DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 26

Full Syllabus Test-10 (Paper-II)

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

DETAILED EXPLANATIONS

1. (c)

$$\text{Sensitivity} = \frac{\text{Change in output}}{\text{Change in input}} = \frac{10}{10} = 1\ \text{mV}/\,^\circ\text{C}$$

Resolution is the minimum input change that should be applied to the sensor such that the output of the sensor such that the output of the sensor changes from its previous value to next possible value.

In the range of input 0°C < T < 10°C thermocouple sensor become insensitive.

2. (a)

Polar (spherical) arm configuration also known by RRP joint configuration.

4. (b)

$$\text{Electric power required by motor} = \frac{750}{0.75} = 1000\ \text{W}$$

$$\text{Cell area in one module} = 40 \times 120 \times 120 \times 10^{-6}$$
$$= 0.576\ \text{m}^2$$
$$\text{Solar radiation incident on panel} = 1\ \text{kW/m}^2 = 1000\ \text{W/m}^2$$
$$\text{Output of solar array} = 1000 \times 0.576 \times \text{N} \times 0.1$$
$$= 57.6\ \text{N}$$

Output of solar array is input to the motor,

$$57.6\,N = 1000$$
$$N = 17.36 \approx 18$$

5. (a)

Total potential energy of water stored in the basin is:

$$W = \int_r^R \rho \cdot A \cdot g \cdot h \cdot dh = \frac{1}{2} \times \rho \cdot A \cdot g\left(R^2 - r^2\right) \text{Joules}$$

Where, ρ = Density of water

g = Gravitational constant

As the time between consecutive high and low tides is 6 hours 12.5 min (22, 350s),

$$P_{avg} = \frac{1025 \times 9.81 \times A \times \left(R^2 - r^2\right)}{2 \times 22350}$$

$$P_{avg} = 0.225 \times A \times (R^2 - r^2)$$

$A = 2\ \text{km}^2$, $R = 13$ m, $r = 3$ m, $\eta_{gen} = 0.7$

$$\therefore \quad P_{avg} = 72 \times 0.7 = 50.4\ \text{MW}$$

6. **(c)**

$$P_{\text{available at turbine}} = \frac{1}{2}\rho A V^3 = \frac{1}{2}\times 1.2\times\pi\times 60^2\times\left(\frac{18\times 5}{18}\right)^3$$

$$= \frac{1}{2}\times 1.2\times\pi\times 60^2\times 3600\times 125$$

$$= 1800\times 1.2\times\pi\times 125$$

$$= 1800\times 150\times\pi$$

$$= 848.23 \text{ kW}$$

7. **(c)**

As per given

$$\text{Young modulus, } E = 9\times 10^{10} \text{ N/m}^2$$

$$\text{Diameter, } d = 15\times 10^{-3} \text{ m}$$

$$\text{Thickness, } t = 3\times 10^{-3} \text{ m}$$

$$\text{Sensitivity} = \frac{Vo}{\Delta t} = \frac{4500V}{\mu\text{m}} = 4500\times 10^6 \text{ V/m}$$

$$\Delta t = \frac{Vo}{4500\times 10^6}$$

$$\frac{F\times t}{AE} = \frac{127.3}{4500\times 10^6}$$

$$F = \frac{127.3\times\frac{\pi}{4}(0.015)^2\times 9\times 10^{10}}{4500\times 10^6\times 3\times 10^{-3}}$$

$$= \frac{127.3\times\frac{\pi}{4}\times 15\times 15\times 10^{-6}\times 9\times 10^{10}}{4500\times 10^6\times 3\times 10^{-3}} = \frac{127.3\times\pi\times 10\times 9}{20\times 3\times 4}$$

$$F = \frac{127.3\times 3.14\times 9}{6\times 4} = 149.89 \text{ N}$$

9. **(a)**

As per given,

$$\gamma = \frac{c_p}{c_v} = 1.4$$

$$T_4 = 700 \text{ K}$$

$$\text{Turbine output} = c_p(T_3 - T_4) = 336.5 \text{ kJ/kg}$$

$$(T_3 - T_4) = \frac{336.5}{1.005} = 334.8 \text{ K}$$

$$T_3 = 334.8 + T_4$$

$$= 334.8 + 700 = 1034.8 \text{ K}$$

$$\text{Pressure ratio} = \frac{p_3}{p_3} = \left(\frac{T_3}{T_4}\right)^{\frac{\gamma}{\gamma-1}} = \left(\frac{1034.8}{700}\right)^{\frac{1.4}{0.4}} = \left(\frac{1034.8}{700}\right)^{7/2}$$

10. (c)

Maximum acceleration in the suction pipe,

$$H_{as} = \frac{L_s}{g}\left(\frac{A}{A_s}\right) r\omega^2$$

$L_s = 5.0$ m, $g = 10$ m, $A = \dfrac{\pi \times (0.2)^2}{4}$

$$A_s = \frac{\pi}{4}(0.1)^2$$

$$r = 0.2 \text{ m}, \omega = 3 \text{ rad/s}$$

$$H_{as} = \frac{L_s}{g}\left(\frac{A}{A_s}\right) r\omega^2 = \frac{5.0}{10} \times \left(\frac{0.2^2}{0.1^2}\right) \times 0.2 \times 3^2$$

$$= \frac{1}{2} \times 4 \times 0.2 \times 3^2 = 3.6 \text{ m}$$

At limiting condition for suction pipe,

$$(H_{p,\ \min}) = H_{atm} - H_s - H_{as}$$

$$2.5 = 10.0 - H_s - 3.6$$

$$H_s = 3.9 \text{ m}$$

11. (a)

As per given data:

$$D_2 = 0.20 \text{ m}, Q = 1800 \text{ L/min}, B_2 = 0.03 \text{ m}$$

$$Q = \frac{1800}{1000 \times 60} = 0.03 \text{ m}^2/\text{s}$$

$$\text{Discharge, } \pi D_2 b_2 V_{f2} = 0.03 \text{ m}^3/\text{s}$$

$$\pi \times 0.2 \times 0.03 \times V_{f2} = 0.03 \text{ m}^3/\text{s}$$

$$V_{f2} = \frac{1}{0.2 \times \pi} = \frac{5}{22} \times 7 = 1.59 \text{ m/s}$$

12. (b)

Optimum pressure ratio of maximum work output

$$(r_{opt}) = \left(\eta_o \eta_T \frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{2(\gamma-1)}}$$

$\eta_c = 0.8$, $\eta_T = 0.8$, $T_{max} = 1120$ K, $T_{min} = 280$ K

$$(r_p)_{opt} = \left(0.8 \times 0.8 \times \frac{1120}{280}\right)^{\frac{1.5}{2(1.5-1)}} = (2.56)^{1.5/1}$$

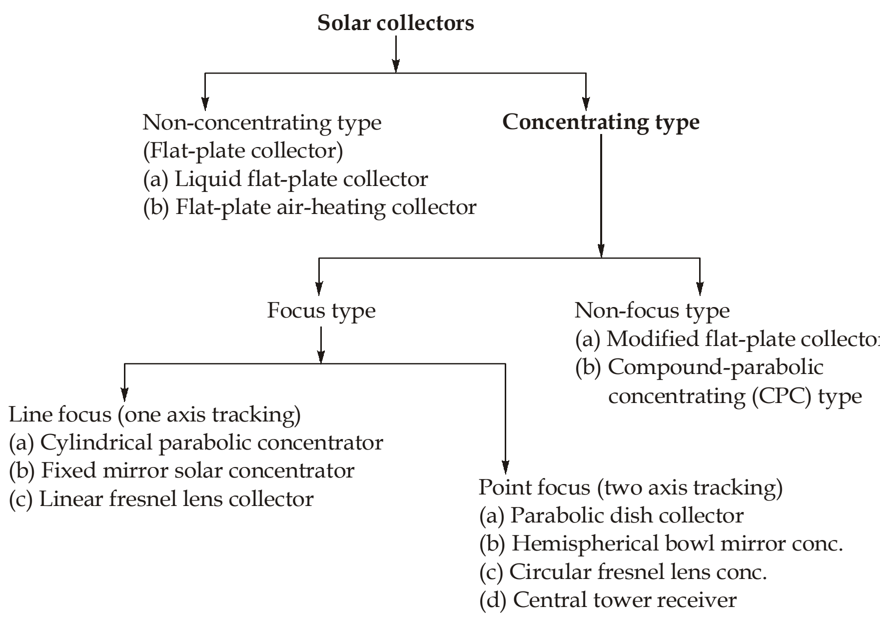
$$= (2.56)^{1.5} = [(2.56)^{1/2}]^3$$

$$= [1.6]^3 = 4.096 \approx 4.0$$

13. (a)

Tip speed ratio is the ratio of the linear speed of the tip of the blade to the wind speed. For lift design, it is more than one and for drag design, it is less than one.

