DETAILED SOLUTIONS

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# ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 18

## Full Syllabus Test 2 : Paper-II

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

## DETAILED EXPLANATIONS

**1. (b)**

The actual assumption is "The tool is perfectly sharp and has no contact along the clearance face".

**3. (d)**

For an optimum side riser of cylindrical shape,

$$D = H = 12 \text{ cm} \qquad \text{(Given)}$$

$$\text{Freezing ratio, } X = \frac{\left(\frac{SA}{V}\right)_{casting}}{\left(\frac{SA}{V}\right)_{riser}}$$

$$X = \left(\frac{2(LB+BH+LH)}{LBH}\right)\left(\frac{\frac{\pi}{4}D^2H}{\pi DH+\frac{\pi}{2}D^2}\right)$$

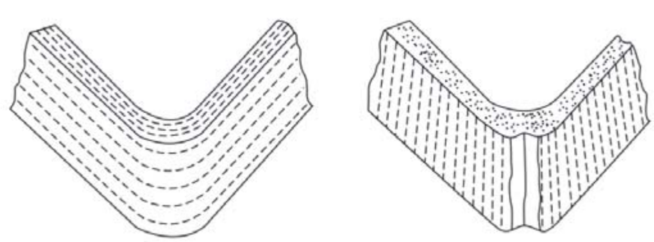
$$X = \left(\frac{2(25\times25+25\times5+5\times25)}{25\times25\times5}\right)\left(\frac{D}{6}\right)$$

$$X = \left(\frac{2(625+250)}{25\times25\times5}\right)\times\left(\frac{12}{6}\right)$$

$$= \frac{2\times2\times875}{25\times25\times5} = 1.12$$

**4. (d)**

- The process of spinning consists of rotating the blank, fixed against the form block and then applying a gradually moving force on the blank so that the blank takes the shape of the form block. Hence, it can be used to make only cup shaped articles which are axisymmetric.
- There is a possibility of cracks appearing at the time of bending if the bending is done along the grains as shown in figure below.



(a) Bent along grain (b) Bent across grain

**Effect of bending along and across grain**

- Spring back is observed only in those operations in which the deformation is done in elastic range. However, in stretch forming, the complete deformation is carried out in plastic state only. The material is first brought into plastic state by stretching.

**5. (a)**

Given, sampling length, $L$ = 31.4 mm

CLA, $$R_a = \frac{1}{L}\int_0^L y(x)\,dx$$

$$R_a = \frac{1}{31.4}\int_0^{31.4}(10+5\sin x)\,dx = \frac{1}{31.4}[10x - 5\cos x]_0^{31.4}$$

$$= \frac{1}{31.4}(10\times 31.4 - (5\cos(31.4) - 5\cos 0))$$

$$= \frac{1}{31.4}(314 - (5-5)) = 10\ \mu\text{m} \quad [\because \cos(31.4) = \cos 10\pi = 1]$$

**6. (b)**

Vickers hardness number, $$\text{VHN} = \frac{1.854P}{d_1^2}$$

where, $P$ : Applied load (in kg)

$d_1$ : Size of indentation (in mm)

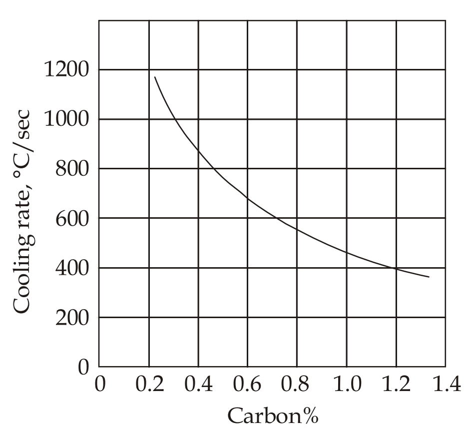
$\therefore$ $$\text{VHN} = \frac{1.854\times 100}{(0.5)^2} = 741.6 \simeq 740$$

**8. (a)**

Since ferrite has a body centred cubic structure, the inter-atomic spaces are small and pronouncedly oblate and cannot readily accommodate even a small carbon atom. Therefore, the solubility of carbon in ferrite is very low, of the order of 0.006% at room temperature.

**9. (c)**

The critical cooling rate required for getting the complete martensitic structure in steels depends on the carbon percentage as shown in figure below. Higher the carbon, lower is the cooling rate required.




**Influence of carbon content on critical cooling rate for missing the transformation curve**

**10. (c)**

- The addition polymerisation consists of breaking the double carbon bond (C=C) in bifunctional polymers, so that the chain can be formed. For example, ethylene when polymerised will be called polyethylene.
- In condensation polymerisation, two different organic molecules react to form a plastic molecule. The reaction generally results in the separation of a small molecule such as $H_2O$ as a by-product.

**11. (b)**

Given, edge length, $a$ = 450 pm

Interplanar spacing between planes ($h\ k\ l$) is given by,

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$= \frac{450}{\sqrt{1^2 + 2^2 + 2^2}}$$

$$= \frac{450}{3} = 150 \text{ pm}$$

**12. (c)**

During solidification or recrystallization, new crystals form in different parts of the material. They are randomly oriented with respect to one another. They grow by the addition of atoms from the adjacent regions and eventually impinge on each other. When two crystals impinge in this manner, the atoms caught in between the two are being pulled by each of the two crystals to join its own configuration. They can join neither crystal due to the opposing forces, and therefore, take up a compromise. The boundary region is called a crystal or grain boundary.

- The crystal orientation changes sharply at the grain boundary. The orientation difference is usually greater than 10 - 15°. For this reason, the grain boundaries are also known as high angle boundaries.
- The average number of nearest neighbours for an atom in the boundary of a closed packed crystal is 11, as compared to 12 in the interior of the crystal. On an average, one bond out of the 12 bonds of an atom is broken at the boundary.

**13. (d)**

- For the single phase region (liquid or solid), from modified phase rule,

$$F = C - P + 1 = 2 - 1 + 1 = 2$$

So, both temperature and composition of the phase can be independently varied.

- In the two-phase region,

$$F = 2 - 2 + 1 = 1$$

As $F$ = 1, only of three variables i.e. temperature, composition of the liquid phase and composition of the solid phase; is independent. If we arbitrarily choose the temperature, the compositions of the two phases are automatically fixed and are given by the end of the tie-line draw at that temperature.

**14. (b)**

- The stress fields around solute atoms interact with the stress field for a moving dislocation, thereby increasing the stress required for plastic deformation.
- The more the size difference between the solute and the solvent, the more intense is the stress field around the solute and its interaction with the moving dislocation is correspondingly stronger.
- With a large concentration of the solute, the moving dislocation interacts with the solute stress fields at many points along its length.

**15. (c)**

For good oxidation resistance, the oxide layer should be adherent to the surface. The adherence of an oxide film is dependent on the ratio of the volume of oxide formed to that of metal consumed during oxidation. This ratio is known as the Pilling-Bedworth ratio. If the ratio is less than unity, tensile stresses will be set up in the oxide layer. The oxide being brittle cannot withstand tensile stresses and, therefore, it cracks and is not protective against further oxidation. If the ratio is more than unity, the oxide layer will be in compression, will uniformly cover the metal surface and be protective. If the ratio is much greater than unity, there is the risk of two much compressive stresses being set up, again resulting in the cracking of the layer.

**16. (b)**

Carbon fibre is expensive compared to glass fibre.

