DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 22

Full Syllabus Test-6 (Paper-II)

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

DETAILED EXPLANATIONS

1. (a)

As $$r_A + 2r_C = r_B$$

$\Rightarrow$ $$T_A + 2T_C = T_B$$

$\Rightarrow$ $$T_B = 120$$

Arm speed	$A(80)$	$D/C(20)$	$B(120)$
0	x	$-4x$	$-\frac{2x}{3}$
y	$y+x$	$y-4x$	$y-\frac{2x}{3}$

$$y + x = 100 \quad \text{... (i)}$$

and $$y - \frac{2x}{3} = -40 \quad \text{... (ii)}$$

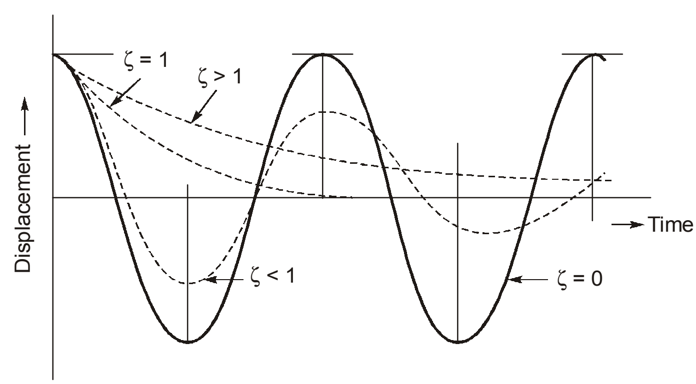
From equation (i) and (ii)

$$\frac{5x}{3} = 140$$

$\Rightarrow$ $$x = 84 \text{ rpm}$$

$\Rightarrow$ $$y = 16 \text{ rpm}$$

3. (b)



4. (d)

Let α be angle between the shafts, θ be angle turned by input shaft and ϕ be angle turned by output shaft.

By geometrry, there exist a relation

$$\tan\theta = \cos\alpha \tan\phi \quad \text{... (i)}$$

For θ = 45° and α = 60°

$$1 = \frac{1}{2}\tan\phi$$

$\Rightarrow$ $$\tan\phi = 2 \quad \text{... (ii)}$$

By differentiating equation (i) w.r.t time

$$\sec^2\theta\frac{d\theta}{dt} = \cos\alpha\cdot\sec^2\phi\frac{d\phi}{dt}$$

$$\Rightarrow \quad \left(\sqrt{2}\right)^2\omega_1 = \frac{1}{2}\times\left(1+2^2\right)\omega_2$$

$$\Rightarrow \quad \frac{4}{5}N_1 = N_2$$

$$\Rightarrow \quad N_2 = \frac{4}{5}\times 840 = 672 \text{ rpm}$$

We can also use the direct formula.

$$\omega_2 = \frac{\cos\alpha}{1-\sin^2\alpha\cos^2\theta}\times\omega_1$$

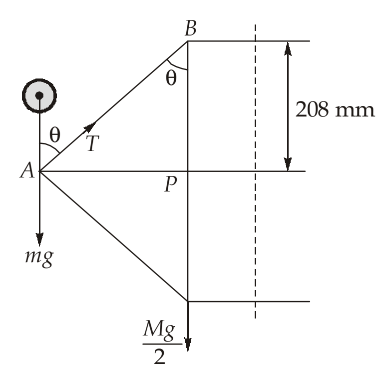
$$\Rightarrow \quad N_2 = \frac{\frac{1}{2}N_1}{1-\frac{3}{4}\times\frac{1}{2}} = \frac{4}{5}N_1 = 672 \text{ rpm}$$

5. (b)

Please note that angular acceleration of input crank is zero if we are making acceleration diagram according to Klein's construction. Draw the acceleration diagram and turn it by 180°, then you can find which line represent centripetal acceleration of (B) w.r.t. (A).