14. (c)



Types of solar collectors

15. (d)

1. Process layout is suitable when the output variety is large and volumes are low.
2. In cellular layout, groups of similar parts or products can be made on the same equipment without significant loss of time for changeovers.
3. Being flexible in approach, process layout uses general purpose machines for a variety of outputs.
4. Material handling in process layout depends upon standard operations hence work in process inventory is there.

16. (d)

$$F_D = 30, \quad D_D = 25$$

$$F_{\alpha = 0.23} = F_D + \alpha_1 [D_D - F_D], \quad \alpha_1 = 0.23$$

$$= 30 + 0.23\,[25 - 30]$$

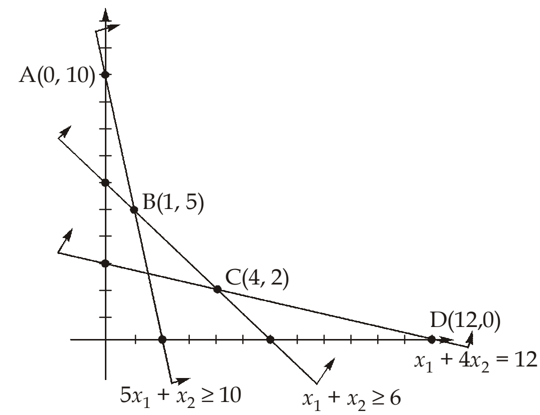
$$= 30 + 0.23 \times -5$$

$$= 28.85$$

$$F_{\alpha = 0.47} = F_D + \alpha_2 [D_D - F_D], \quad \alpha_2 = 0.47$$
$$= 30 + 0.47 \times -5$$
$$= 27.65$$
$$F_{\alpha 1} - F_{\alpha 2} = 28.85 - 27.65 = 1.2$$

17. (c)

From graph,



Solving, $x_1 + 4x_2 = 12$ and $x_1 + x_2 = 6$

$x_1 = 4, x_2 = 2, \quad C(4, 2)$

Solving, $5x_1 + x_2 = 10$ and $x_1 + x_2 = 6$

$x_1 = 1, x_2 = 5, \quad B(1, 5)$

A→ (0, 10), $Z = 20$

B→ (1, 5), $Z = 13$

C→ (4, 2), $Z = 16$ $\quad [Z_{min} = 13]$

D→ (12, 0), $Z = 36$

19. (a)

Humidity ratio, $\omega = 0.05$ kg w.v./kg d.a.

$$\text{Mass fraction of water vapour} = \frac{\omega}{1+\omega} = \frac{0.05}{1.05} = \frac{5}{105} = \frac{1}{21} = 0.047 \text{ kg w.v./kg of mixture}$$

20. (c)

For temperature equal to dew point temperature, only cooling will take place.

21. (c)

- Compressed air forms a free vortex after passing through nozzle and the cold air forms forced vortex in the inner core.
- Energy transfer is from inner core having cold air to periphery having hot air.

22. (c)

$$\therefore \quad \dot{Q}_{absorbed} = \frac{\text{Heat absorbed}}{1 \text{ hour}} = \frac{180(4.2 \times 25 + 335)}{3600} = 22 \text{ kW}$$

$$\therefore \qquad \dot{Q}_{rejected} = 40 \text{ kW}$$

According to 1st law of thermodynamics, (for refrigerator)

$$\dot{Q}_{rejected} = \dot{Q}_{abs} + \dot{W}_{in}$$

$$\Rightarrow \qquad 40 = 22 + \frac{VI}{1000}$$

$$\Rightarrow \qquad VI = 18 \times 1000$$

$$V = \frac{18 \times 1000}{100} = 180 \text{ Volts}$$

23. (d)

$$T_g = 102 + 273 = 375 \text{ K}$$
$$T_o = 27 + 273 = 300 \text{ K}$$
$$T_e = -23 + 273 = 250 \text{K}$$

$$\therefore \qquad (COP)_{max} = \left(\frac{T_g - T_o}{T_g}\right)\left(\frac{T_e}{T_o - T_e}\right) = \left(\frac{375-300}{375}\right)\left(\frac{250}{300-250}\right) = 1$$

So, $\quad$ COP of system $= 1 \times 0.75$

$$0.75 = \frac{Q_{absorbed}}{Q_{generator} + w_{pump}} = \frac{Q_a}{Q_g}$$

$$\Rightarrow \qquad 0.75 = \frac{4.101}{Q_g} \times 10^3$$

$$\Rightarrow \qquad Q_g = \eta_{collector} \times I_{sc} \times A = \frac{4101}{0.75}$$

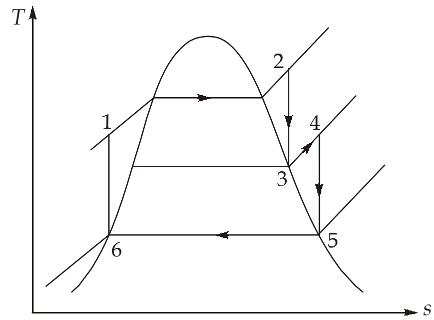
$$\Rightarrow \qquad A = \frac{4101 \times 4}{1367 \times 3 \times 0.5} = 8 \text{ m}^2$$

24. (b)

In pressure compounding as the pressure drop occurs in parts so the steam velocities are not very large and hence the turbine velocity gets reduced to acceptable value. Turbine velocity may be further lowered if number of stages is increased. Therefore, pressure compounded impulse turbine has large number of stages which make it most expensive.

26. (a)

For the given reheat cycle obtained T-S diagram is:



$$W_{net} = \{(h_2 - h_3) + (h_4 - h_5) - (h_1 - h_6)\} \cdot \dot{m}_s$$

Heat supplied for $\dot{m}_s$ mass of steam; $Q_{add} = (h_2 - h_1) \cdot m_s + (h_4 - h_3)\dot{m}_s$

$$\text{Cycle thermal efficiency, } \eta_{thermal} = \frac{W_{net}}{Q_{add}}$$

$$\eta_{thermal} = \frac{\{(h_2 - h_3) + (h_4 - h_5) - (h_1 - h_6)\}}{\{(h_2 - h_1) + (h_4 - h_3)\}}$$

27. (c)

Statement 1 and 2 are correct.

Decrease in partial pressure of gas in water is achieved by increasing the vapour pressure by heating the water. Here, feed water is heated by low pressure steam for heating it upto its saturation temperature. Feed water entering deaerator is broken into small particles so as to increase contact area for better heat exchange with high temperature steam.

28. (a)

Emergency governor trips the turbine, closes the stop valve and stop the steam supply, under following conditions:

1. Shaft speed exceeds 110% of rated value.
2. Lubrication system fails.
3. Balancing of turbine (static and dynamic) is not proper.
4. When condenser becomes hot due to inadequate cooling water circulation or vacuum is less.

30. (b)

It has single-stage having a nozzle fitted in the casing followed by ring of moving blades mounted on the shaft. Here, pressure drop occurs only in the nozzle and ideally no pressure drop occurs in blades. Simple impulse turbine is used where small output at very high speed is required or only a small pressure drop is available. It occupies less space for same power with respect to reaction turbine.

31. (a)

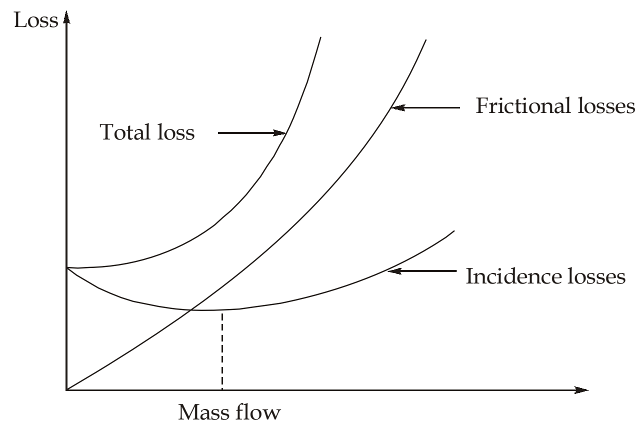
$$K_{sp} = \frac{(Q/ND^3)^{1/2}}{(gH/N^2D^2)^{3/4}} = \frac{NQ^{1/2}}{(gH)^{3/4}}$$

32. (c)

- Weatherability is a measure of how well coal can be stockpiled for long periods of time without crumbling to pieces.
- Sulphur content in coal is combustible and generates some energy by its oxidation to SO_2. Sulphur dioxide is a major source of atmospheric pollution. There is an environmental regulation on SO_2 emission. The operating cost of SO_2 removal equipment need be considered while selecting a coal with high sulphur content.

34. (b)

Incidence losses: During the off design conditions, the direction of relative velocity of fluid at inlet does not match with the inlet blade angle and therefore fluid cannot enter the blade passage smoothly by gliding along the blade surface. The loss in energy that takes place because of this is known as incidence loss. This is sometimes referred to as shock losses.



