefore \quad \text{Biogas required} = \frac{106250}{17500} = 6.07 \text{ m}^3/\text{day}$$

53. (c)

$$\text{Indicated thermal efficiency, } \eta_{ith} = \frac{\text{Heat equivalent of IP}}{\text{Heat input}} \times 100$$
$$= \frac{22 \times 60 \times 60}{(10 \times 10^{-3}) \times 800 \times 44000} \times 100$$
$$= 22.5\%$$

54. (a)

The valve overlap is usually greater in supercharged engines. Increased valve overlap permits greater time during which cooler air will flow past the valves and the piston crown. This cools the exhaust valve seat, the exhaust valves and the piston crown.

55. (b)

As the pressure and temperature at the beginning of injection are lower for higher ignition advance, the delay period increases with increase in injection advance.

56. (d)

In Top-down approach, the bulk material is reduced to nano size.
e.g. crushing, milling, mechanical attrition.

57. (a)

The forced draught fans should have high blade velocity so as to rotate at high speeds and handle large volume flow of air. Therefore, centrifugal fans with backward curved blading are normally used for FD fans.

58. (d)

In turboprop engines, since the shaft speed of gas turbine is very much higher than that of a propeller, a reduction gear must be placed between the turbine shaft and the propeller to enable the propeller to operate efficiently.

59. (c)

$$\text{Blade velocity, } u_1 = \pi \times 0.15 \times \frac{20000}{60} = 157 \text{ m/s}$$

$$\therefore \quad \text{Relative velocity at inlet, } V_{r_1} = \frac{u_1}{\cos\beta_1} = \frac{157}{\cos 45°}$$

$$V_{r_1} = 222 \text{ m/s}$$

$$\therefore \quad \text{Mach number, } M = \frac{\text{Relative velocity at inlet}}{\text{Velocity of sound}}$$

$$M = \frac{222}{\sqrt{1.4 \times 287 \times 305}} = \frac{222}{350}$$

$$M = 0.63$$

or $$M \simeq 0.6$$

60. (d)

$$\text{Turbine work, } w_T = h_1 - h_2 = 3000 - 500$$

$$w_T = 2500 \text{ kJ/kg}$$

$$\therefore \quad w_{net} = 2500 - 25 = 2475 \text{ kJ/kg}$$

$$\text{Power, } \dot{P} = 500 \text{ MW}$$

or $$\dot{m}_s = \frac{500 \times 10^3}{2475} = 202 \text{ kg/s}$$

$$\text{and work ratio} = \frac{w_{net}}{w_T}$$

$$= \frac{2475}{2500} = 0.99$$

62. (c)

Draught produced by chimney in terms of water column is given by,

$$h = 353H\left[\frac{1}{T_a} - \frac{m+1}{m} \times \frac{1}{T_g}\right]$$

$$h = 353 \times 50\left[\frac{1}{300} - \frac{20+1}{20 \times 600}\right]$$

$$h = 27.94 \simeq 28 \text{ mm of water}$$

64. (c)

If four 50% reaction stages are used, then

$$\Delta h_{\text{stage}} = \frac{1800}{4} = 450 \text{ kJ/kg}$$

$\therefore$ Absolute velocity of steam at inlet,

$$V_1 = 44.72\left[\frac{\Delta h_{stage}}{2}\right]^{1/2}$$

$$V_1 = 44.72\left[\frac{450}{2}\right]^{1/2} = 44.72 \times 15 = 670.8 \text{ m/s}$$

For maximum efficiency of blade,

$$V_b = V_1 \cos\alpha$$

or $$\frac{\pi D_m N}{60} = 670.8 \times \cos 30$$

or $$D_m = \frac{670.8 \times \cos 30 \times 60}{\pi \times 3000}$$

$$= 3.7 \text{ m}$$

65. (c)

Drift is fine water droplets entrained and carried by the air. Drift eliminators are provided at exit to minimise the drift loss. The baffles force the air to make a sudden change in direction. Heavier water particles separate out by gravity. Drift loss is much less, about 0.03 percent.