**17. (a)**

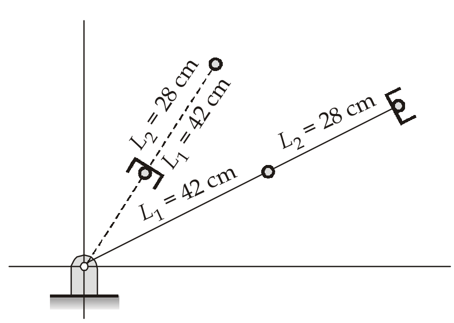
The SCARA configuration has vertical major axis rotations such that gravitational load, Coriolis, and centrifugal forces do not stress the structure as much as they would if the axes were horizontal.

**18. (a)**

- Statement 1 is correct for forward kinematics.
- Statement 2 is correct for inverse kinematics.

**19. (a)**

$$L_1 = 42 \text{ cm}$$
$$L_2 = 28 \text{ cm}$$




$$R_1 = L_1 + L_2 = 42 + 28 = 70 \text{ cm}$$
$$R_2 = L_1 - L_2 = 42 - 28 = 14 \text{ cm}$$

$\therefore$ So, the work space $= \pi \times \left(R_1^2 - R_2^2\right)$

$$= \pi \times \left(70^2 - 14^2\right)$$

$$= \frac{22}{7} \times (70+14) \times (70-14) = 14784 \text{ cm}^2$$

**20. (c)**

**In online programming,** the robot arm itself is used during the direct programming operation. There are two methods:

**(i) Teach by lead through or lead through programming:** In this type, the work cycle is taught to robot by moving the manipulator through the requires motion cycle and simultaneously entering the program into controller memory for later playback. This is used for programming continuous path operations such as are found in spray painting. In this type, no computer programming is needed and can be easily learned by the shop personnel.

**(ii) Teach by pendent:** It is used for work that required point to point and point to point with coordinated path movements, this is the normal method of programming. It involves the programmer using a hand-held pendent which transmits commands through a cable to the robot controller, the robot then responds to these commands. The robot is programmed by moving the end-effectors to a desired position using and orientation a key in the keyboard is pressed to record the point.

**21. (d)**

Single wheel or ball robots are classified as wheeled robots.

**22. (a)**

The area occupied below the velocity time graph gives the displacement.
So,

$$\text{Average velocity between } t = 0\text{s to } 50\text{s} = \frac{\text{Displacement between } t = 0\text{s to } 50\text{s}}{\text{Time duration}}$$

$$= \frac{\text{Area below velocity time plot between } t = 0\text{s to } 50\text{s}}{\text{Time duration}}$$

$$= \frac{\left[\frac{1}{2} \times 10 \times 50 + (30-10) \times 50 + \frac{1}{2} \times (50+80) \times (40-30) + \frac{1}{2} \times (50+80)(50-40)\right]}{(50-0)}$$

$$= \frac{250+1000+650+650}{50} = 51 \text{ m/s}$$

**23. (b)**

| Collision type | Coefficient of restitution ($e$) |
|---|---|
| (i) Perfectly elastic | $e = 1$ |
| (ii) Perfectly inelastic | $e = 0$ |
| (iii) Partially elastic | $0 < e < 1$ |

**24. (a)**

Given : $v = 3x^2 - 2x + 2$

$$\Rightarrow \quad \frac{dv}{dx} = 6x - 2$$

The acceleration is given as,

$$a = v \cdot \frac{dv}{dx} = \left(3x^2 - 2x + 2\right)(6x - 2)$$

at $x = 1$ m,

$$a = (3 \times 1^2 - 2 \times 1 + 2)(6 \times 1 - 2)$$
$$= 12 \text{ m/s}^2$$

**25. (b)**

The principle of moments, also known as Varignon's theorem, states that the moment of any force is equal to the algebric sum of the moment of the components of that force.

**26. (d)**

Given : $m = 15$

For a perfect frame

$$2j = m + 3$$
$$\Rightarrow \quad 2j = 15 + 3$$
$$\Rightarrow \quad 2j = 18$$
$$\Rightarrow \quad j = 9$$

Hence, the total number of joints is 9.

**27. (c)**

$$\dot{m}_a = \frac{120}{0.8 \times 60} = 2.5 \text{ kg/s}$$

Now,

$$Q_{coil} = \dot{m}_a (h_2 - h_1)$$

$$\therefore \quad h_2 = h_1 + \frac{Q_{coil}}{\dot{m}_a} = 14 + \frac{42}{2.5}$$
$$= 30.8 \text{ kJ/kg}$$

**28. (c)**

Using the following equation

$$B_n = B_1^n$$

Bypass factor of 5-depth coil is given by

$$\therefore \quad B_5 = 0.7^5 = 0.168 \simeq 0.17$$

**29. (d)**

Solenoid valves are placed in line liquid the between the condenser and evaporator. This valve either allows to flow constant quantity of refrigerant to the evaporator or stops the flow.

**30. (c)**

Low specific volume of the refrigerant at the suction into the compressor is always desirable, because it reduces the size of the compressor for the same refrigeration capacity.

**32. (d)**

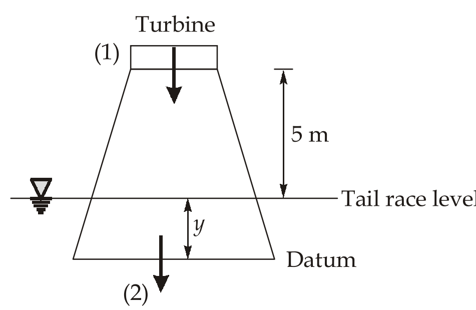
At inlet, $U_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 3 \times 300}{60} = 47.12 \text{ m/s}$

$\therefore$ At the outlet, $U_2 = \frac{D_2}{D_1} \times U_1$

$$U_2 = \frac{1.5}{3} \times 47.12 = 23.56 \text{ m/s}$$

**33. (c)**

Refer figure,




By Bernoulli's equation applied to sections 1 and 2

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + H_L$$

or $$\frac{P_1}{\rho g} + 4 + (5 + y) = (10.3 + y) + 2 + 0.35 \times 2$$

$\therefore$ $$\frac{P_1}{\rho g} = 10.3 + 2 + 0.7 - 9$$

or $$\frac{P_1}{\rho g} = 4 \text{ m (abs)}$$

**34. (a)**

$$\text{Net head, } H = \text{Static lift + Friction loss}$$
$$= 40 + 1.5 + 7.5$$
$$= 49 \text{ m}$$

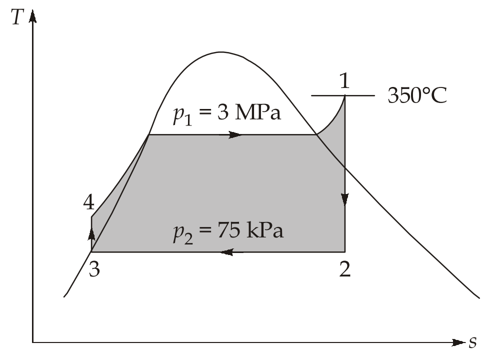
$$\text{Peripheral velocity at outlet, } U_2 = \frac{\pi \times 0.5 \times 1200}{60} = 31.42 \text{ m/s}$$

$$\text{Manometric efficiency, } \eta_{mano} = \frac{gH_{net}}{V_{w_2} \cdot U_2}$$