6. (a)

$$\cos\theta = \frac{BP}{AB} = \frac{208}{240}$$



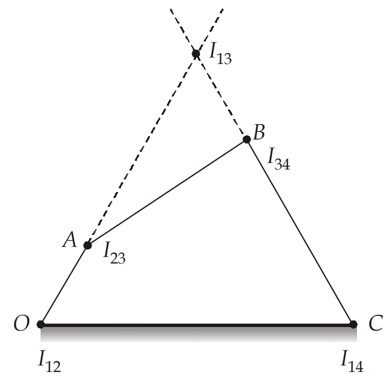
Force equilibrium in vertical direction,

$$T\cos\theta = mg + \frac{Mg}{2}$$

$$\Rightarrow \quad T\times\frac{208}{240} = 30 + \frac{80}{2}$$

$$T = 70\times\frac{240}{208} = 80.77 \text{ N}$$

7. **(a)**



About I_{13}, link 3 is in pure rotation as link 1 is fixed. Clearly velocity of A will be greater as

$$I_{13}I_{23} > I_{13}I_{34}$$

8. **(d)**

It is one of the displacement type sensor also known as electro-mechanical device which can be used to convert rotary or linear displacement into a voltage. Advantages are:

- Simple and inexpensive.
- Useful for measurement of large amplitude of displacement.
- Electrical efficiency is high.

9. **(c)**

Given: t = 80 mm, d = 20 mm, p = 60 mm, Number of river/pitch = 3

∵ This is a case of infinite riveting, so

$$\text{Shear strength per pitch} = nk \times \frac{\pi}{d} d^2 \times \tau_{per} = 3 \times 1 \times \frac{\pi}{4} \times 20^2 \times 80$$

$$= 24000\,\pi \text{ N}$$

$$\text{Crushing strength per pitch} = ndt\ \sigma_{\text{per}}$$

$$= 3 \times 20 \times 10 \times 155 = 93000 \text{ N}$$

$$\text{Tearing strength of plate} = (p - d) \times t \times (\sigma_{\text{per}})_{\text{plate}}$$

$$= (60 - 20) \times 10 \times 95 = 38000 \text{ N}$$

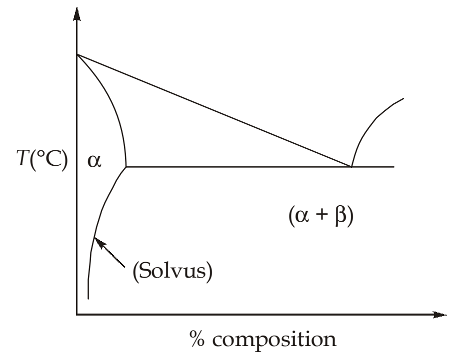
$$\text{Strength of solid plate} = pt\ \sigma_{\text{per}} = 60 \times 10 \times 95 = 57000 \text{ N}$$

$$\eta = \frac{\text{Minumum of strength}}{\text{Strength of Solid plate}} = \frac{38000}{57000} \times 100$$

$$= 66.67\%$$

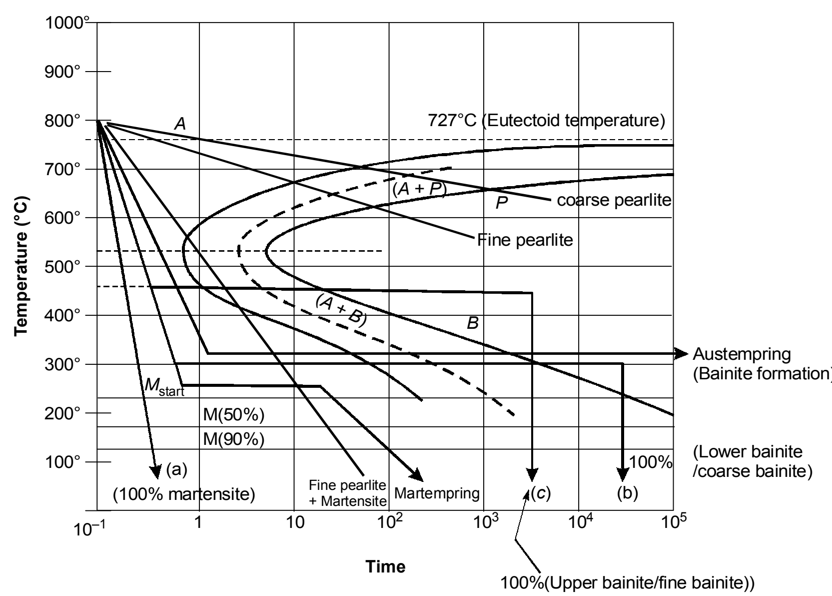
10. (c)

A line representing the solubility limit of a terminal solid solution w.r.t. a two-phase solid region is called solvus line.



11. (c)

At 350°C austenite isothermally transforms to bainite, this reaction begins in 10 seconds and reaches completion at about 500 seconds elapsed time. As given in question the time is 10^4 s, 100% of the specimen will transformed in bainite and no further transformation is possible even though final quenching line passes through the martensite region of the diagram.