35. (d)

A simple microprocessor consists of following basic elements:

- **Data Bus:** The data flow between various storage units ALU and memory units.
- **Address Bus:** It controls the flow of memory addresses between ALU and memory unit.
- RD (read) and WR (write) lines set or obtain the addressed locations in the memory.
- **Clock line:** transfers the clock pulse sequence to the processor.
- **Reset Line:** is used to restart execution and reset the processor to zero.
- **Address Latch:** is a register which stores the addresses in the memory.
- **Program Counter:** It is a register which can increment its value by 1 and keeps the record of number of instructions executed. It can be set to zero when it instructed.
- **Test Register:** It is a register which stores intermediate or in-process data of ALU operations. For example it is required to hold the 'carry' while ALU is performing 'addition' operation. It also stores the data which can be accessed by Instruction decoder to make any decision.
- **Instruction register and instruction decoder:** The are responsible for controlling the operations of all other components of a microprocessor.

37. (c)

Given data:

$$Q_1 = 100 \text{ kJ}$$
$$T_1 = 30°\text{C} = (273 + 30)\text{ K} = 303 \text{ K}$$
$$W = 7 \text{ kJ}$$
$$Q_2 = 93 \text{ kJ}$$
$$T_2 = 10°\text{C} = (273 + 10)\text{ K} = 283 \text{ K}$$

Actual efficiency:
$$\eta = \frac{W}{Q_1} = \frac{7}{100} = 0.07 = 7\%$$

Carnot efficiency:
$$\eta_{Carnot} = 1 - \frac{T_2}{T_1} = 1 - \frac{283}{303}$$
$$= 1 - 0.9339 = 0.0661 = 6.61\%$$

As $\eta_{Carnot} < \eta$, it violates the second law of thermodynamics.

39. (c)

As per given data

Normal thrust on a moving plate is given by

$$F_x = \dot{m}\left[(v-u)-0\right]$$

and mass flow rate impacted on plate, $\dot{m} = \rho A(v - u)$

$$\dot{m} = 1000 \times \frac{\pi}{4} \times (0.05)^2 (20-8)$$

$$= 1000 \times \frac{\pi}{4} \times 0.05 \times 0.05 \times 12 = 25 \times 10^{-4} \times 1000 \times 3 \times \pi$$

$$= \pi \times 2.5 \times 3 = 7.5\pi \text{ kg/s}$$

$$F_x = \dot{m}\,[v - u]$$
$$F_x = 7.5\pi(20 - 8) = 7.5 \times 12 \times \pi$$

Work done per second on the plate = $F_x \times u = 7.5 \times 12 \times \pi \times 8 = 2261.946$ Nm/s

40. (b)

- Radiation is considered volumetric phenomenon for gases and for solids and liquids, radiation is considered as surface phenomenon.
- Radiation intensity is defined as rate at which radiation energy is emitted in a direction per unit area normal to that direction per unit solid angle about this direction.

$$I_{(\lambda,\theta,\phi)} = \frac{dQ}{dA\cos\theta \; d\omega \; d\lambda} \text{ W/m}^2 \text{ Sr } \mu\text{m}$$

- As blackbody does not reflects radiation so its radiosity will be its emissive power.

41. (a)

- Emissivity of non-conductors are generally very high (more than 0.6) while metals have low emissivity (as low as 0.2).

- For a gray body, monochromatic emissivity is equal to its total hemispherical emissivity and for a gray body total hemispherical emissivity is equal to its total hemispherical absorptivity when body is in thermal equilibrium e.g. temperature of body remains same as there is no net heat transfer.
- Flux plot is required to estimate the rate of heat flow. There is no heat transfer through an adiabatic line and heat will flow in direction perpendicular to Isotherm line, as for same temperature, there is no heat flow along the isotherm line. Hence adiabatic and isothermal (diathermic) lines are perpendicular to each other.
- Low value of Biot number (B_i < 0.1) signifies that temperature of body is function of time only. For higher value of Biot number, temperature of body is function of space and time.

42. (b)

It is a balance heat exchanger, i.e. $C_h = C_c = 0.5 \times 1000 = 500$ J/K

Now,
$$\text{NTU} = \frac{UA}{C} = \frac{25 \times 20}{500} = 1$$

For balanced parallel flow heat exchanger,

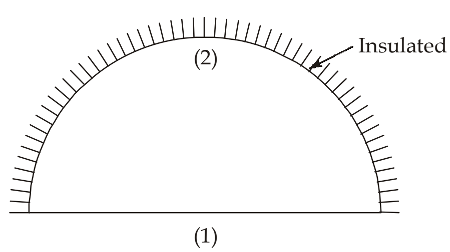
$$\varepsilon = \frac{1 - e^{-2NTU}}{2} = \frac{(e^2 - 1)}{2e^2} = \frac{2.72^2 - 1}{2 \times 2.72^2} = \frac{6.39}{2 \times 7.39} = 0.4324$$

We can also write,
$$\varepsilon = \frac{T_{ce} - T_{ci}}{T_{hi} - T_{ci}} = \frac{T_{ce} - 270}{300 - 270}$$

$$T_{ce} = 0.4324 \times 30 + 270 = 282.972 \text{ K}$$

43. (a)

Let unit length of duct,



$$T_1 = 1000 \text{ K}$$
$$T_2 = 600 \text{ K}$$
$$T_{m,\text{ air}} = 400 \text{ K}$$
$$q_{\text{conv, 1}} = 2400 \text{ W/m} = h(2r) \times 1 \times (T_1 - T_{\text{m, air}})$$
$$h = \frac{2400}{2 \times 0.02 \times (1000 - 400)} = 100 \text{ W/m}^2\text{K}$$

As surface 2 is insulated and maintained at fixed temperature.

At steady state
$$q_{\text{rad,2}} = q_{\text{conv, 2}}$$
$$= h(\pi r \times 1) \times (T_2 - T_{\text{m, air}})$$
$$= 100 \times \pi \times 0.02 \times 200$$
$$= 400\pi = 1256 \text{ W/m}$$

45. **(b)**

$$\text{Total heat lost by fuel rod} = \int_0^L \dot{q}_0 \sin\left(\frac{\pi x}{L}\right)\frac{\pi}{4}D^2 dx$$

$$= \dot{q}_0 \frac{\pi}{4}D^2 \int_0^L \sin\left(\frac{\pi x}{L}\right)dx = \dot{q}_0 \frac{\pi}{4}D^2\left(-\cos\left(\frac{\pi x}{L}\right)\right)_0^L \times \frac{L}{\pi}$$

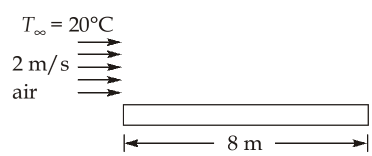
$$q = \dot{q}_0 \frac{D^2 L}{2}$$

46. **(c)**

The part of fin which is inside insulator will act as slab hence temperature variation in that region will be linear and for a infinitely long fin, the tip temperature is equal to atmospheric temperature ($T_1 = T_\infty$).

47. **(c)**

$$l = 8 \text{ m}$$



For laminar flow over a flat plate,

$$h_x \propto \frac{1}{\sqrt{x}}$$

$$\Rightarrow \qquad h_x = \frac{c}{\sqrt{x}}$$

So,

$$\frac{h_I}{h_{II}} = \frac{\frac{1}{(l/2)}\int_0^{l/2} \frac{c}{\sqrt{x}}dx}{\frac{1}{\left(l-\frac{l}{2}\right)}\int_{l/2}^{l} \frac{c}{\sqrt{x}}dx} = \frac{\frac{1}{(l/2)}\int_0^4 \frac{1}{\sqrt{x}}dx}{\frac{1}{(l/2)}\int_4^0 \frac{1}{\sqrt{x}}dx} = \frac{\left[2x^{1/2}\right]_0^4}{\left[2x^{1/2}\right]_4^8} = 2.414$$

48. **(a)**

$$T_o = 550°\text{C}$$

$$T = 300°\text{C}$$

$$T_\infty = 50°\text{C}$$

$$\frac{300-50}{550-50} = e^{-0.04 \times 0.3t}$$

$$\frac{250}{500} = e^{-12 \times 10^{-3}t}$$

$$-0.693 = -12 \times 10^{-3}t$$

$$t = \frac{0.693}{12\times 10^{-3}} = \frac{693}{12} = 57.76 \text{ second} \approx 58$$

51. (c)

This appears as a small crack at the corners of the forging. This is caused mainly by the improper design of the die wherein the corner and fillet radii are small as a result of which the metal do not flow properly into the corner and ends up as a cold shut.

52. (d)

One of the walls of the pouring basin is made inclined at about 45° to the horizontal. The molten metal is poured on this face such that metal momentum is absorbed and vortex formation is avoided. In order that a vortex is not formed during pouring, it is necessary that the pouring basin be kept full.