$\therefore$ $$V_{w_2} = \frac{9.81 \times 49}{31.42 \times 0.8} = 19.12 \text{ m/s}$$

**35. (c)**

Refer figure,




$$h_1 = 3116 \text{ kJ/kg}, h_2 = 2400 \text{ kJ/kg}, h_3 = 385 \text{ kJ/kg}$$

$$\text{Pump work, } w_p = v_f(P_1 - P_2) = 0.00104(3000 - 75)$$

$$w_p = 3.04 \text{ kJ/kg}$$

Enthalpy at state 4:

$$h_4 = h_3 + w_p = 385 + 3.04 = 388.04 \text{ kJ/kg}$$

$$\text{Rankine cycle efficiency, } \eta_{rankine} = 1 - \frac{h_2 - h_3}{h_1 - h_4}$$

$$\therefore \quad \eta_{rankine} = 1 - \frac{2400 - 385}{3116 - 388.04} = 0.2613 \text{ or } 26.13\%$$

**36. (b)**

$$\text{Back work ratio, } r_{bw} = \frac{\text{Pump work}}{\text{Turbine work}} = \frac{3.04}{3116 - 2400}$$

$$r_{bw} = 0.0042$$

**37. (c)**

$$\text{Work ratio, } r_w = \frac{W_{net}}{W_T} = \frac{(3116 - 2400) - 3.04}{3116 - 2400}$$

$$= 0.995$$

**39. (d)**

Anthracite is the next generation of bituminous coal and has the highest rank. It is a hard coal composed of about 90% carbon with little volatile content and practically no moisture, it has highest heating value, approximately 3600 kJ/kg.

**40. (b)**

Theoretical air required for complete combustion

$$= \frac{100}{23}\left[\frac{8}{3}C + 8\left(H - \frac{O}{8}\right) + S\right]$$

Considering 1 kg of coal,

$$\text{Mass of carbon} = 0.8 \text{ kg, and}$$
$$\text{Mass of hydrogen} = 0.12 \text{ kg}$$

$$\therefore \quad \left(\frac{A}{F}\right)_{th} = \frac{100}{23}\left[\frac{8}{3}\times 0.8 + 8\times 0.12 + 0\right]$$
$$= 13.45 \text{ kg/kg of fuel}$$

**42. (c)**

The La Mont boiler is a high-pressure, water tube type boiler. It works on a forced-circulation principle. The water circulation is maintained by a centrifugal pump.

**43. (b)**

A steam trap is a device that drains away the condensed steam and air automatically from the steam pipe, steam jackets or steam separator without discharging the steam.

**44. (d)**

Temperature of chimney gases for maximum discharge is given by

$$T_g = 2T_a\left[\frac{m_a + 1}{m_a}\right]$$
$$= 2\times 303\left[\frac{20+1}{20}\right] = 636.3 \text{ K}$$

**45. (d)**

Advantages of artificial draught over natural draught:

(i) Forced draught puts better control on combustion.

(ii) Low-grade fuel can be efficiently burnt.

(iii) Overall efficiency of a thermal power plant is higher due to better heat recovery from the exhaust flue gases in economisers and preheaters.

(iv) The height of the chimney can be reduced than that required in natural draught.

(v) Higher the rate of fuel-burning capacity on the grate, higher the heat-supply rate at higher effective temperature.

(vi) Smoke formation is less.

(vii) Tendency for air leakage in the furnace is less.

**46. (a)**

$$\text{Blade efficiency, } \eta_b = \frac{\text{Work done on the blade}}{\text{Energy supplied to the blade}}$$

**47. (d)**

In by-pass governing, when a steam turbine is overloaded, additional fresh steam is admitted through a by-pass valve to later stages of the turbine.

**48. (d)**

Jet condenser has low vacuum efficiency, thus it is less suitable for large plants.

**49. (c)**

$$T_{c_1} = 21°C;\ T_{c_2} = 35°C;\ T_{sat} = 42°C$$

$$\text{Condenser efficiency, } \eta_{cond} = \frac{\text{Temperature rise of cooling water}}{\text{Maximum possible temperature rise of water}}$$

$$\eta_{cond} = \frac{35 - 21}{42 - 21} = 0.667 \text{ or } 66.7\%$$

**50. (c)**

$\dot{m}_a$ = 30 kg/min = 0.5 kg/sec; $T_1$ = 30°C = 303 K; $T_2$ = 480 K; $n$ = 1.25

$$\therefore \quad \text{Indicated power, I.P.} = \frac{n}{n-1} \times \dot{m}_a R (T_2 - T_1)$$

$$\text{I.P.} = \frac{1.25}{0.25} \times 0.5 \times 0.287 \times (480 - 303)$$

$$= 126.99 \simeq 127 \text{ kW}$$

**51. (a)**

The motor brake power, $$\text{B.P.} = \frac{I.P.}{\eta_{mech}} = \frac{127}{0.8} = 158.75 \text{ kW}$$

**54. (c)**

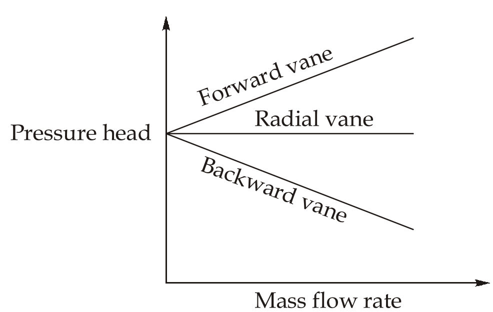



**Fig. : Characteristics of backward, radial and forward curved vanes**

**55. (c)**

A compressor stalling is a situation of abnormal air flow resulting from a reduction in the lift coefficient generated by an airfoil within the compressor. The stalling is the separation of flow from blade surface at low flow rates.

**56. (d)**

The blade velocity and flow velocity are related as

$$\frac{U}{V_f} = \tan\alpha_1 + \tan\beta_1$$

For 50% DOR

$$\alpha_1 = \beta_2 = 30°, \text{ and } \alpha_2 = \beta_1 = 45°$$

$$\therefore \quad V_f = \frac{150}{\tan 30° + \tan 45°} = 95 \text{ m/s}$$

**57. (a)**

Gas turbines runs at higher speed than steam turbines.

**59. (c)**

$$\text{Let } b_p \text{ at full load} = x \text{ kW}$$

$$\text{B.P. at 50\% of load} = 0.5x \text{ kW}$$

$$\text{I.P. at 50\% of load} = 0.5x + \text{F.P. kW}$$

where I.P. = Indicated power; B.P. = Brake power; F.P. = Friction power

At 50% load, $$\eta_{mech} = \frac{B.P.}{I.P.}$$

or $$0.7 = \frac{0.5x}{0.5x + F.P.}$$

$$\Rightarrow \quad 0.35x + 0.7\text{F.P.} = 0.5x$$

or $$\text{F.P.} = \frac{0.5x - 0.35x}{0.7} = 0.214x$$

It remains constant at all loads,

$$\text{I.P.} = 100 \text{ kW}$$

or $$x + 0.214x = 100 \text{ kW}$$

$$\Rightarrow \quad x = 82.37 \text{ kW}$$

**60. (b)**

Mechanical efficiency, at full load

$$\eta_{mech} = \frac{B.P.}{I.P.} = \frac{82.37}{100} = 0.8237 \text{ or } 82.37\%$$