66. (c)

Using Dalton's law,

$$P_{\text{Tot}} = P_{\text{air}} + P_{\text{sat}}$$

$\therefore$ $$P_{\text{air}} = 0.08 - 0.07 = 0.01 \text{ bar}$$

Now, we have

$$P_{air} \times \dot{m}_s \times v_g = \dot{m}_a \times R_a \times T_{sat} \qquad \left[\because\ \dot{V}_{steam} = \dot{V}_{air}\right]$$

$$\frac{0.01 \times 10^5 \times 20 \times 10^3 \times 22}{3600} = \dot{m}_a \times 287 \times 311$$

$$\therefore \qquad \dot{m}_a = \frac{0.01 \times 10^5 \times 20 \times 10^3 \times 22}{287 \times 311 \times 3600}$$

$$\dot{m}_a = 1.37 \text{ kg/s}$$

68. (b)

The heat loss with the exhaust flue gas from a steam generator is the biggest heat loss. The final flue gas temperature and volume of flue gases affect flue gas loss. To reduce flue gas losses, the flue gases should exit the boiler at the lowest temperature possible. The flue gas is typically restricted to 150-200°C due to equipment, cost, or corrosion problems.

69. (c)

Efficiency with heat exchanger cycle rises very rapidly with increase in maximum temperature of the cycle.

70. (b)

Variations occurring in an axial flow compressor

	Absolute velocity	Relative velocity	Flow width	Static pressure
Rotor	Increases	Decreases	Increases	Increases
Stator	Decreases	–	Increases	Increases

71. (a)

$$\dot{m} = \left(\frac{PV}{RT}\right)_{suction} = \left(\frac{PV}{RT}\right)_{FAD}$$

$$\therefore \qquad \frac{1 \times V_s}{300} = \frac{1.013 \times 1.5}{290}$$

$$\therefore \qquad V_s = 1.57 \text{ m}^3/\text{min}$$

72. (d)

The primary use of internal sensors on a robot is to sense position, velocity, acceleration etc. of the manipulator for position and motion control. These sensors form an essential part of the basic or internal closed-loop control systems.

The degree of accuracy that can be achieved by a manipulator depends on the resolution and accuracy of internal sensors.

73. (c)

Rotation matrix is given by,

$$R_z(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

or

$$R_z(90°) = \begin{bmatrix} \cos 90° & -\sin 90° & 0 \\ \sin 90° & \cos 90° & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R_z(90°) = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

New position vector,

$$2_p = R(90°) \cdot 1_p$$

$$2_p = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 2 \\ 1 \end{bmatrix}$$

$$2_p = [-2 \;\; 3 \;\; 1]^T$$

74. (a)

Monel metal contains 68% nickel, 29% copper and 3% other constituents.

76. (b)

The rate of oxidation of the metal and the tendency of the oxide film to protect the film from further oxidation are related to the relative volume of oxide and metal. Ratio of these volumes is known as PB ratio (Pilling-bedworth ratio), which is given by the expression,

$$\text{PB ratio} = \frac{M_o \cdot \rho_m}{M_m \cdot \rho_o}$$

PB ratio < 1 results in porous film, which is unprotective and insufficient to fully cover the metal surface. PB ratio > 1, as the film forms compressive stresses are developed in the film. For PB ratio 2-3, oxide films may crack and can flake off.

77. (c)

The term buffer is used for a device that provides isolation and current or voltage amplification.

78. (c)

Intel 8051 has the five modes of immediate, direct, register, indirect and indexed.

80. (d)

In selecting a micro-controller, the following factors need to be considered:

1. Number of input/output pins
2. Interfaces required

3. Memory required
4. The number of interrupts required
5. Processing speed required

81. (d)

The accumulator register (A) is where data for an input to the arithmetic and logic unit is temporarily stored. The accumulator register is thus a temporary holding register for data to be operated on by the arithmetic and logic unit and also after the operation the register for holding the results, it is thus involved in all data transfers associated with the execution of arithmetic and logic operations.

82. (b)

With the two-step mode, the control action is discontinuous. The controller is essentially just a switch which is activated by the error signal and supplies just an on-off correcting signal.

83. (b)

With the shunt wound motor, the armature and field coils are in parallel. It provides the lowest starting torque, a much lower no-load speed and has good speed regulation. Because of this almost constant speed regardless of load, shunt wound motors are very widely used.