53. (b)

$$\text{Sand density} = 1.5 \text{ g/cm}^3$$
$$= 1.5 \times 10^{-3} = 1.5 \times 10^{-3} \text{ kg/cm}^3$$
$$\text{Core volume, } V = \frac{20}{1.5 \times 10^{-3}} = \frac{40}{3} \times 10^3 \text{ cm}^3$$
$$\text{Alloy density} = 2.7 \text{ g/cm}^3 = 2.7 \times 10^{-3} \text{ kg/cm}^3$$

Weight of displaced Al-Cu alloy, $W_b = \frac{40}{3} \times 10^3 \times 2.7 \times 10^{-3}$

$$W_b = 36 \text{ kg}$$
$$\text{Net force} = (W_b - W) \times 9.81 = (36 - 20) \times 9.81 = 156.96 \text{ N}$$

54. (b)

We know that,

$$\text{MRR} = \frac{AI}{ZF \times \rho} = \frac{55 \times 965 \times 10^3}{2 \times 96500 \times 7.8}$$
$$\text{MRR} = 35.25 \text{ mm}^3/\text{sec}$$

Material removal rate is also given as

$$\text{MRR} = \text{Feed rate} \times \text{Area}$$
$$35.25 = 0.05 \times \text{Area}$$
$$\text{Area} = 705 \text{ mm}^2$$

55. (c)

Blow holes are spherical, flattener or elongated cavities present inside the casting or on the surface. These are caused by the moisture left in the mould and the core. Because of the heat in the molten metal, the moisture is converted into steam, part of which when entrapped in the casting ends up as a blow hole or ends up as an open blow when it reaches the surface. The main reason for this is the low permeability of the mould sand.

56. (b)

Factors for continuous chip with BUE are:

1. High friction.
2. Ductile material.
3. Low cutting speed, high feed and low rake angle.
4. Higher the work hardenability, rougher is the machined surface produced.

57. (a)

Orthogonal rake angle, $\alpha = 0°$

Chip thickness ratio, $r = \frac{t}{t_c} = \frac{1}{\sqrt{3}}$

We know that,

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$$

$$\tan\phi = r$$

$$\phi = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 30°$$

Shear strain $= \varepsilon = \cot\phi + \tan(\phi - \alpha)$

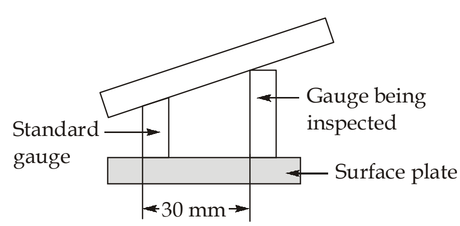
$= \cot 30° + \tan 30°$

$$= \frac{1 + \tan^2 30°}{\tan 30°} = \frac{\sec^2 30°}{\tan 30°} = \frac{1}{\cos 30° \sin 30°} = 2.31$$

58. (c)

Flakes are basically internal ruptures caused by the improper cooling of the large forging. Rapid cooling causes the exteriors to cool quickly causing internal fractures. This can be remedied by the proper cooling practices.

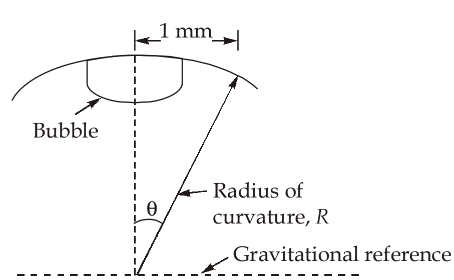
59. (a)



The difference in height h is given by

$$h = \frac{\lambda \times N}{2} \times \frac{L}{l} = \frac{0.5 \times 10 \times 30}{2 \times 15} = 5\ \mu\text{m}$$

60. (b)



$$\theta = \frac{1}{R} \qquad \text{(Since } \theta \text{ is very small)}$$

For 10″ angle deflection, θ^C is:

$$\theta^C = \frac{10}{60\times 60}\times\frac{\pi}{180}$$

Also we know that

$$\theta^C = \frac{h}{L} \qquad \text{(where } L \text{ is base length)}$$

$$\frac{10}{60\times 60}\times\frac{\pi}{180} = \frac{h}{300}$$

$$h = 0.014 \text{ mm}$$

61. **(c)**

In mass production, quality control is typically defined in terms of an acceptable quality level or AQL, which means that a certain minimum level of fraction defects is tolerated. In lean production, by contrast, perfect quality is required. The just-in-time delivery discipline used in lean production necessitates a zero defects level in parts quality, because if the part delivered to the downstream workstation is defective, production is forced to stop. There is little or no inventory in a lean system to act as a buffer.

62. **(c)**

At constant throttle, delay period is constant in time and thus increases in angle with speed, combustion period is constant in crank angle.

Delay period = from 26° btdc to 4° btdc = 22°

Combustion period = from 4° btdc to 12° atdc = 16°

Half throttle half speed will result in an increase of 15% delay time over that at full throttle half speed. At full throttle half speed delay period being reduced to $\frac{22}{2} = 11°$, because time = $\frac{\text{angle}}{\text{speed}}$, for constant time speed is proportional to angle.

Time of delay period at full throttle half speed = 11°.

Time of delay period at half throttle half speed = 11 × 1.15 = 12.65°

Thus ignition timing should be arranged so that the total of 12.65° + 16° = 28.65°, ends 12° after tdc.

So time of spark is = 28.65 – 12 = 16.65° btdc

63. **(b)**

Crankcase dilution: Liquid fuel in the cylinder causes loss of lubricating oil (by washing away oil from cylinder walls) which deteriorates the quality of lubrication and damage to the engine through increased friction. The liquid gasoline may also dilute the lubricating oil and weaken the oil film between rubbing surfaces. To prevent these possibilities, the upper portion of the distillation curve should exhibit sufficiently low distillation temperatures to insure that all gasoline in the cylinder is vapourized by the time the combustion starts.

64. (b)

Turbolag is a phenomena which refers to the short delay period before the boost or manifold pressure increase. This is due to the time the turbocharger assembly takes the exhaust gases to accelerate the turbine and compressor wheel to speed up.

66. (b)

During a missed cycle of operation, there is no power developed and so entire area is negative. Only option (b) gives the anticlockwise direction for whole cycle.

68. (d)

$$\text{Specific energy consumption} = \frac{\text{kW heat input}}{\text{kW work output}}$$

$$bsec = \frac{CV \times \dot{m}_f}{B.P.} = C.V. \times bsfc$$

$$bsfc = \frac{5}{50} = 0.1 \text{ g/kWs} = 0.1 \times 10^{-3} \text{ kg/kWs}$$

$$bsec = 42 \times 10^3 \times 0.1 \times 10^{-3}$$

$$bsec = 4.2$$

$$isec = \text{bsec} \times \eta_m = 4.2 \times 0.75 = 3.15$$

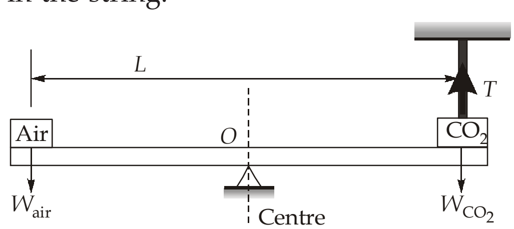
69. (c)

Effect of overcooling:

1. Thermal efficiency is decreased due to more loss of heat carried by the coolant.
2. The vaporization of the fuel is less results in lower combustion efficiency.
3. At low temperatures, the sulphurous and sulphuric acids resulting from combustion of fuel (fuel always contains same sulphur) attack the cylinder barrel. To avoid condensation of acids the coolant temperature should be greater than 70°C.

71. (b)

Assuming T be the tension in the string.