$$\therefore \quad \eta_{ith} = \frac{\eta_{bth}}{\eta_{mech}} = \frac{30}{82.37}$$

$$\therefore \quad \eta_{ith} = 0.3642 \text{ or } 36.42\%$$

**61. (d)**

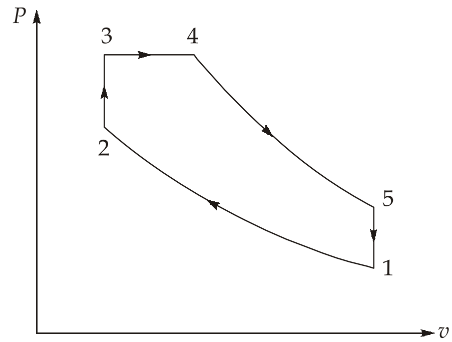
Indicated specific fuel consumption

$$isfc = bsfc \times \eta_{mech}$$

$$isfc = 0.25 \times 0.8237 = 0.206 \text{ kg/kWh}$$

**62. (c)**

Refer figure,




$$P_2 = 45 \text{ bar}; T_2 = 900 \text{ K}; P_3 = 60 \text{ bar}$$

Considering the process 2-3,

$$\frac{P_2 v_2}{T_2} = \frac{P_3 v_3}{T_3}$$

or $$T_3 = T_2 \times \frac{P_3}{P_2} \qquad (\because v_2 = v_3)$$

$\therefore$ $$T_3 = 900 \times \frac{60}{45} = 1200 \text{ K}$$

Given, $$Q_{2\text{-}3} = 2 \times Q_{3\text{-}4}$$

$\therefore$ $$C_V(T_3 - T_2) = 2C_p(T_4 - T_3)$$

$\therefore$ $$0.717(1200 - 900) = 2 \times 1.005(T_4 - 1200)$$

$$T_4 = 1307 \text{ K}$$

**63. (d)**

Following are the effects of knocking:

1. Noise and vibration
2. Increase in heat transfer
3. Mechanical damage
4. Preignition
5. Loss of power and efficiency
6. Carbon in the exhaust

**64. (c)**

An increase in spark advance from the optimised timing increases the peak pressure of the cycle and therefore increases the pressure and temperature to which last part of the charge is subjected.

**66. (c)**

In indirect injection swirl chamber, higher specific fuel consumption results in poorer fuel economy. It is because of greater heat losses and pressure losses through the throat which result in lower thermal efficiency and higher pumping losses.

**68. (c)**

For a given orifice and combustion chamber pressure, it is found that

$$s = f\left(t\sqrt{\Delta P}\right)$$

where $t$ is the time required for the spray to penetrate the distance $s$ and $\Delta p$ is the pressure difference between the injection pressure and the combustion chamber pressure.

If the penetration $s_1 = s_2$ then

$$t_1\sqrt{\Delta p_1} = t_2\sqrt{\Delta p_2}$$

$$\therefore \quad 15.7\sqrt{(184-15)} = t_2\sqrt{(456-15)}$$

$$\therefore \quad t_2 = 9.72 \text{ ms}$$

**70. (b)**

The structure of PLC is based on the same principles of computer architecture, it is capable of performing other functions such as counting, logistics, numerical applications, comparing and processing of signals.

**71. (c)**

**RAM :** RAM is for the user's program and data storage. It is designed so that information can be written into or read from the memory and normally incorporated in the solid-state form contained in an integrated circuit. Dynamic RAMs refreshed typically by external refresh circuits can hold data for few million seconds. Pseudo-static RAMs are refreshed internally, whereas the static RAM stored the data flip-flops.

**72. (b)**

Range of voltage span at input = 10 – 5 = 5V

If the error constitutes 2% of the input range then,

Change in input = 0.02 × 5 = 0.1V

Change in output = (15 – 0) × 0.05 = 0.75V

$$\therefore \quad \text{Gain} = \frac{0.75}{0.10} = 7.5$$

**73. (b)**

Address bus is a unidirectional bus used to transmit the address of a location in memory of I/O parts.

**74. (d)**

Sign flag is set when a negative result is produced in the accumulator. In other words, $S$ bit is a copy of $D_7$ bit of the accumulator. $D_7$ is 1 for a negative number, therefore, $S$ is set. $D_7$ is 0 for a positive number and so $S$ is reset.

**75. (a)**

The output voltage is given by,

$$V_0 = V_s \times t \times p$$
$$= 0.062 \times 2.4 \times 10^{-3} \times 2.04 \times 10^6$$
$$= 303.55\text{ V}$$

**76. (d)**

- The Hall effect sensor has the advantage of being able to operate as a switch and it can operate upto 100 kHz.
- Hall effect sensor is used to determine the carrier concentration.

**77. (c)**

Given : $m$ = 2 kg; $p_1$ = 0.1 MPa; $p_2$ = 0.4 MPa; $\rho_1$ = 1.2 kg/m$^3$

We have, $pv$ = constant (Given), So the process is isothermal

$$\therefore \quad W_{\text{net}} = mp_1v_1 \ln\frac{p_1}{p_2}$$

or

$$W_{\text{net}} = 2\times 0.1\times\frac{1}{1.2}\times\ln\left(\frac{0.1}{0.4}\right)\times 10^3$$
$$= -231\text{ kJ}$$

**78. (b)**

$$\text{Heat removed from the milk, } Q_1 = 41.87\text{ MJ/h}$$
$$\text{Heat leaked into the milk, } Q_2 = 4.187\text{ MJ/h}$$
$$\therefore \quad \text{Net heat transfer, } \dot{Q}_{net} = 41.87 - 4.187$$
$$= 37.683\text{ MJ/h}$$

Now, heat transfer from the milk is,

$$Q = mc_p\Delta T$$
$$= 500 \times 4.187 \times 50$$
$$= 104675\text{ kJ}$$

$\therefore$ Time required for this heat transfer,

$$t = \frac{Q}{\dot{Q}_{net}} = \frac{104675}{37.683\times 10^3} = 2.77\text{ hr}$$

**79. (b)**

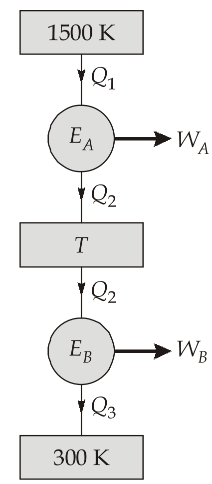
For same efficiency,

$$T = \sqrt{T_1 \cdot T_2} = \sqrt{1500\times 300} = 670.82\text{ K}$$

**80. (c)**

Refer figure,

For engine 'A'




$$\frac{Q_1}{T_1} = \frac{Q_2}{T}$$

$$\therefore \quad Q_2 = \frac{T}{T_1} \times Q_1$$

$$Q_2 = \frac{670.82}{1500} \times 2100 = 939.15 \text{ kJ}$$

Now, for engine 'B'

$$\frac{Q_3}{T_3} = \frac{Q_2}{T}$$

$$\therefore \quad Q_3 = \frac{T_3}{T} \times Q_2 = \frac{300}{670.82} \times 939.15$$

$$\therefore \quad Q_3 = 420 \text{ kJ}$$

**81. (a)**

Given : $Q_1$ = 420 kJ; $T_1$ = 327°C = 600 K; $Q_2$ = 210 kJ; $T_2$ = 27°C = 300 K