84. (b)

Force 'F' applied to the diaphragm,

$$F = P \times A$$

$$\therefore \quad A = \frac{F}{P} = \frac{500}{200 \times 10^3} = 0.0025 \text{ m}^2$$

85. (c)

$$\text{Change in resistance, } \Delta R = R \times G \times \epsilon = 120 \times 3 \times 0.001 = 0.36$$

86. (a)

Order of increasing ductility.

Chilled cast iron, white cast iron, gray cast iron, nodular cast iron.

87. (b)

Resilience is ability of material to absorb energy when deformed elastically to return the same energy when unloaded.

88. (d)

Eutectoid reaction,

$$\gamma \rightleftharpoons \alpha + Fe_3C$$

where α ferrite and cementite is known as pearlite.

89. (b)

$$\text{Number of atoms in unit cell} = \frac{1}{8} \times 8 + \frac{1}{2} \times 6 + 4 = 8$$

$$\text{Volume occupied by atoms} = 8 \times \frac{4}{3}\pi R^3$$

$$\text{Volume of unit cell} = a^3$$

$$\text{PF} = \frac{32}{3a^3} \times \pi \times \left(\frac{\sqrt{3}a}{8}\right)^3$$

$$= \frac{\sqrt{3}}{16}\pi$$

90. (c)

Good mechanical properties are obtained by normalizing but better machinability is obtained when annealing is done.

91. (b)

- Primary shear stress are caused by force acting through centre of gravity which causes direct shear stress in weld.
- Secondary shear stress in weld are caused by couple which causes torsional shear stress in the weld.

92. (d)

There are 2 inactive coils in spring with square ends.
There is no inactive coils in spring with plain ends.

93. (b)

Maximum shear stress theory is the most conservative theory.

94. (b)

As per distortion energy theory,

$$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 \leq \frac{\sigma_{yt}^2}{N^2}$$

$$(120)^2 + (50)^2 + 120 \times 50 \leq \frac{\sigma_{yt}^2}{N^2}$$

$$N = 1.65$$

95. (c)

Self aligning ball bearing and spherical roller bearing are used in applications where a misalignment between axes of shaft and housing exist. But to carry heavy load, roller bearings are preferred. So option (c) is the correct answer.

96. (d)

$$F = \pi p_0 \frac{d}{2}(D - d)$$

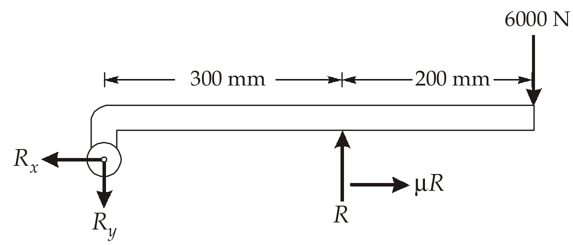
$$= \pi \times 1 \times 10^6 \times \frac{0.1}{2}(0.1)$$

$$= 15.71 \text{ kN}$$

97. (c)

The clutch should engage or disengage at will of operator. So semi cone angle should be greater than angle of static friction.

98. (c)



$$R \times 300 = 6000 \times 500$$
$$R = 10000 \text{ N}$$
$$F_t = \mu R = 0.3 \times 10000 = 3000 \text{ N}$$

So,
$$R_x = 3000 \text{ N}$$
$$R_y = 10000 - 6000 = 4000 \text{ N}$$
$$R_0 = \sqrt{3000^2 + 4000^2} = 5000 \text{ N}$$

99. (b)

$$s = \frac{ZN}{P}\left(\frac{d}{c}\right)^2$$
$$= \frac{25 \times 10^{-3} \times 1500 \times 0.05^2}{2500 \times 60} \times \left(\frac{50}{0.1}\right)^2$$
$$= 0.156$$

100. (b)

On a plate facing south ($\gamma = 0°$), at solar noon

$$\theta_i = |\phi - \beta - \gamma|$$
$$= |30 - 20 - 12|$$
$$= 2°$$

101. (c)

Optimum tip speed ratio, $\lambda_0 = \frac{4\pi}{n}$

n = number of blades = 2

$$\lambda_0 \simeq \frac{4\pi}{2} \simeq 6.28$$

102. (b)

Paraboloidal dish collector (Scheffler solar concentrator) is a focus type solar collector which requires two-focus tracking.