$$V_{CO_2} = V_{air} = 1.2 \text{ m}^3$$

$$\rho_{air} = 1.177 \text{ kg/m}^3, \rho_{CO_2} = 1.8 \text{ kg/m}^3$$

$$\text{Weight of air, } W_{air} = \rho_{air} V_{air} \cdot g$$

$$= 1.177 \times 1.2 \times 9.81 = 13.855 \text{ N}$$

$$\text{Weight of } CO_2, W_{CO_2} = \rho_{CO_2} \cdot V_{CO_2} \cdot g = 1.8 \times 1.2 \times 9.81 = 21.19 \text{ N}$$

$$\text{For equilibrium, } \Sigma M_o = 0$$

$$W_{air}\frac{L}{2}+T\times\frac{L}{2} = W_{CO_2}\frac{L}{2}$$

$$T = W_{CO_2} - W_{air} = 21.19 - 13.85 = 7.33 \text{ N}$$

72. **(b)**

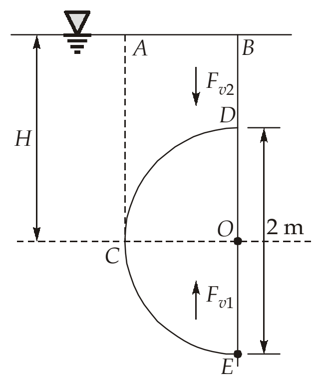
Given: D = 2 m, R = 1 m,

Vertical force, $F_v = F_{v1} - F_{v2}$

F_v = weight of volume of water ECAB – weight of volume of water $DCAB$

= Weight of volume of water contained by hemisphere DCE

$$= \rho g V_{hemisphere} = \rho g\times\frac{1}{2}\times\left(\frac{4}{3}\pi R^3\right)$$



$$= 1000\times10\times\frac{1}{2}\times\frac{4}{3}\times\pi\times1^3$$

$$= 20.944 \times 10^3 \text{ N} = 20.944 \text{ kN}$$

74. **(b)**

$$D = 100 \text{ mm} = 0.1 \text{ m}$$

$$\text{Re} = \frac{\rho(V_{mean})D}{\mu}=\frac{800\times V_{mean}\times0.1}{0.08}$$

$$V_{mean} = \frac{500\times0.08}{800\times0.1} = 0.5 \text{ m/s}$$

$$V_{max} = 2\,V_{mean} = 2\times0.5 = 1 \text{ m/s}$$

$$\frac{V}{V_{max}} = \left[1-\left(\frac{r}{R}\right)^2\right]$$

$$V_{(r\,=\,40\text{ mm})} = 1\left(1-\left(\frac{40}{50}\right)^2\right)=1-\frac{16}{25}=\frac{9}{25} = 0.36$$

$$V_{(r\,=\,40\text{ mm})} = 0.36 \text{ m/s}$$

75. **(b)**

Vorticity is equal to twice the angular velocity of fluid particle.

76. **(c)**

The loss coefficient for a submerged pipe exit is often listed as $k_L = 1$. More precisely, however, k_L is equal to kinetic energy correction factor α at the exit of the pipe. Although α is indeed close to 1 for fully developed turbulent pipe flow, it is equal to 2 for fully developed laminar pipe flow.

77. **(c)**

For smooth boundary, $$\frac{u}{u^*} = 5.75\log\left(\frac{yu^*}{\nu}\right) + 5.5$$

For rough boundary, $$\frac{u}{u^*} = 5.75\log\left(\frac{y}{\varepsilon}\right) + 8.5$$

78. **(b)**

The boundary conditions are:

At $y = 0$, $u = 0$ (no slip condition)

At $y = \delta$, $u = u_\infty$

At y = δ, $\frac{du}{dy} = 0$

At $y = 0$, $\frac{d^2v}{dy^2} = 0$

All the boundary conditions are satisfied only in option (b).

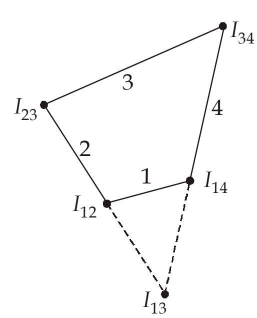
80. **(a)**

The pitch curve of a gear is the theoretical curve along which the gear rolls (without slipping) on the corresponding pitch curve of the other gear.

If the pitch curve is a straight line, then it will transmit only translating motion. Such gear is called rack.

The number of teeth per unit length of the pitch circle diameter is termed the diametral pitch. The inverse of the diametral pitch is module of gear.

81. **(a)**



As I_{12} and I_{13} are on same side of I_{23}, the sense of rotation of input link and coupler will be same.

83. **(b)**
Option (a) and (c) are of isochronous governor which have infinite sensitivity and zero stability. Out of (b) and (d), governor of option (b) has more slope and hence more stability.

84. **(a)**
Flywheel decreases fluctuation within the cycle, not across the cycle.

85. **(d)**
By increasing centre distance, pressure angle increases because of this interference reduces.

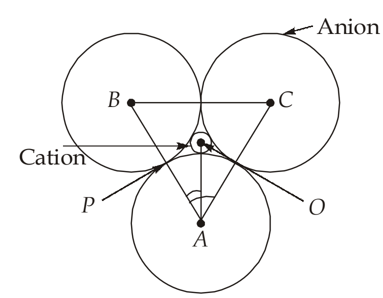
- Interference can be avoided by profile shifting and making non standard gear. In this addendum of pinion and gear are made unequal i.e. longer addendum for pinion and shorter for gear.

86. **(b)**
Helical gear gives axial thrust. Herringbone gear is double helical gear in which axial thrust cancel out each other and end thrust is zero.

87. **(c)**
Hypoid bevel gear: Also known as skew bevel gear. It is used for non-intersecting and non-parallel axis gear which introduces a considerable amount of sliding. So good lubrication is required

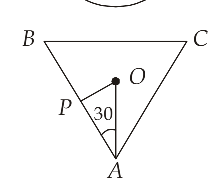
88. **(c)**
In cycloidal gear, pressure angle varies from maximum at the beginning of engagement, reduces to zero at the pitch point and again increases to maximum at the end of engagement.
Hob of cycloidal gear has curved teeth unlike straight involute rack teeth. Hence hob manufacturing is difficult and costly.

89. **(d)**



$$\angle BAC = 60^\circ$$
$$OA = r_A + r_C$$
$$AP = r_A$$
$$\angle OAP = 30^\circ$$

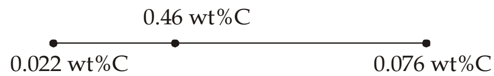
In ΔOPA



$$\cos 30^\circ = \frac{AP}{AO} = \frac{r_A}{r_A + r_C}$$
$$\frac{\sqrt{3}}{2} = \frac{r_A}{r_A + r_C}$$
$$\sqrt{3}r_A + \sqrt{3}r_C = 2r_A$$
$$\sqrt{3}r_C = (2-\sqrt{3})r_A$$
$$\frac{r_C}{r_A} = \frac{2-\sqrt{3}}{\sqrt{3}} = \frac{2}{\sqrt{3}} - 1 = 0.155$$

90. (a)

The fraction of proeutectoid ferrite is determined by using lever rule and a tie line that extends only to the eutectoid composition as



$$W_{\alpha}' = \frac{0.76-0.46}{0.76-0.022} = \frac{0.3}{0.738} = 0.406$$

Amount of proeutectoid ferrite (M_{α}') = 10 × 0.406 = 4.06 kg

91. (b)

The diffusivity of N in ferrite is higher than that in austenite. However the solubility of N in ferrite is low.

- The formation of brittle layer of Fe_4N should be avoided. It is also known as white layer. It is detrimental. It is prone to cracking.

92. (b)

- Leaded yellow brass: (29% Zn, 3% Pb 1%Sn. rest copper)- Furniture hardware, radio for fittings.
- Cartridge brass: (30% Zn, 70%Cu) Automative radiator cores, ammunition components, lamp fixtures, kickplates.
- Martensitic stainless steels-Riffle barrels, cutlery, jet engine parts.
- Compacted graphite iron-Diesel engine blocks, exhaust mainfolds, gearbox housings, track discs for high speed trains and flywheels.

93. (c)

$$d \propto \sqrt{\frac{\rho}{\mu f}}$$

where ρ = Resistivity; f = Frequency; μ = Magnetic permeability

Higher frequency leads to lower depth of hardening (d).

Magnetic permeability of steel decreases significantly as the temperature goes beyond Curie temperature. Therefore, there will be a sudden increases in depth of penetration 'd' as the temperature goes beyond 750°C.

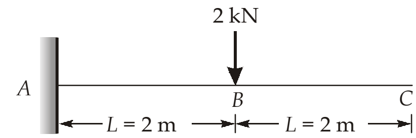
95. (d)

A sol-gel process occur in the steps as given below:

1. Hydrolysis and condensation of molecules, formation of sol.
2. Gelation (sol-gel transformation)
3. Ageing
4. Drying

96. (b)

Deflection at free end,



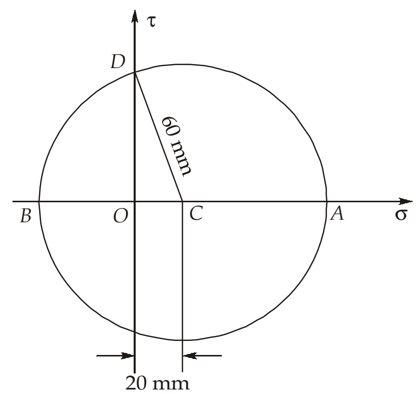
$$\Delta_C = \Delta_B + \theta_B \times BC$$

$$= \frac{WL^3}{3EI} + \frac{WL^2}{2EI} \times L$$

$$= \frac{WL^3}{EI}\left(\frac{1}{3}+\frac{1}{2}\right) = \frac{5}{6} \times \frac{2\times10^3\times2^3}{200\times10^9\times10^{-4}} = 6.66 \times 10^{-4} \text{ m}$$

$$\Delta_C = 0.67 \text{ mm}$$

97. (b)



$$OC = 20 \text{ mm}$$

$$CD = 60 \text{ mm}$$

In triangle OCD, $OD^2 = CD^2 - OC^2$

$$OD = \sqrt{60^2 - 20^2} = \sqrt{3200} \text{ mm}$$

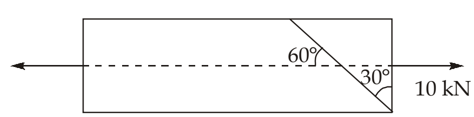
$$OD = 40\sqrt{2} \text{ mm}$$

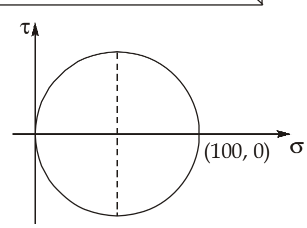
So, shear stress at pure shear plane,

$$\tau_s = 40\sqrt{2}\times 2 = 80\sqrt{2} = 113.13 \text{ MPa}$$

98. (c)