Now, $$\oint \frac{dQ}{T} = 0$$

$$\therefore \quad \frac{Q_1}{T_1} - \frac{Q_2}{T_2} = 0$$

$$\therefore \quad \frac{420}{600} - \frac{210}{300} = 0$$

$0 = 0$, hence given cycle is reversible

**82. (c)**

Given : $h_1$ = 4200 kJ/kg; $h_2$ = 2600 kJ/kg; $\phi_1$ = 1800 kJ/kg; $\phi_2$ = 150 kJ/kg; $T_0$ = 300 K

Actual work/kg of steam, $W_{act} = h_1 - h_2 = 4200 - 2600 = 1600$ kJ/kg

Maximum possible work/kg of steam,

$$W_{rev} = \phi_1 - \phi_2 = 1800 - 150 = 1650 \text{ kJ/kg}$$

Now, Irreversibility, $T_0 s_{gen} = W_{rev} - W_{act}$

$$\therefore \quad s_{gen} = \frac{1650 - 1600}{300} = 0.167 \text{ kJ/kgK} \simeq 0.17 \text{ kJ/kgK}$$

**83. (c)**

The sublimation line separates the solid and vapour regions, the vaporization line separates the liquid and vapour regions and the melting (or fusion) line separates the solid and liquid regions.

**84. (c)**

Given : $D$ = 10000 units/year, $P$ = 2000 × 12 = 24000 units/year, $C_0$ = Rs. 400/setup,
$C_h$ = Rs.0.2 × 12 = Rs.2.4/unit/year

$$\therefore \quad \text{Optimum lot size, EOQ, } Q^* = \sqrt{\frac{2C_0D}{C_h}} \times \sqrt{\frac{P}{P-D}}$$

$$Q^* = \sqrt{\frac{2 \times 400 \times 10000}{2.4}} \times \sqrt{\frac{24000}{24000-10000}}$$

$$Q^* = 2390.45 \simeq 2391 \text{ units}$$

**85. (c)**

Free float is that portion of the total float within which an activity can be manipulated without affecting the floats of subsequent activities.

**86. (b)**

Given : $s$ = Rs.15, $v$ = Rs 12, $F$ = 120000

$$\therefore \quad \text{BEP, } x = \frac{F}{s-v} = \frac{120000}{15-12} = 40000 \text{ units}$$

$$\therefore \quad \text{Margin of safety, MOS} = 50000 - 40000 = 10000 \text{ units}$$

**88. (b)**

Magnetic particle testing is specifically designed to identify surface and near-surface defects in ferromagnetic materials.

**89. (d)**

The apparent viscosity of a pseudoplastic fluid decreases with increases in the shear rate.

**90. (c)**

For turbulent flow over flat plate

$$\text{Boundary layer thickness : } \delta = \frac{0.38x}{(Re_x)^{1/5}}$$

$$\text{Local skin friction coefficient : } C_{f_x} = \frac{0.059}{(Re_x)^{1/5}}$$

**91. (d)**

- Flows where streamlines are concentric circles and tangential velocity is directly proportional to the radius of curvature are known as plane circular force vortex flow.
- Free vortex flows are the plane circular vortex flow where the total mechanical energy remains constant in the entire flow field.

**92. (a)**

Given : $D_1$ = 150 mm; $L_1$ = 300 m; $f_1$ = 0.024; $D_2$ = 450 mm; $f_2$ = 0.018

$$\text{Frictional head loss, } (h_f)_1 = (h_f)_2$$

$$\Rightarrow \quad \frac{8f_1L_1Q^2}{\pi^2 g D_1^5} = \frac{8f_2L_2Q^2}{\pi^2 g D_2^5}$$

$$\Rightarrow \quad \frac{f_1L_1}{D_1^5} = \frac{f_2L_2}{D_2^5}$$

$$\Rightarrow \quad L_2 = \frac{f_1 L_1}{f_2 D_1^5} \times D_2^5$$

$$= \frac{0.024 \times 300 \times (450)^5}{0.018 \times (150)^5} = 400 \times 3^5$$

$$= 400 \times 243 = 97200 \text{ m}$$

**93. (b)**

$$\vec{V} = 2xz^2\hat{i} - 3xyt\hat{j} - yz^2t^2\hat{k}$$

$$\Rightarrow \quad u = 2xz^2, \quad v = -3xyt, \quad w = -yz^2t^2$$

The convective acceleration in $y$-direction is given as

$$[a_y]_{\text{convective}} = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}$$

$$= (2xz^2)(-3yt) + (-3xyt)(-3xt) + (-yz^2t^2)(0)$$

$$= -6xyz^2t + 9x^2yt^2 + 0$$

$$= -6(-1)(1)(2)^2(2) + 9(-1)^2(1)(2)^2$$

$$= 48 + 36$$

$$= 84 \text{ units}$$

**94. (c)**

$$u = 2xz^2, \; v = -3xyt \text{ and } w = -yz^2t^2$$

The temporal acceleration in $z$-direction is given as

$$[a_z]_{\text{temporal}} = \frac{\partial w}{\partial t}$$

$$= \frac{\partial}{\partial t}\left(-yz^2t^2\right) = -2yz^2t$$

$$= -2(-1)(-2)^2(2)$$

$$= 16 \text{ units}$$

**95. (d)**

$$\vec{V} = (2x + y)\hat{i} + (x - 2y)\hat{j}$$

$$\Rightarrow \quad u = 2x + y \text{ and } v = x - 2y$$

Slope of potential line is given as

$$\frac{dy}{dx} = \frac{-u}{v}$$

$$= \frac{-(2x + y)}{(x - 2y)}$$

$$\left(\frac{dy}{dx}\right)_{(3,-2)} = \frac{-(2(3) + (-2))}{(3) - 2(-2)} = \frac{-(6 - 2)}{3 + 4}$$

$$= \frac{-4}{7}$$

**96. (a)**

$$Re = 1600$$

As Re < 2200, so the flow is laminar.

For laminar flow through pipe, Darcy friction is given as:

$$f = \frac{64}{Re} = \frac{64}{1600} = 0.04$$

**97. (c)**

Given : $\Delta P$ = 160 Pa; $D$ = 3 mm; $R = \frac{D}{2} = 1.5$ mm = 0.0015 m

For air bubble in water:

$$\Delta P = \frac{2\sigma}{R}$$

$$\Rightarrow \quad \sigma = \frac{\Delta P \times R}{2} = \frac{160 \times 0.0015}{2}$$

$$= 0.120 \text{ N/m}$$

**98. (c)**

Glass and plastic surfaces are generally considered to be hydrodynamically smooth surfaces because the viscous sublayer submerges the roughness elements.