103. (a)

$$\text{Perturbation factor, } a = \frac{1}{2}\frac{u_0 - u_2}{u_0}$$

$$= \frac{1}{2}\frac{u_0 - 0.5u_0}{u_0} = \frac{1}{4}$$

$$\text{Axial thrust, } F_A = C_F F_{A,\max}$$

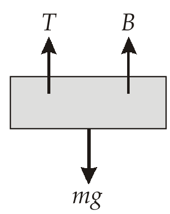
$$= 4a(1 - a) \times 18 \text{ kN}$$

$$= 4 \times \frac{1}{4}\left(\frac{3}{4}\right) \times 18$$

$$= 13.5 \text{ kN}$$

105. (c)

Let ρ_s, ρ_L be the density of silver and liquid respectively and m and v to be mass and volume of the silver block.



From equilibrium equation,

$$T + B = mg$$

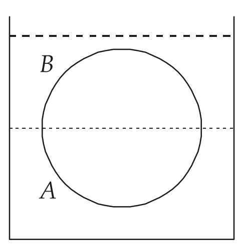
$$\Rightarrow \quad T = mg - B = \rho_s vg - \rho_L vg$$

$$\Rightarrow \quad T = (\rho_s - \rho_L)v \times g \qquad \left\{v = \frac{m}{\rho_s}\right\}$$

$$\Rightarrow \quad T = \frac{\rho_s - \rho_L}{\rho_s} \times mg$$

$$\Rightarrow \quad T = \frac{10 - 0.5}{10} \times 10 \times 10 = 95 \text{ N}$$

106. (b)



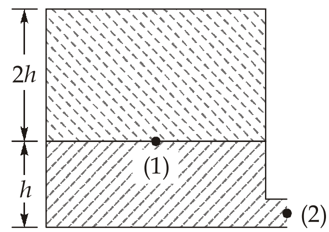
From the equilibrium of the sphere,

$$\text{Weight} = \text{Buoyant force}$$

$$\Rightarrow \quad V\rho_m g = \frac{V}{2}\rho_A g + \frac{V}{2}\rho_B g$$

$$\Rightarrow \qquad \rho_m = \frac{\rho_A + \rho_B}{2} = \frac{5 + 2.5}{2} = 3.75 \text{ gm/cm}^3$$

107. (d)



Pressure at point 1,

$$P_1 = P_{atm} + 2\rho g(2h)$$

Applying Bernoulli's equation between points (1) and (2)

$$P_1 + 3\rho gh = P_{atm} + 3\rho g(0) + \frac{1}{2} \times 3\rho v^2$$

$$\Rightarrow \qquad P_{atm} + 4\rho gh + 3\rho gh = P_{atm} + \frac{3\rho}{2} v^2$$

$$\Rightarrow \qquad 7\rho gh = \frac{3\rho}{2} v^2$$

$$\Rightarrow \qquad v = \sqrt{\frac{14gh}{3}}$$

109. (a)

Thixotropic fluids thin out with time and require decreasing stress.

111. (a)

$$\text{Convective acceleration, } a_c = v\frac{\partial v}{\partial x}$$

$$= 2t\log_e x \times \frac{2t}{x} = \frac{4t^2}{x}\log_e x$$

$$= \frac{4 \times 4}{4} \times 1.386 = 5.54 \text{ m/s}^2$$

112. (b)

At the stagnation point,

$$u = 0 \text{ and } v = 0$$

$$3x + 4y - 12 = 0$$

$$4x + 3y - 12 = 0$$

$$\therefore \qquad 3x + 4y = 12 \qquad \text{...(i)}$$

$$4x + 3y = 12 \qquad \text{...(ii)}$$

Solving equations (i) and (ii),

$$x = \frac{12}{7},\ y = \frac{12}{7}$$

113. (c)