Since there is no compressive stress on any plane, plane of pure shear doesn't exist in this case.





$$\sigma = \frac{P}{A} = \frac{10\times10^3}{100} = 100 \text{ MPa}$$

$$\tau_s = \frac{\sigma}{2}\sin 2\theta = \frac{100}{2}\sin(2\times30°) = \frac{100}{2}\times\frac{\sqrt{3}}{2}$$

$$\tau_s = 43.3 \text{ MPa}$$

99. (b)

$$\tau_{per} = \frac{S_{ys}}{N} = \frac{120}{1.5} = 80 \text{ MPa}$$

As per the MSST,

$$\text{Abs } \tau_{max} \leq \tau_{per}$$

$$\text{Maximum of } \left(\left| \frac{\sigma_x - \sigma_y}{2} \right|, \left| \frac{\sigma_y}{2} \right|, \left| \frac{\sigma_x}{2} \right| \right) \leq \tau_{per}$$

$$\text{Maximum of } \left(\left| \frac{2\sigma + 3\sigma}{2} \right|, \left| \frac{3\sigma}{2} \right|, \left| \frac{2\sigma}{2} \right| \right) \leq 80$$

$$\frac{5\sigma}{2} \leq 80$$

$$\sigma \leq \frac{160}{5} \text{ MPa}$$

$$\sigma \leq 32 \text{ MPa}$$

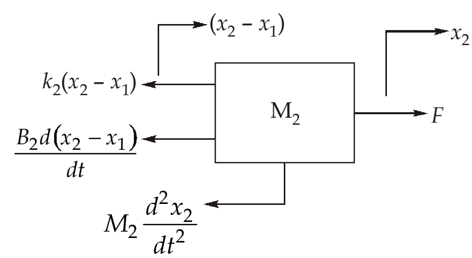
100. (*)

By drawing free body diagram for mass (m_1)
From D'alembert principle.

$$M_2 \frac{d^2x_2}{dt^2} + \frac{B_2 d(x_2 - x_1)}{dt} + k_2(x_2 - x_2) - F = 0$$

$$M_2 \frac{d^2x_2}{dt^2} + B_2 \frac{dx_2}{dt} - B_2 \frac{dx_1}{dt} + k_2x_2 - k_2x_1 - F = 0$$

$$M_2 \frac{d^2x_2}{dt^2} + B_2 \frac{dx_2}{dt} + k_1x_2 = k_2x_1 + B_2 \frac{dx_1}{dt} + F$$



101. (b)

Given

$$a_i(t) = 50 \times 10^{-8} \sin(20t) \text{ m/s}^2$$

$$\omega = 20 \text{ rad/s}$$

$$m = 0.005$$

$$k = 8 \text{ N/m}$$

$$\text{Sensitivity, } K = 4000 \text{ V/}\mu\text{m}$$

$$\text{Natural frequency, } \omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{8}{0.005}} = \sqrt{1600} = 40 \text{ rad/s}$$

$$\text{Output voltage, } V_o = \frac{K\beta}{\omega_n^2} A_i$$

[From piezoelectric material , $\Delta t \propto x_o$, $\Delta t = \beta x_o$, given, $\Delta t = x_o$, $\beta = 1$, K = Sensitivity; A_i = Maximum amplitude of acceleration]

$$V_o = \frac{4000 \times 10^6 \times 1 \times 50 \times 10^{-8}}{40^2}$$

$$V_o = \frac{4000 \times 10^{-2} \times 50}{40 \times 40} = \frac{5}{4}$$

$$V_o = 1.25 \text{ Volt}$$

102. (a)

For homogeneous transformation matrix.

$$\begin{bmatrix} n_x & o_x & a_x \\ n_y & o_y & a_y \\ n_z & o_z & a_z \end{bmatrix}$$

$$\begin{aligned} |n| &= 1 \\ |o| &= 1 \\ n \cdot o &= 0 \\ o \cdot a &= 0 \\ a \cdot n &= 0 \end{aligned}$$

$$\begin{bmatrix} 0.5 & Q & 0 & 1 \\ 0 & 0.5 & 0 & 5 \\ P & 0 & R & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{aligned} n_x^2 + n_y^2 + n_z^2 &= 1 \\ (0.5)^2 + 0^2 + P^2 &= 1 \\ P^2 &= 1 - 0.25 = 0.75 \\ P &= \pm 0.866 \end{aligned}$$

Similarly

$$\begin{aligned} Q^2 + 0.5^2 + 0^2 &= 1 \\ Q^2 &= 1 - 0.25 = 0.75 \\ Q &= \pm 0.866 \\ R &= \pm 1 \end{aligned}$$

103. (d)

$$\text{Observability matrix, } \phi_o = [C^T \; AC^T]$$

$$AC^T = \begin{bmatrix} -1 & 0 \\ 0 & 2 \end{bmatrix}\begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} -1 \\ 0 \end{bmatrix}$$

$$C^T = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$\text{Observability matrix, } [\phi_o] = \begin{bmatrix} 1 & -1 \\ 0 & 0 \end{bmatrix}$$

$$\text{Determinant, } |\phi_o| = \begin{vmatrix} 1 & -1 \\ 0 & 0 \end{vmatrix} = 0,$$

Hence system not observable

Controllability matrix $\phi_c = [B \quad AB]$

$$[\phi_c] = \begin{bmatrix} 1 & -1 \\ 0 & 0 \end{bmatrix}$$

$$\text{Determinant, } |\phi_c| = \begin{vmatrix} 1 & -1 \\ 0 & 0 \end{vmatrix} = 0$$

Hence system is uncontrollable.

104. (a)

$$k = \text{transformation ratio} = 0.4$$

The induced voltages in secondary windings for any particular position of shaft is

Given by

$$V_{s1}(t) = (kV_i \sin\omega t)\cos\theta$$

$$V_{s2}(t) = (kV_i \sin\omega t)\sin\theta$$

$$v_i(t) = 10 \sin\omega t$$

$$k = 0.4$$

$\theta = 30°$

$$V_{s1}(t) = (0.4 \times 10\sin\omega t)\cos 30°$$

$$V_{s1}(t) = 3.464 \sin\omega t$$

$$V_{s2}(t) = (0.4 \times 10 \sin\omega t)\sin 30°$$

$$V_{s2}(t) = 2\sin\omega t$$

105. (c)

$$\eta = \frac{V_{max.} \times I_{max}}{P_{in}}$$

$$V_{max} = \frac{\eta \times P_{in}}{I_{max}}$$

$$= \frac{0.2 \times 0.9 \times 10^{-3}}{5 \times 10^{-3}} = \frac{0.18}{5} = \frac{180 \times 10^{-3}}{5} = 36 \times 10^{-3}$$

$$V_{max} = 0.036 \text{ V}$$

106. (b)

Methanol is a liquid hydrocarbon fuel and can directly be oxidized to operate as a fuel. Operating temperature of molten carbonate fuel cell is 650° and Solid oxide fuel cell has operating temperature in the range of 800 – 1000°C. The internal resistance polarization can be reduced by decreasing the electrode size, coating the electrodes with a good electric conductor and increasing the electrolyte concentration.

107. (b)

$$\text{Concentration ratio} = \frac{W - D_o}{\pi D_o}$$

$$\text{Concentration ratio} = \frac{W \times L - D_o \times L}{\pi D_o \times L} = \frac{W - D_o}{\pi D_o} = \frac{2.5 - 7 \times 10^{-2}}{\pi \times 7 \times 10^{-2}} = \frac{2.5 - 0.07}{22 \times 10^{-2}}$$

$$= \frac{2.43}{22} \times 100 = 11.049 \approx 11$$

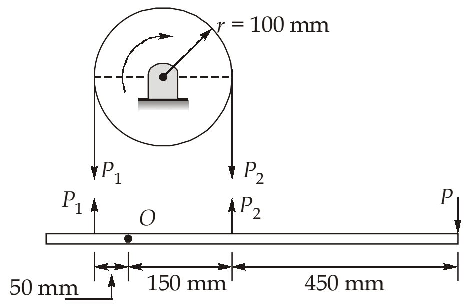
108. **(b)**

Critical point : Properties of saturated liquid and saturated vapour are identical.
Sublimation : Heating process, where solid gets directly transformed to gaseous phase.
Triple point : All the three phases-solid, liquid and vapour co-exists in equilibrium.