12. (a)

Ductility is measured as percentage elongation or percentage reduction in area.

$$\text{percentage reduction in area} = \frac{A_o - A_f}{A_o} \times 100 = \frac{\frac{\pi}{4}d_o^2 - \frac{\pi}{4}d_f^2}{\frac{\pi}{4}d_o^2} \times 100$$

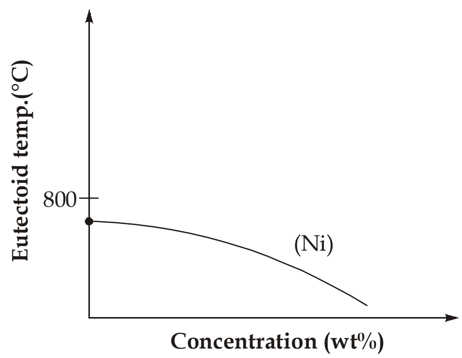
$$= \frac{12^2 - 10^2}{12^2} \times 100 = \frac{144 - 100}{144} \times 100 = \frac{4400}{144}$$

$$= 30.56\%$$

13. **(c)**

The more the prior cold work the lower the temperature required for recrystallization. The reason for this inverse relationship is that as the amount of cold work increases, the number of dislocation and the amount of energy stored in the dislocations also increases. The stored energy supplies some of the energy required for recrystallization. Hence the temperature required is also less for recrystallization.

14. **(d)**



15. **(b)**

- Bronze alloys are stronger and more corrosion resistant than brasses.

16. **(d)**

- Stress corrosion cracking is the growth of crack formation in corrosive environment. It can lead to unexpected sudden failure of normally ductile metal alloys subjected to tensile stress, especially at elevated temperatures.
- Duplex-structure steel contain a mixture of austenite and ferrite. They have higher resistance to corrosion and to stress corrosion cracking than the austenite steels.

17. **(c)**

Air refrigeration works on bell-coleman cycle or Reverse Brayton cycle. It is preferred in aircrafts due to low weight per tonnage of refrigeration.

In open air system, air comes in contact with the cold chamber or cold food and collects moisture. This moisture freezes during expansion and there is chances of choking of valve.

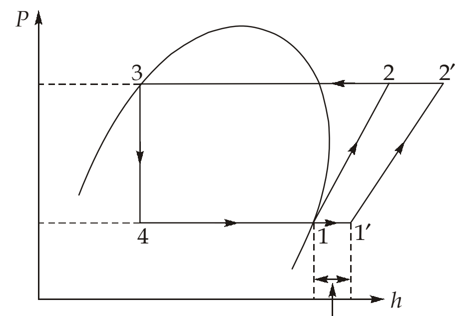
18. **(c)**

The difference between the latest start time and earliest start time of an activity is called total float.

19. (b)

1 - 2 - 3 - 4 Simple VCRS

1′ - 2′ - 3 - 4 VCRS with superheat



As pressure ratio remains same the volumetric efficiency of compressor will remain same. Due to superheating, specific volume of refrigerant will increase hence the compressor work will increases.

$$\because \qquad \text{COP} = \frac{RE \uparrow}{W_{in} \uparrow}$$

∵ In COP, both are increasing. Hence COP may decrease or increase. For refrigerant like R_{12}, R_{134a} it increases and for refrigerant like R_{22}, NH_3 it decreases.

20. (c)

$$(\text{COP})_{\text{Heat pump}} = 1 + (\text{COP})_{\text{Ref}}$$

So, if refrigerating systems will be use as heat pump,

$$(\text{COP})_{xP1} = 1 + 4 = 5$$

$$(\text{COP})_{xP2} = 1 + 5 = 6$$

$$\because \qquad (\text{COP})_{\text{cascade system}} = \frac{(\text{COP})_1 \times (\text{COP})_2}{1 + (\text{COP})_1 + (\text{COP})_2} = \frac{5 \times 6}{1 + 5 + 6}$$

$$= \frac{30}{12} = 2.5$$

21. (c)

The air mass flow rate is, $\dot{m}_a = \dfrac{cmm \times 60}{v_1} = \dfrac{80 \times 60}{0.8}$

$$\dot{m}_a = 6000 \text{ kg d.a./hr}$$

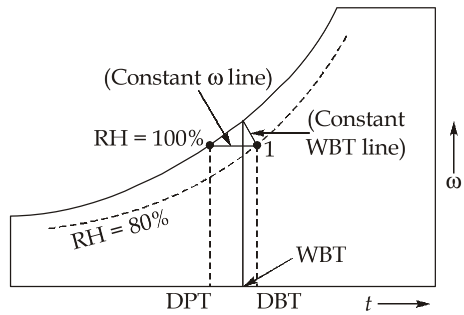
Amount of saturated steam picked up is, $m = \dot{m}_a(\omega_3 - \omega_2)$

$$= 6000 \times (0.0096 - 0.0036)$$

$$= 6000 \times 6 \times 10^{-3}$$

$$m = 36 \text{ kg/hr}$$

22. (b)



So, DBT > WBT > DPT

24. (d)

Pressure drop in evaporator is large, this is due to the cummulative effect of frictional pressure drop and momentum pressure drop.