**99. (a)**

Given : $x$ = 70 cm = 700 mm; $(Re)_{x = 70\text{ cm}} = 19600$

As Re < $5 \times 10^5$, so the flow is laminar

For laminar flow over flat plate, boundary layer thickness is given as

$$\delta = \frac{5x}{\sqrt{Re_x}} = \frac{5 \times 700}{\sqrt{19600}} = \frac{5 \times 700}{140}$$

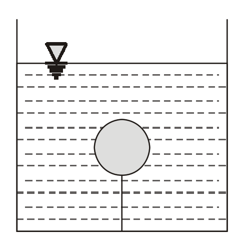
$$= 25 \text{ mm}$$

**100. (b)**

Given : $D$ = 80 cm = 0.8 m, $T$ = 2 kN

At static equilibrium,

Tension in the string + Weight of ball = Buoyancy force



$$T + W = \rho g V$$

$$T + W = \rho g \frac{4}{3}\pi R^3$$

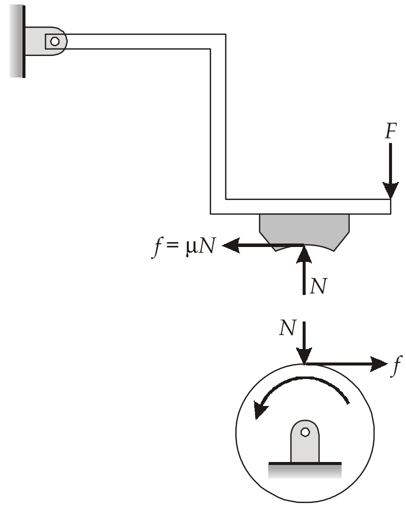
$$2000 + W = 1000 \times 9.81 \times \frac{4}{3} \times \pi \times \left(\frac{0.8}{2}\right)^3$$

$$\Rightarrow \quad 2000 + W = 2629.89$$

$$\Rightarrow \quad W = 629.89 \text{ N}$$

$$\Rightarrow \quad W = 630 \text{ N}$$

**101. (b)**




For anti-clockwise rotation of drum, the friction force ($f = \mu N$) helps to reduce the magnitude of the actuating force ($F$). Hence, it is self emergizing for anti-clockwise rotation of the drum.

**102. (a)**

Given : $D_o$ = 80 mm; $D_i$ = 40 mm; $R_o = \frac{D_o}{2}$ = 40 mm; $R_i = \frac{D_i}{2}$ = 20 mm; $\mu$ = 0.5; $P_{max}$ = 2 MPa; $n$ = 1

According to the uniform wear theory,

$$T_{f,\max} = n\mu\pi P_{\max}\left(R_o^2 - R_i^2\right)R_i$$

$$= 1 \times 0.5 \times \pi \times 2 \times (40^2 - 20^2) \times (20 \times 10^{-3})$$

$$= 75.398 \text{ Nm} \simeq 75.4 \text{ Nm}$$

**103. (c)**

The horizontal component ($F_H$) is parallel to the axis of the rivets has following effects:

- A direct tensile force on each rivet.
- A turning moment about the centre of gravity ($G$) of four rivets in clockwise direction.

**104. (a)**

The vertical component ($F_V$) is perpendicular to the axis of the rivets has following effects:

- A direct shear force on the each rivet.
- A turning moment about the tilting edge C in clockwise direction.

**105. (d)**

Given : $S_{yt}$ = 240 MPa; $\mu$ = 0.28

According to the total strain energy theory,

$$\frac{S_{ys}}{S_{yt}} = \frac{1}{\sqrt{2(1+\mu)}}$$

$$\Rightarrow \quad S_{ys} = \frac{S_{yt}}{\sqrt{2(1+\mu)}} = \frac{240}{\sqrt{2(1+0.28)}}$$

$$= \frac{240}{\sqrt{2.56}} = \frac{240}{1.6} = 150 \text{ MPa}$$

**106. (c)**

Diameter, $D_A = 3D_B$

Power transmission capacity of shaft,

$$(\text{PTC}) \propto \text{Section modulus of shaft}$$

$$(\text{PTC}) \propto D^3$$

$$\Rightarrow \quad \frac{(PTC)_A}{(PTC)_B} = \left(\frac{D_A}{D_B}\right)^3$$

$$= (3)^3 = 27$$

$$\Rightarrow \quad (\text{PTC})_A = 27 \times (\text{PTC})_B$$

**107. (b)**

Given : $M$ = 12 kNm; $T$ = 16 kNm; $D$ = 100 mm

According to the maximum shear stress theory,

$$T_e = \sqrt{M^2 + T^2}$$

$$\Rightarrow \quad \frac{\pi}{16} D^3 \tau = \sqrt{M^2 + T^2}$$

$$\Rightarrow \quad \frac{\pi}{16} \times (100)^3 \times \tau = \sqrt{12^2 + 16^2} \times 10^6$$

$$\Rightarrow \quad \tau = \frac{20 \times 10^6 \times 16}{\pi \times 100^3}$$

$$\Rightarrow \quad \tau = 101.859 \text{ MPa} \simeq 102 \text{ MPa}$$

**108. (c)**

$$\sigma_{max} = \sqrt{40^2 + 30^2} = 50 \text{ MPa}$$

$$\sigma_{min} = -\sqrt{40^2 + 30^2} = -50 \text{ MPa}$$

$$\text{Mean stress, } \sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = \frac{50 - 50}{2} = 0$$

$$\text{Stress amplitude, } \sigma_a = \left|\frac{\sigma_{max} - \sigma_{min}}{2}\right| = \left|\frac{50 - (-50)}{2}\right| = 50 \text{ MPa}$$

**109. (a)**

Given : $S_{yt}$ = 300 MPa; $S_{ut}$ = 500 MPa; $S_e$ = 200 MPa

According to the Soderberg's criterion;

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{yt}} = \frac{1}{N}$$

$$\frac{50}{200}+\frac{0}{300} = \frac{1}{N}$$

$$\Rightarrow \quad N = \frac{200}{50} = 4$$

**111. (c)**

Given : $d$ = 10 mm; $M_t$ = 12 Nm

The maximum torsional shear stress induced in the spring wire is

$$\tau_{max} = \frac{16M_t}{\pi d^3} = \frac{16\times12\times10^3}{\pi\times10^3}$$

$$= 61.11 \text{ MPa}$$

**113. (d)**

The principal types of gear tooth wear are:

- Abrasive wear
- Corrosive wear
- Initial pitting
- Destructive pitting
- Scoring

Since all the given wears, the correct option is (d).

**114. (c)**

- Non-conventional sources are available in nature free of cost.
- They produce no or very little pollution. Thus, by and large, they are environment friendly.
- They are inexhaustible.
- They have a low gestation period.

**115. (a)**

**Water has the following advantages:**

1. It is abundant and inexpensive.
2. It is easy to handle, non-toxic and non-combustible.
3. Its flow can take place by thermo-siphon action.
4. It has high density, high specific heat, good thermal conductivity and low viscosity.
5. Can be used both as storage medium as well as working medium (thus eliminating the need for a heat exchanger, e.g., in a space-heating system)
6. Charging and discharging of heat can occur simultaneously.
7. Control of water system is flexible.