109. **(a)**

$$\text{Torque capacity} = 1718 \text{ N-m}$$

$$\Rightarrow \quad (P_1 - P_2) \times R = 1718$$



$$\Rightarrow \quad P_1 - P_2 = \frac{1718}{0.1} \text{N} = 17180 \text{ N} \quad \text{... (i)}$$

$$\because \quad \frac{P_1}{P_2} = e^{\mu\theta} = e^{1/\pi \times \pi} = e = 2.718$$

$$P_1 = 2.718\, P_2 \quad \text{... (ii)}$$

So,

$$P_2 = 10000 \text{ N}$$

$$P_1 = 27180 \text{ N}$$

On balancing moment about O,

$$\because \quad P_1 \times 50 + P \times 600 = P_2 \times 150$$

$$\Rightarrow \quad P = \frac{10000 \times 150 - 27180 \times 50}{600} = 235 \text{ N}$$

110. **(a)**

Jaw clutches can be engaged only when both shafts are stationary or rotate with very small speed difference.

111. **(a)**

In a flash welding, heat is generated from the arc as the ends of the two members begin to make contact developing an electric resistance at the joint. A significant amount of metal expelled from the joint as a shower of sparks during the flashing process. After the temperature rise and the interface begins to soften an axial force is applied at a controlled rate and a weld is formed by plastic deformation of the joint. As impurities and contaminants also are squeezed out during this operation, the quality of the weld is good.

112. (a)

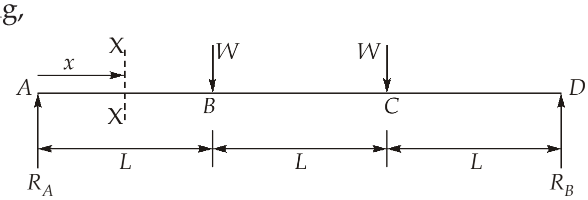
$$J_1 = A\left[\frac{l^2}{12}+r_1^2\right] = (50\times 5)\left[\frac{50\times 50}{12}+25^2\right]$$
$$= 250 \times [208.33 + 625]$$
$$= 208332.5 \text{ mm}^4$$
$$J = 2J_1 = 2 \times 208332.5$$
$$= 416665 \text{ mm}^4$$

113. (b)

$$k_t = 1 + 2\left[\frac{\text{Semi major axis}}{\text{Semi minor axis}}\right]$$
$$= 1+2\frac{A}{B} = 1+2\times 2 = 5$$

114. (d)

Since, symmetric loading,



$$R_A = R_D = \frac{2W}{2} = W$$

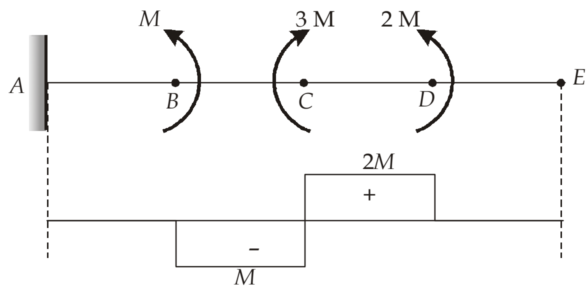
$$U_{AB} = \int_0^L \frac{(Wx)^2\,dx}{2EI} = \frac{W^2}{2EI}\left[\frac{x^3}{3}\right]_0^L = \frac{W^2L^3}{6EI}$$

$$U_{BC} = \frac{M^2L}{2EI} = \frac{(WL)^2L}{2EI} = \frac{W^2L^3}{2EI}$$

Strain energy in beam, $U = U_{AB} + U_{BC} + U_{CD}$

$$= 2U_{AB} + U_{BC}$$
$$= 2\frac{W^2L^3}{6EI}+\frac{W^2L^3}{2EI} = \frac{5}{6}\frac{W^2L^3}{EI}$$

115. (b)

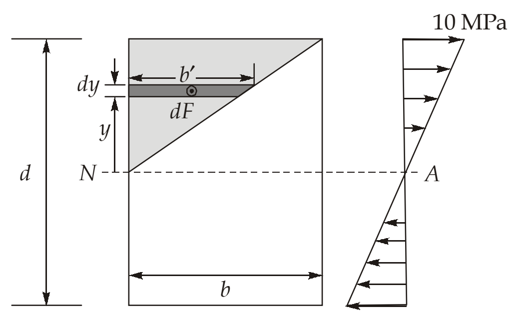


BM in AB and DE is zero, so

$$R = \frac{EI}{M} = \frac{EI}{0} = \infty$$

i.e. elastic curve is straight line.

116. (b)



$$\sigma_{max} = 10 \text{ MPa}$$

$$F = \int_0^{d/2} dF = \int_0^{d/2} \sigma_b \times b' dy$$

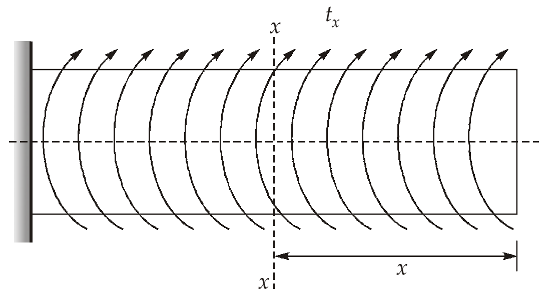
$$= \int_0^{d/2} \frac{\sigma_{max} y}{d/2} \times \left(\frac{b}{d/2} \times y \right) \times dy$$

$$= \frac{\sigma_{max}}{d/2} \times \frac{2b}{d} \left[\frac{y^3}{3} \right]_0^{d/2} = \sigma_{max} \times \frac{4b}{3d^2} \times \frac{d^3}{8}$$

$$F = \sigma_{max} \times \frac{1}{6} bd = 10 \times \frac{1}{6} \times 100 \times 300$$

$$F = 50 \text{ kN}$$

117. (a)



Intercity of torque,

$$t_x = t$$

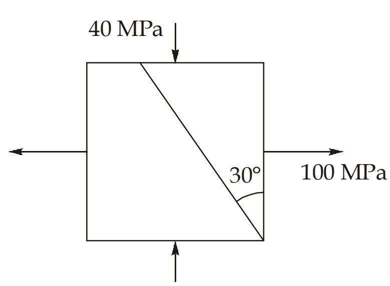
$$T = t_x \times x = tx$$

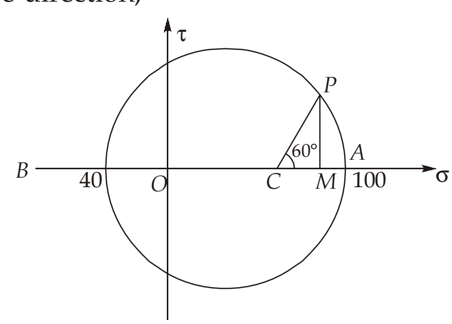
$$\text{Angle of twist, } \theta_C = \int_{L/2}^{L} \frac{T_x dx}{GJ} = \frac{1}{GJ}\int_{L/2}^{L} (tx)\,dx$$

$$\theta_C = \frac{t}{GJ}\left[\frac{x^2}{2}\right]_{L/2}^{L} = \frac{3tL^2}{8GJ} = \frac{3tL^2}{8\times G\times \frac{\pi}{32}d^4} = \frac{12tL^2}{\pi G d^4}$$

118. (d)

Making Mohr's circle taking θ in anti-clockwise direction,





$$OA = 100 \text{ MPa}$$

$$CA = \frac{100+40}{2} = \frac{140}{2} = 70 \text{ MPa}$$

$$OC = OA - CA = 100 - 70 = 30 \text{ MPa}$$

Normal stress on oblique plane,

$$\sigma_n = OM = OC + CM = 30 + CP\cos 60°$$

$$= 30 + 70\cos 60° = 30 + \frac{70}{2} = 65 \text{ MPa}$$

119. (b)

For isobaric process, $dQ = C_p \cdot dT$

$$\Rightarrow \quad Q = \int dQ = \int_{T_1}^{T_2} C_p dT = \int_{T_1}^{T_2} (C_v + R)\,dT$$

$$= \int_{T_1}^{T_2} \left[C_{vo} + R + a(T - T_o)\right] dT$$

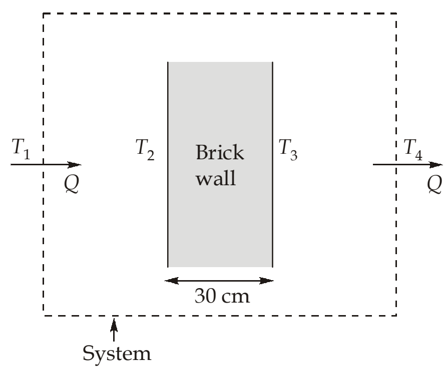
$$= \int_{347}^{447} \left[2 + 0.01(T - 347)\right] dT$$

$$= \left. 2T + 0.01\frac{(T-347)^2}{2} \right]_{347}^{447}$$

$$= 2(447 - 347) + \frac{0.01}{2}\left[100^2 - 0^2\right]$$

$$= 200 + \frac{0.01}{2} \times 100^2 = 250 \text{ kJ}$$

121. (c)