In condensor, pressure drop is negligible since the frictional pressure drop is positive and momentum pressure drop is negative.

25. (b)

Automatic expansion valve is preferred for constant load requirement. While thermostatic expansion value is preferred for varying load requirements. Hence thermostatic expansion valve is most suitable for application in air conditioning and refrigeration plants.

26. (c)

For an ideal refrigerant desired properties are:

- Low boiling point temperature.
- Low freezing point temperatrue.
- Higher critical temperatrue.
- High latent heat of refrigerant.
- High thermal conductivity in liquid and vapour state.
- Low specific heat of liquid refrigerant.
- High specific heat of vapour refrigerant.
- Low viscosity in both liquid and vapour state.

27. (a)

Deep groove ball bearing is also known as noiseless ball bearing because it has least noise among all antifriction bearings.

Thrust ball bearings can bear only axial load, not radial load. So these are preferred for vertical shaft. Spherical roller bearing permits misalignment between shaft and bearing.

28. (b)

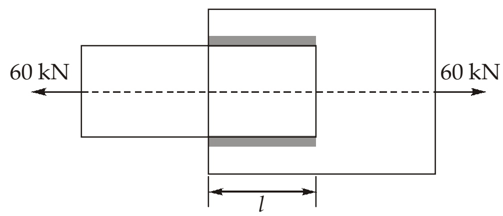
Material requirement planning (MRP) is a computational technique that converts the master schedule for end products into a detailed schedule for the raw materials and components used in the end products. MRP is often thought as a method of inventory control. It is both an effective tool for minimizing unnecessary inventory investment and a useful technique in production scheduling and purchasing of materials.

A push system of production control, parts at each workstation are produced irrespective of the immediate need for those parts at its respective downstream station. In effect, this production discipline pushes parts through the plant. Material requirement planning is a push system of production control.

30. (b)

Countersunk head rivets are used in structural work and ship hulls below the water line.

31. (a)



$$P = 2 \times 0.707 \times h \times l \times \tau$$

$$60 \times 10^3 = 1.414 \times 10 \times l \times 90$$

$$l = 47.15 \text{ mm}$$

So, required length of weld $= 2l = 2 \times 47.15 = 94.3$ mm

32. (b)

$$\text{Loss of available energy} = 1400\left[1-\frac{300}{800}\right]-1400\left[1-\frac{300}{500}\right]$$

$$= 1400\left[\frac{300}{500}-\frac{300}{800}\right] = 1400\times 300\left[\frac{1}{500}-\frac{1}{800}\right]$$

$$= 315 \text{ kJ/s}$$

33. (c)

The use of cambered rolls to compensate for roll bending and to produce uniform thickness strips.

34. (b)

Punching operation is performed on inner diameter,

∴ Punch size = 30 mm

Die size = 30 + 2 × 0.06 × 4 = 30.48 mm

35. (d)

$$\text{Shape factor} = \frac{\text{Length + Width}}{\text{Thickness}}$$

$$\text{Width} = \frac{\pi(D_i + D_o)}{2} = \frac{\pi(10+30)}{2} = \pi \times 20 \text{ cm}$$

$$\text{Shape factor} = \frac{30 + \pi \times 20}{10} = 9.28$$

Note: Here width has been calculated based on mean perimeter of cylindrical shape casting.

36. **(c)**

Taylor equation,

$$V_1 T_1^{0.5} = V_2 T_2^{0.5}$$

$$V_1 T_1^{0.5} = 0.5 \times V_1 \times (T_2)^{0.5}$$

$$\left(\frac{1}{0.5}\right)^{1/0.5} = \frac{T_2}{T_1}$$

$$T_2 = 4T_1$$

So, percentage increase in tool life is

$$= \frac{T_2 - T_1}{T_1} = \frac{4T_1 - T_1}{T_1} = 3 \text{ or } 300\%$$

37. **(a)**

Diffusion induced crater wear can be observed when a diamond cutting tool is used to machine steel. The high solubility of carbon in steel leads to rapid crater wear and eventually to tool failure.