(1) $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=c+(-c)=0$

(2) $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=5y+6x\neq 0$

(3) $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=\frac{c}{y}+\left(\frac{-c}{xy}\times x\right)=\frac{c}{y}-\frac{c}{y}=0$

114. (b)

$$Q = \frac{\pi}{4}\times D^2\times(v-u)$$
$$= \frac{22}{7\times 4}\times 4\times 10^{-4}\times 14 = 44\times 10^{-4}\ m^3/s$$
$$\text{Reaction of plate, } R = \rho Q v_r$$
$$= 1000\times 44\times 10^{-4}\times 14$$
$$= 616\times 10^{-1} = 61.6\ N$$
$$\text{Work done per second} = R\times u$$
$$= 61.6\times 6 = 369.6\ W$$

116. (b)

$$\text{Shear stress is given by, } \tau = \mu\frac{\partial u}{\partial y}$$
$$\Rightarrow \quad \tau = \frac{15}{10}\times\frac{2}{1.5\times 10^{-2}} = 200\ N/m^2$$
$$\text{Force acting, } F = \tau\times A$$
$$= 200\ N/m^2\times 5\ m^2 = 1000\ N$$
$$= 1\ kN$$

117. (b)

Velocity of fluid coming out of the nozzle is,

$$V = \sqrt{2gh} = \sqrt{2\times 10\times 5} = 10\ m/s$$
$$\text{Mass flow rate, } \dot{m} = \rho A v$$
$$= \rho\times\frac{\pi}{4}D^2\times v$$
$$= 1000\times\frac{22}{7\times 4}\times 196\times 10^{-4}\times 10$$
$$= 154\ kg/sec$$

∴ Net reaction force on the spring,

$$R = \dot{m}v\cos 60^\circ - 0$$
$$= 154\times 10\times\frac{1}{2} = 770\ N$$

$\therefore$ Compression of the spring, $R = kx$

$$\Rightarrow \quad x = \frac{R}{k} = \frac{770}{1540} = 0.5 \text{ m}$$

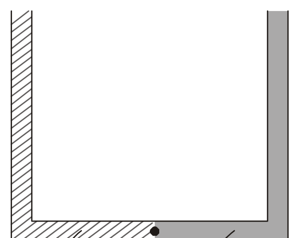
118. (c)

$$F_D = C_D A\rho \frac{V^2}{2}$$

$$F_D = 1.2 \times 1 \times 2 \times \frac{1000 \times 4}{2}$$

$$= 4800 \text{ N}$$

119. (d)



For the given situation, liquid of density 3ρ should be behind that of ρ.

$$\therefore \quad P_A = P_{\text{atm}} + \rho g h$$

$$P_B = P_A + \rho a \frac{l}{2} = P_{atm} + \rho g h + \rho a \frac{l}{2}$$

$$P_C = P_B + 3\rho a \frac{l}{2}$$

$$= P_{atm} + \rho g h + \rho a \frac{l}{2} + 3\rho a \frac{l}{2}$$

$$= P_{atm} + \rho g h + 2\rho a l \quad \text{...(i)}$$

But $P_C = P_{\text{atm}} + 3\rho g h$ ...(ii)

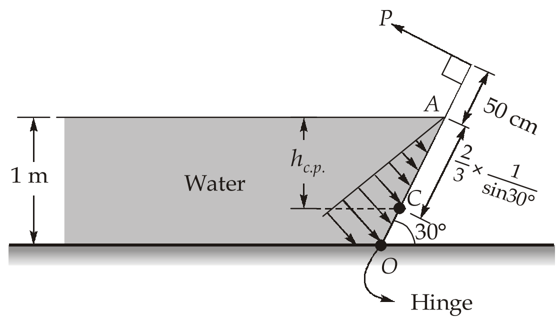
From equation (i) and (ii),

$$P_{\text{atm}} + \rho g h + 2\rho a l = P_{\text{atm}} + 3\rho g h$$

$$\Rightarrow \quad 2\rho a l = 2\rho g h$$

$$\Rightarrow \quad h = \frac{2\rho a l}{2\rho g} = \frac{al}{g}$$

120. (c)