**The main disadvantages with water as storage media are :**

1. Limited temperature range (0°C to 100°C).
2. Corrosive medium.
3. Low surface tension (i.e., leaks easily).

**117. (c)**

The electric current ($I$) is obtained in the external circuit is the difference between the solar light generated current ($I_L$) and diode dark function current ($I_j$).

$$I = I_L - I_j$$

$$= I_{sc} - \left[I_0\left\{\exp\left(\frac{eV}{kT}\right) - 1\right\}\right]$$

**118. (d)**

$$WT = 1100 \text{ hours; } L_{Lo} = 72.5°\text{E; } L_{st} = 82.5°\text{E}$$

$\therefore$ Solar time, ST $= WT - 4(L_{st} - L_{Lo})$

$$= 1100 - 4 \times (82.5 - 72.5)$$

$$= 1020 \text{ hours}$$

$\therefore$ Hour angle ($\omega$) $= 15°(\text{ST} - 1200)$

$$= 15° \times (1020 - 1200) = -25°$$

**119. (c)**

**Line focus (one axis tracking):**

(a) Cylindrical parabolic concentraor
(b) Fixed mirror solar concentrator
(c) Linear fresnel lens collector

**Point focus (two-axis tracking)**

(a) Paraboloidal dish collector
(b) Hemispherical bowl mirror concentrator
(c) Circular fresnel lens concentrator
(d) Central Tower receiver

**120. (a)**

Actual power density is given by

$$\left(\frac{P}{A}\right)_{Actual} = \eta_{\max} \times (P_{total}) = \eta_{\max} \times \frac{1}{2} \times \rho \times U_\infty^3$$

$$= 0.46 \times \frac{1}{2} \times 1.2 \times 15^3 = 931.5 \text{ W/m}^2$$

**121. (b)**

Maximum axial thrust for maximum power extraction is given by

$$(F_{\text{axial}})_{\max} = \frac{\pi}{9}\rho D^2 \times U_\infty^2$$

$$= \frac{\pi}{9} \times 1.2 \times 10^2 \times 15^2$$

$$= 9424.78 \text{ N}$$

**122. (b)**

Thermal insulation is bad as heat loss due to steel drum.

**123. (a)**

The fuel used in Alkaline fuel cell must be free from carbon dioxide gas because carbon dioxide gas can combine with potassium hydroxide electrolyte to form potassium carbonate. This increases the electrical resistance of the cell, which in turn decreases the available output voltage of the cell.

**124. (c)**

Let the thickness be : $l$, $2l$ and $3l$

and thermal conductivities be : $2k$, $3k$ and $4k$

The heat flux through all the layers remains the same.

Hence,
$$q = \frac{\Delta T_1}{\left(\frac{l_1}{k_1}\right)} = \frac{\Delta T_2}{\left(\frac{l_2}{k_2}\right)} = \frac{\Delta T_3}{\left(\frac{l_3}{k_3}\right)}$$

$$\Delta T_1 : \Delta T_2 : \Delta T_3 = \frac{ql_1}{k_1} : \frac{ql_2}{k_2} : \frac{ql_3}{k_3}$$

$$= \frac{l_1}{k_1} : \frac{l_2}{k_2} : \frac{l_3}{k_3} = \frac{l}{2k} : \frac{2l}{3k} : \frac{3l}{4k}$$

$$= \frac{1}{2} : \frac{2}{3} : \frac{3}{4} = 6 : 8 : 9$$

**125. (a)**

Given : $\in = 5$; $\eta = 25\% = 0.25$; $q_{actual} = 10$ W

The fin efficiency is given as,

$$\eta_{fin} = \frac{\text{Actual heat loss from the fin}}{\text{Heat loss from fin when entire fin surface it at base temperature}}$$

$$\eta_{fin} = \frac{q_{actual}}{q_{max\,possible}}$$

$$\Rightarrow \quad q_{max\ possible} = \frac{q_{actual}}{\eta_{fin}} = \frac{10}{0.25} = 40\,\text{W}$$

**126. (a)**

- $$\text{Schmidt number} = \frac{\text{Kinematic viscosity}}{\text{Mass diffusivity}}$$
- $$\text{Prandtl number} = \frac{\text{Kinematic viscosity}}{\text{Thermal diffusivity}}$$
- $$\text{Lewis number} = \frac{\text{Thermal diffusivity}}{\text{Mass diffusivity}}$$
- $$\text{Grashof number} = \frac{\text{Bouyancy force}}{\text{Viscous force}}$$

**127. (d)**

Using Wien's displacement law:

$$\lambda_m \cdot T = 2898 \ \mu\text{m-K}$$

$$\Rightarrow \quad \lambda_m = \frac{2898}{T} = \frac{2898}{4000}$$

$$= 0.7245 \ \mu\text{m} = 724.5 \text{ nm} \simeq 725 \text{ nm}$$

**128. (d)**

Given : $T_1 = 150°C$; $T_2 = 50°C$; $\Delta x = 50$ mm; $K = 350$ W/mK

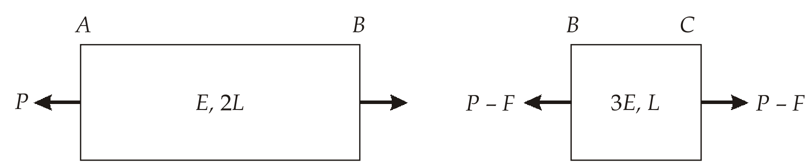
From Fourier's law, heat flux is given as

$$q = -k\frac{dT}{dx} = -k\frac{(T_2 - T_1)}{\Delta x} = -350 \times \frac{(50-150)}{(50 \times 10^{-3})}$$

$$= 70000 \text{ W}$$

$$= 700 \text{ kW}$$

**129. (a)**




The deflection of $A$ is given as

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

$$\frac{P(2L)}{A(E)} + \frac{(P-F)L}{A(3E)} = 0$$

$$\Rightarrow \quad \frac{L}{AE}\left[2P + \frac{P-F}{3}\right] = 0$$

$$\Rightarrow \quad 6P + P - F = 0$$

$$\Rightarrow \quad 7P = F$$

$$\Rightarrow \quad \frac{F}{P} = 7$$

**130. (d)**

Given : $\Delta\sigma = 300$ MPa; $\Delta\varepsilon_L = 0.001$; $\mu = 0.3$

$$\text{Young's modulus, } E = \frac{\Delta\sigma}{\Delta\varepsilon_L} = \frac{300}{0.001} = 300 \text{ GPa}$$

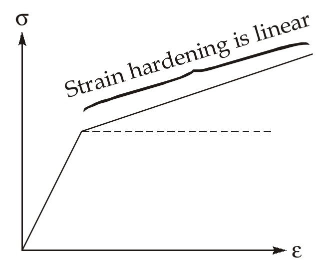
The relation between elastic constant is given as

$$E = 2G(1 + \mu)$$

$$\Rightarrow \quad G = \frac{E}{2(1+\mu)} = \frac{300}{2(1+0.3)}$$

$$= \frac{300}{2.6} = 115.38 \text{ GPa} \simeq 115.4 \text{ GPa}$$

**131. (d)**




**132. (c)**

Given : $L$ = 1 m; $\alpha = 10^{-5}$ per °C; $E$ = 200 GPa; $\Delta T$ = 100°C; $e$ = 0.5 mm

$$\text{Thermal expansion, } \delta = L\alpha\Delta T = 1000 \times 10^{-5} \times 100 = 1 \text{ mm}$$

From δ, $e$ = 0.5 mm expansion is free and remaining is restricted.