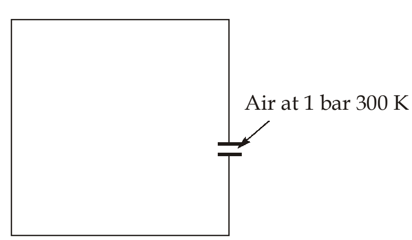
T_1 = 1200 K; T_2 = 600 K; T_3 = 400 K; T_4 = 300 K

Let us consider wall and its immediate surrounding as the system,

So, total entropy generation = $\frac{-Q}{T_1} + \frac{Q}{T_4} = 2400\left(\frac{-1}{1200} + \frac{1}{300}\right)$

$$= 2400 \times \frac{3}{1200} = 6 \text{ W/K}$$

122. (b)



As air moves inside evacuated tank, air has energy $m_i h_i$

∴ $h_i = u_i + pv$

and when same mass of air gets stored inside the tank, air will have energy $m_i u_2$.
Air coming inside the tank and air stored finally in tank are at same temperature so $u_2 = u_i$.
So part of only energy that will be lost as heat

$$= m_i pv$$
$$= p \cdot V$$
$$= 100 \text{ kPa} \times 0.75 \text{ m}^3 = 75 \text{ kJ}$$

Alternate solution: This is problem of unsteady state [1 → at initial state, 2 → at final state]

Mass balance: $m_i - m_o = m_2 - m_1$

$\Rightarrow$ $m_i = m_2$ [$m_1 = 0$ (initially evaluated) $\dot{m}_o = 0$]

Energy balance: $\left(\dfrac{du}{dt}\right) = \dot{m}_i h_i - \dot{m}_o h_o - \dot{Q} - \dot{W}$

$\Rightarrow$ $m_2 u_2 - m_1 u_1 = m_i h_i - m_o h_o - Q - W$

$\Rightarrow$ $m_2 u_2 = m_i u_i + Q$

$\Rightarrow$ $Q = m_2 u_2 - m_i u_i$

$= m_2(u_2 - h_i) = m_2(c_v T_2 - c_p T_i)$

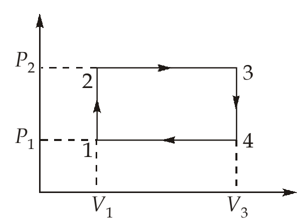
$= m_2(c_v - c_p)T$ ($T_2 = T_i = T = 300$ K)

$= -m_2 RT = -pV$

$= -(100 \text{ kPa}) \times (0.75 \text{ m}^3) = -75 \text{ kJ}$

123. (c)

According to 1st law of thermodynamics



$$đQ = đW$$
$$= (P_2 - P_1)(V_3 - V_1)$$

124. (d)

Specific volume of water, $v_w = \dfrac{V_w}{m_w} = \dfrac{0.33}{0.667} = 0.5 \text{ m}^3/\text{kg}$

Pressure of air, $P_a = \dfrac{m_a R T_1}{V} = \dfrac{0.667 \times 0.287 \times 300}{0.287} = 200 \text{ kPa}$

$P_a = 0.2$ MPa

For equilibrium of piston, $P_a = P_w = 0.2$ MPa

Now $v_w = (v_f + x_{w1} v_{fg})$ at 0.2 MPa

$0.5 = 0.001 + x_{w1} \times 0.884$

$x_{w1} = 0.56$

125. (b)

For mixing of same gas at same temperature and pressure, the entropy change associated zero.

126. (b)

Work done = Mass of water reached at top × Total height + Mass of water leaks out × Average height it reached

$$= 100 \times 10 + 100 \times \frac{100}{2} = 1500 \text{ J}$$

[As leaking is linear, average height = $\frac{\text{Total height}}{2}$]

127. (d)

New, FC = 1.05 × 1000000

New, VC = 1.1 × 60/unit

SC = ₹100/unit

$$\text{New Breakeven quantity} = \frac{\text{Fixed cost}}{\text{Selling cost} - \text{Variable cost}}$$

$$= \frac{1.05 \times 1000000}{(100 - 1.1 \times 60)} = \frac{1050000}{34}$$

$$= 30882.352 \approx 30883 \text{ unit}$$

128. (c)

D = 1500 bag/day, C = ₹400/bag, C_h = ₹0.2/bag/day, C_o = ₹150/order

$$\text{EOQ} = \sqrt{\frac{2DC_o}{C_h}} = \sqrt{\frac{2 \times 1500 \times 150}{0.2}} = 1500 \text{ bags}$$

System cost = Cement cost + Inventory cost

= 1500 × 400 + ₹300

= ₹600300

129. (b)

The probability that the waiting time in the system is greater than T,

$$P(W_s > T) = e^{-T/W_s}$$

130. (a)

λ = 3.5 customer/hr

μ = 5 customer/hr

Average length of non-empty queue or average length of queue containing at least one customer,

$$\rho = \frac{3.5}{5} = \frac{0.7}{1} = 0.7$$

$$L_q' = \frac{1}{1-\rho} = \frac{1}{1-0.7} = \frac{1}{0.3} = 3.33$$

131. (c)

- Cost of hydrostatic bearing is more than that of rolling contact bearing because hydrostatic bearing requires additional accessories like pump, filter and pipe lines.
- As in hydrodynamic bearing initially there will be metal to metal contact so in this starting torque will be more than in rolling contact bearing.

132. (d)

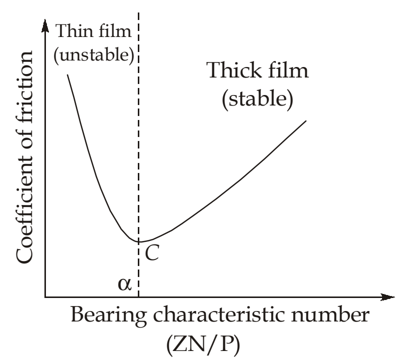
The endurance limit, in the true sense, is not a property of material because it gets affected by factor like size of component, temperature, surface finish, shape etc.

133. (c)

- Producer gas obtained through gasification on process contains mixture of H_2(15-20)%, CO (10-20)%, CH_4(1-5)%, CO_2(9-12)% and N_2(45-55)%.
- Producer gas is formed in the reduction zone of gasifier.

139. (c)

$\frac{ZN}{P}$ curve developed by Mckee Brother's helps to visualize the transition from the film lubrication to thick film lubrication



$$\alpha = \text{Bearing modulus}$$

$$\frac{ZN}{P} = \text{Bearing characteristic number}$$

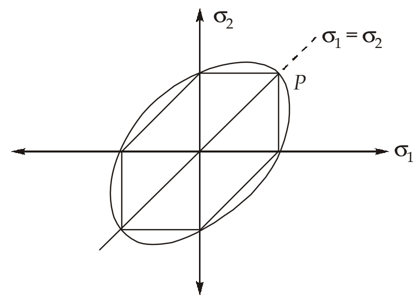
For fluctuating loads, bearing characteristic numbers almost 15 times of bearing modulus.

142. (c)

If determinant of controllability of system matrix is zero then we can say, system is uncontrollable.

143. (b)

At point P, i.e., when principle stresses equal and like in nature, both MSST and MDET gives same results.



For bi-axial state of stress condition with both principal stress unlike in nature, safe region of MSST lies under the safe region of MDET. So, MSST is more conservative than MDET.

144. (d)

Standard electrode potential of iron lies below copper and above zinc.

145. (b)

- **Bernoulli's equation**: Integration of Euler's equation along a streamline for steady flow.
- In general viscous stresses are present when we have fluid deformation; when we have no fluid deformation i.e. when we have rigid body motion, no viscous stresses will be present, even if $\mu \neq 0$. Hence Euler's equation applies to rigid body motions as well as to inviscid flows.

146. (c)

For particular valve setting, charge per cylinder per cycle increases with speed due to ram effect and it reaches to maximum in its operating range of speed. If the revolutions of engine are increased beyond this, ram effect decreases and high residual gas dilution takes place which decreases volumetric efficiency.

If the closing of the exhaust stroke is delayed beyond TDC, the inertia of the exhaust gases tends to scavenge the cylinder better and results in increased volumetric efficiency.

147. (a)

The strength of a brazed joint is typically stronger than the filler metal out of which it is made because parent material strength is greater than filler material and at the interface of parent and filler, it does not allow to deform at lower value of stress (i.e. σ_{filler}).

150. (d)

If velocity of air is increased, its effective temperature will decrease.