$h_{c.p.}$ = Height of centre of pressure from free surface

Centre of pressure will lie at the centroid of pressure prism,

$$\therefore \quad AC = \frac{2}{3}\times\frac{1}{\sin 30°} = \frac{4}{3}\text{ m}$$

$$\therefore \quad OC = \frac{1}{\sin 30°} - \frac{4}{3} = 2 - \frac{4}{3} = \frac{2}{3}\text{ m}$$

$\therefore$ Taking moment about O:

$$P\times\left(\frac{1}{\sin 30°}+0.5\right) = \rho g A\bar{x}\times OC$$

$$\Rightarrow \quad P\times(2.5) = 1000\times 10\times\left(\frac{1}{\sin 30°}\times 4\right)\times 0.5\times\frac{2}{3}$$

$$\Rightarrow \quad P = 10.67\text{ kN}$$

121. (c)

$$\text{Gross head} = 200\text{ m}$$

$$\text{Loss of head at the penstock} = \frac{1}{4}\times 200 = 50\text{ m}$$

$$\text{Net head at turbine, } H = 200 - 50 = 150\text{ m}$$

$$\text{Power generated by the wheel, } P = \eta_0\,\gamma Q H$$

$$= 0.8\times 10\times 1000\times 2\times 150$$

$$= 2400\text{ kW}$$

$$= 2.4\text{ MW}$$

122. (a)

Present day Francis machines have a very high overall efficiency that is about 90 to 95%. Therefore, statement 3 is incorrect.

123. (a)

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1080\sqrt{Q}}{(81)^{3/4}} = \frac{1080\sqrt{Q}}{27}$$

$$\Rightarrow \quad N_s = 40\sqrt{Q}$$

$$\Rightarrow \quad 80 = 40\sqrt{Q}$$

$$\Rightarrow \quad \sqrt{Q} = 2$$

$$\Rightarrow \quad Q = 4 \text{ m}^3/\text{sec}$$

$$\therefore \quad \text{Pumps required, } n = \frac{Q_{\text{total}}}{Q} = \frac{20}{4} = 5$$

124. (c)

$$Q_1 = 0.8 \text{ m}^3/\text{s}, Q_2 = 2 \text{ m}^3/\text{s}$$

Since, same pump is used in both the cases, then $D_1 = D_2$

$$\therefore \quad \frac{Q_1}{N_1 D_1^3} = \frac{Q_2}{N_2 D_2^3}$$

$$\Rightarrow \quad \frac{0.8}{N_1} = \frac{2}{N_2}$$

$$\Rightarrow \quad N_2 = 2.5\, N_1$$

$$\text{Percentage increase in speed} = \frac{N_2 - N_1}{N_1} \times 100\%$$

$$= \frac{2.5N_1 - N_1}{N_1} \times 100$$

$$= 1.5 \times 100$$

$$= 150\%$$

125. (d)

$$\text{Arrival rate, } \lambda = \frac{12}{6} = 2 \text{ customers/minute}$$

$$\text{Service rate, } \mu = \frac{18}{6} = 3 \text{ customers/minute}$$

$$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} = \frac{\lambda}{\mu} \times \frac{\lambda}{(\mu - \lambda)}$$

$$L_q = \frac{2 \times 2}{3 \times (3 - 2)} = \frac{4}{3} = 1.33$$

126. (b)

Given data : C = unit cost = Rs. 48; D = Demand per year = 4000;

$C_C = 0.25 \times C = 0.25 \times 48$ = Rs. 12/unit/year

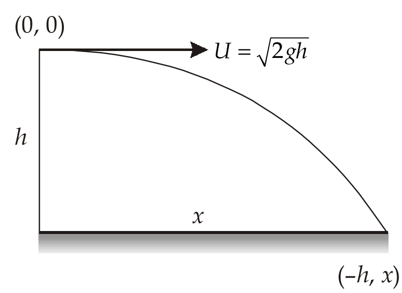
$$Q^* = \sqrt{\frac{2DC_0}{C_C}} = \sqrt{\frac{2 \times 4000 \times 240}{12}}$$

$$Q^* = 400 \text{ units/order}$$

$$\therefore \quad \text{Number of orders/year} = \frac{D}{Q^*} = \frac{4000}{400}$$

$$= 10 \text{ orders/year}$$

127. (c)