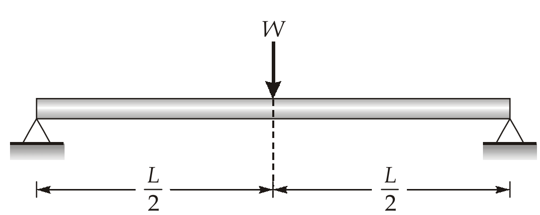
The restricted expansion will result in stress in the component.

$$(\delta - e) = \frac{\sigma L}{E}$$

$$\Rightarrow \quad \sigma = (\delta - e) \times \frac{E}{L} = (1 - 0.5) \times \frac{200}{1000}$$

$$= 0.1 \text{ GPa} = 100 \text{ MPa}$$

**133. (d)**




Given : $L$ = 10 m; $EI = 200 \times 10^6$ Nm$^2$

The maximum deflection of the beam is given as:

$$\Delta = \frac{WL^3}{48EI}$$

$$\Rightarrow \quad \text{Stiffness} = \frac{W}{\Delta} = \frac{48EI}{L^3}$$

$$= \frac{48 \times (200 \times 10^6)}{10^3}$$

$$= 9.6 \times 10^6 \text{ N/m} = 9.6 \text{ MN/m}$$

**134. (d)**

Given : $d_i$ = 800 mm; $P$ = 15 MPa; $\sigma_{working}$ = 160 MPa

Hoop stress for spherical pressure vessel,

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

$$\Rightarrow \quad t = \frac{Pd_i}{4\sigma} = \frac{15 \times 800}{4 \times 160} = 18.75 \text{ mm}$$

**135. (d)**

| Materials | Number of independent elastic constants |
|---|---|
| Isotropic | 2 |
| Orthotropic | 9 |
| Anisotropic | 21 |

**136. (c)**

Given : $\sigma_x$ = 100 kPa; $\sigma_y$ = –80 kPa; $\tau_{xy}$ = 120 kPa

$$\text{Radius of Mohr circle} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \sqrt{\left(\frac{100-(-80)}{2}\right)^2 + (120)^2} = \sqrt{90^2 + 120^2}$$

$$= 150 \text{ kPa}$$

**137. (b)**

Given : $L$ = 1 m; $W$ = 600 N; $EI$ = 20 kNm$^2$

For cantilever beam with transverse shear load $W$,

$$\delta_1 = \text{Deflection at mid location}$$

$$= \frac{WL^3}{3EI}$$

$$\delta_2 = (\text{Slope at mid location}) \times L$$

$$= \frac{WL^2}{2EI} \times L$$

$$\text{Deflection at the tip, } \delta = \delta_1 + \delta_2$$

$$= \frac{WL^3}{3EI} + \frac{WL^3}{2EI} = \frac{5WL^3}{6EI}$$

$$= \frac{5 \times 600 \times 1^3}{6 \times 20000} = 0.025 \text{ m} = 25 \text{ mm}$$

**138. (b)**

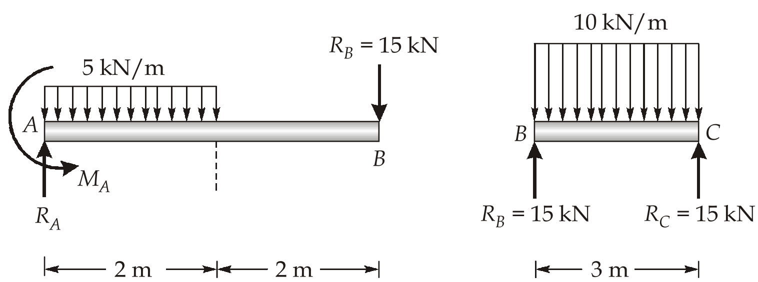
At internal hinge point $B$, the bending moment should be zero.

Hence,
$$\Sigma M_{right} = 0; \quad R_C \times 3 - (10 \times 3) \times 1.5 = 0$$

$$\Rightarrow \quad R_C = \frac{10 \times 3 \times 1.5}{3} = 15 \text{ kN}$$

$$R_B = (10 \times 3) - R_C = 30 - 15 = 15 \text{ kN}$$

**139. (a)**




Taking moment about point $A$,

$$M_A - (5 \times 2) \times 1 - 15 \times 4 = 0$$

$$\Rightarrow \quad M_A = 10 + 60 = 70 \text{ kNm}$$

**140. (d)**

Inversion of single slider crank chain

| Single Slider Crank Inversion | Application |
|---|---|
| (i) Cylinder is fixed | • Reciprocating engine<br>• Reciprocating compressor |
| (ii) Crank is fixed | • Whitworth quick return mechanism<br>• Rotary engine (GNOME engine) |
| (iii) Connecting rod is fixed | • Oscillating cylinder engine<br>• Crank and slotted-lever mechanism |
| (iv) Piston (slider) is fixed | • Hand pump<br>• Pendulum pump |

**141. (a)**

$$P_C = 11 \text{ mm}$$

The diametral pitch of spur gear is given as

$$P_d = \frac{\pi}{P_c} = \frac{22}{7} \times \frac{1}{11}$$

$$= \frac{2}{7} \text{ tooth/mm}$$

**142. (c)**

Given : $T_1 = 80$; $T_2 = 50$; $m = 5$ mm

$$\text{Module, } m = \frac{D}{T}$$

$$\Rightarrow \quad D_1 = mT_1 = 5 \times 80 = 400 \text{ mm}$$

$$\text{and} \quad D_2 = mT_2 = 5 \times 50 = 250 \text{ mm}$$

$$\text{Centre distance} = \frac{D_1 + D_2}{2} = \frac{400 + 250}{2} = 325 \text{ mm}$$

**143. (a)**

Given : $s = 80$ mm; $l = 190$ mm; $p = 120$ mm; $q = 150$ mm

Clearly $s + l = p + q = 270$ mm

Hence, $s + l \leq p + q$ [Grashof's law is satisfied]

If link 120 mm is fixed, then the shortest link becomes coupler for the mechanism. Hence, the mechanism will be a double rocker resulting in no crank. So, the number of links that can rotate fully is zero.

**145. (c)**

Pressure angle of a cam profile:

- It represents the steepness of the cam profile.
- It varies in magnitude at all instants of the follower motion.
- It is the angle between the normal to the pitch curve at a point and the direction of the follower motion.

**146. (c)**

The height of a Watt governor is inversely proportional to the square of the speed. At high speeds, the movement of the sleeve becomes very small and thus this type of governor is unsuitable for high speed applications.

**147. (b)**

Given : $R_g = 2$ m; $W = 20000$ N; $g = 10$ m/s$^2$; $N_{max} = 130$ rpm; $N_{min} = 120$ rpm

$$\text{Mass moment of inertia, } I = \frac{W}{g}R_g^2 = \frac{20000}{10} \times 2^2 = 8000 \text{ kgm}^2$$

Maximum fluctuation of energy,

$$(\Delta E)_{max} = \frac{1}{2}I\left(N_{max}^2 - N_{min}^2\right)\left(\frac{2\pi}{60}\right)^2$$

$$= \frac{1}{2} \times 8000 \times \left(130^2 - 120^2\right)\left(\frac{2\pi}{60}\right)^2$$

$$= 109662.27 \text{ Nm} \simeq 109662 \text{ Nm}$$

**148. (a)**

Given : $r$ = 200 mm; $l$ = 800 mm; ω = 20 rad/s

Angular velocity of connecting rod,

$$\omega_{CR} = \frac{r\omega}{l}\cos\theta$$

$$\Rightarrow \quad [\omega_{CR}]_{max} = \frac{r\omega}{l} = \frac{200 \times 20}{800} = 5 \text{ rad/s}$$

**149. (c)**

The static vertical displacement of the tip of cantilever beam due to the weight $W$ is given as

$$\Delta_{static} = \frac{WL^3}{3EI}$$

Using Rayleigh's method, the natural frequency of vibration is given as,

$$\omega_n = \sqrt{\frac{g}{\Delta_{static}}}$$

$$= \sqrt{\frac{g}{\left(\frac{WL^3}{3EI}\right)}} = \sqrt{\frac{3EIg}{WL^3}}$$

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