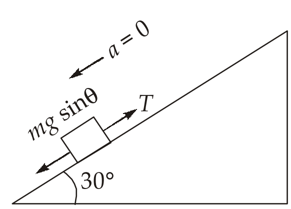


Time of flight is given by, $t = \sqrt{\frac{2h}{g}}$

Horizontal distance covered during the time of flight is

$$x = U_x t = \sqrt{\frac{2h}{g}} \times \sqrt{2hg} = 2h$$

128. (c)

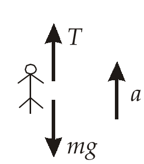


For the block to be stationary,

$$T = mg \sin\theta$$

$$= 150 \times 10 \times \frac{1}{2} = 750 \text{ N}$$

If boy moves up by an acceleration a,



$$T - mg = ma$$

$$750 - 50 \times 10 = 50a$$

$$\Rightarrow \quad a = \frac{250}{50} = 5 \text{ m/s}^2$$

129. (a)

Let at any time, the speed of the block along the incline upwards be V.

Then, from Newton's second law,

$$\frac{P}{V} - mg\sin\theta - \mu mg\cos\theta = ma = m\frac{\partial V}{\partial t}$$

The speed is maximum, when $\frac{\partial V}{\partial t} = 0$

$$\therefore \quad \frac{P}{V} = mg\sin\theta + \mu mg\cos\theta$$

$$\therefore \quad V = \frac{P}{mg\sin\theta + \mu mg\cos\theta}$$

130. (a)

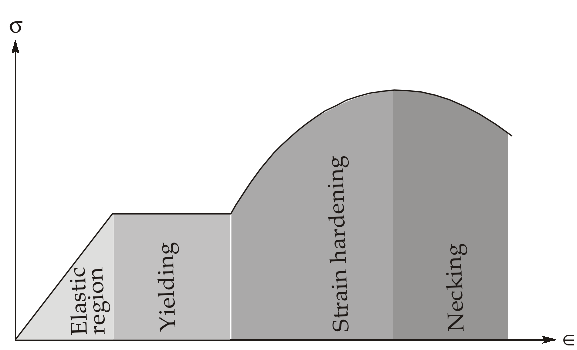
The stress in the walls of the spherical tank is given by,

$$\sigma = \frac{Pd}{4t}$$

$$\Rightarrow \quad P = \frac{\sigma 4t}{d} = \frac{150 \times 10^6 \times 4 \times 10^{-2}}{30}$$

$$\Rightarrow \quad P = 200 \text{ kPa}$$

131. (b)

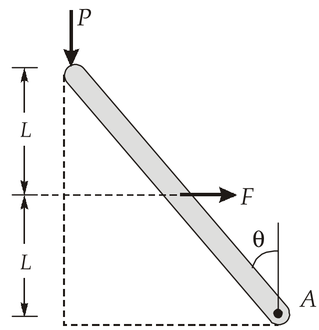


132. (c)

The shear formula should not be used to determine the shear stress on cross-sections that are short or flat, at points of sudden cross-sectional changes, or at a point on an inclined boundary.

133. (b)

The disturbing force F can be determined by summing the moment about point A



$\Sigma M_A = 0$

$$\Rightarrow \quad P(2L)\theta - F \times L = 0$$

$$\Rightarrow \quad F = 2P\theta$$

The restoring spring force F_s can be determined using spring formula

$$F_s = kx = kL\theta$$

For the mechanism to be in equilibrium, the disturbing force F must be equal to the restoring spring force F_s.

$$2P\theta = kL\theta$$

$$P = \frac{kL}{2}$$

134. (d)

When the specimen is subjected to the load, it strain-hardens until the point B is reached on the σ–ε diagram. The strain at this point is approximately 0.005 mm/mm. When the load is released, the material behaves by following the straight line BC, which is parallel to straight line OA. Since both the lines have the same slope, the strain at point C can be determined analytically.

$$E = \left(\frac{\sigma}{\epsilon}\right)_{OA} = \frac{600}{0.002} = 300 \text{ GPa}$$

From triangle CBD, we have

$$E = \frac{BD}{CD}$$

$$\Rightarrow \quad 300 \times 10^9 = \frac{900 \times 10^6}{CD}$$

$$\Rightarrow \quad CD = \frac{900}{300 \times 10^3} = 3 \times 10^{-3}$$

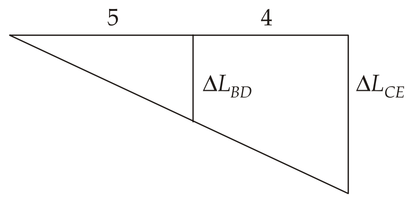
$$\Rightarrow \quad CD = 0.003 \text{ mm/mm}$$

This strain CD represents the amount of recovered elastic strain. The permanent strain ϵ_{oc} is given by

$$\epsilon_{oc} = 0.005 - 0.003$$

$$= 0.002 \text{ mm/mm}$$

135. (b)



From the similarity of triangles,

$$\frac{\Delta L_{BD}}{5} = \frac{\Delta L_{CE}}{9}$$

$$\frac{\Delta L_{BD}}{\Delta L_{CE}} = \frac{\epsilon_{BD}}{\epsilon_{CE}} = \frac{5}{9} = 0.555$$

136. (c)

The external force applied will be resisted by both the matrix and the fibre

$$\therefore \quad \Sigma F = 0$$

$$\Rightarrow \quad -P + P_f + P_m = 0$$

$$P_f + P_m = P \quad \text{...(i)}$$

Also, the change in dimension for both will also be the same

$$\delta_m = \delta_f$$

$$\Rightarrow \quad \frac{P_m L}{A_m E_m} = \frac{P_f L}{n A_f E_f}$$

$$\Rightarrow \quad P_f = \frac{n A_f E_f P_m}{A_m E_m} \quad \text{...(ii)}$$

Solving (i) and (ii) equation, we get

$$P_f = \frac{n A_f E_f}{n A_f E_f + A_m E_m} P$$

$$\sigma_f = \frac{P_f}{n A_f} = \frac{E_f P}{n A_f E_f + A_m E_m}$$

138. (d)

When frictional force is opposite to velocity, its kinetic energy will decrease.

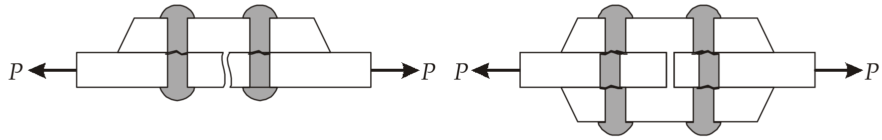
139. (d)

The Pelton turbine is ideal for high-head and low-discharge situations. Second statement is correct. The turbine is housed in a steel casing essentially to confine the spent water and to divert it to the tail race.

140. (d)

It is observed that there is a greater reduction in the endurance limit of fine-grained materials as compared to coarse-grained materials, due to stress concentration.

141. **(a)**



Shear failure in single strap butt joint

Shear failure in double strap butt joint

142. **(d)**

In a closed loop control system, the output does have an effect on the input signal, modifying it to maintain an output signal at the required value.

143. **(a)**

The use of initial curtis stage reduces the length of the rotor i.e. the number of stages required since a two-row curtis stage can replace about eight 50% reaction stages and hence, the cost of the rotor significantly at the expense of some loss in efficiency. It is often called the control stage, where steam at the highest pressure and temperature is immediately expanded down into a region of more moderate pressures and temperatures, such that the leakage between stages is reduced, expansion problems are simplified and the overall length of the rotor is reduced.

144. **(a)**

In Ramjet engine, after a certain flight velocity a condition is reached where the discharge nozzle becomes choked, and nozzle operates with a constant Mach number of 1 at its throat. Therefore, a ramjet having fixed geometry is designed for a specific Mach number and altitude and at the design point, will give the best performance.

148. **(c)**

In infiltration process, a low melting point material is used to fill pores by capillary action.

149. **(d)**

Mean flow stress required to deform material is less in hot working operation as compared to cold working operation.

150. **(b)**

LiBr-H_2O system may not require analyser, rectifier column as boiling point difference is sufficiently large. So, statement II is not the correct reason.