38. **(d)**

The rpm of the hob is

$$N_h = \frac{1000 \times V_C}{\pi \times D_h} = \frac{1000 \times 44}{\frac{22}{7} \times 70} = 200 \text{ rpm}$$

So, speed of the gear blank, $N_g = 200 \times \frac{1}{40} = 5 \text{ rpm}$

39. **(c)**

Material removal rate can be increased by increasing the current and increasing the frequency of spark.

40. **(c)**

For parts that are symmetrical, it is often a problem for the operator to correctly place the part in the fixture. In such cases, a foolproofing pin is located on the fixture base such that the operator will be able to place the part in the correct orientation.

41. **(c)**

Transfer function for negative feedback closed loop system is

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}$$

For given system, $G(s) = G_3$

$$H(s) = H_3$$

$$\frac{C(s)}{R(s)} = \frac{G_3}{1 + G_3 H_3}$$

42. **(b)**

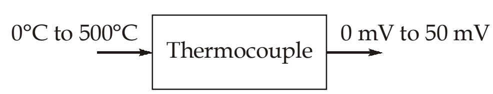
Three track absolute encoder signifies 3 bit binary data, consist of 2^3 combination,

$$\text{Resolution} = \frac{360°}{2^N} = \frac{360°}{2^3} = 45°$$

$\theta°$	b_2	b_1	b_o	Combination
$0 < \theta < 45°$	0	0	0	0
$45° < \theta < 90°$	0	0	1	1
$90° < \theta < 135°$	0	1	0	2
$135° < \theta < 180°$	0	1	1	3
$180° < \theta < 225°$	1	0	0	4
$225° < \theta < 270°$	1	0	1	5
$270° < \theta < 315°$	1	1	0	6
$315° < \theta < 360°$	1	1	1	7

$\theta = 130°$ lie in between $90° < \theta < 135°$ so, binary output display will [0 1 0]

43. **(c)**



$$\text{Sensitivity} = \frac{\text{Output}}{\text{input}} = \frac{50}{500} = 0.1\ \text{mV}/°\text{C}$$

$$\text{True value at } 200°\text{C} = \frac{50}{500} \times 200 = \frac{100}{5} = 20\ \text{mV}$$

Non linear error = Measured value – True value

= 22 mV – 20 mV = 2 mV

$$\%\ \text{of non linear error in true value} = \frac{2}{20} \times 100 = 10\%$$

44. **(b)**

For steady state and one-dimensional conduction,

By Fourier law,

$$\frac{Q}{A} = q = -k\frac{dT}{dx}$$

$$q\int_0^L dx = -\int_{T_1}^{T_2} k_o(1 + bT)\,dT$$

$$q(L - 0) = -k_o\left[1 + \frac{bT^2}{2}\right]_{T_1}^{T_2} = -k_o\left[(T_2 - T_1) + \frac{b(T_2^2 - T_1^2)}{2}\right]$$

$$q = -\frac{k_o}{L}\left[(T_2 - T_1) + \frac{b}{2}(T_2 - T_1)(T_2 + T_1)\right]$$

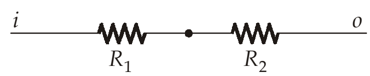
$$q = -\frac{k_o}{L}(T_2 - T_1)\left[1 + \frac{b}{2}(T_1 + T_2)\right]$$

So,
$$q = -\frac{0.01}{1}(100 - 200)\left[1 + \frac{0.2}{2}(300)\right]$$

$$= 1[1 + 30] = 31 \text{ W/m}^2$$

45. (a)

Let, R_i - Thermal resistance,



$$R_{eq} = R_1 + R_2 = \frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi k_1 L} + \frac{\ln\left(\frac{r_3}{r_2}\right)}{2\pi k_2 L} = \frac{\ln(2)}{2\pi k_1} + \frac{\ln(2)}{2\pi(2k_1)}$$

$$= \frac{\ln(2)}{2\pi k_1}\left[1 + \frac{1}{2}\right] = \frac{3\ln(2)}{4\pi k_1}$$

$$= \frac{3 \times 0.7}{4\pi k_1} = \frac{2.1}{4\pi k_1} = \frac{0.525}{\pi k_1}$$

$$R_{eq} = \frac{1}{5.98 k_1} \approx \frac{1}{6k_1}$$

46. (d)

Crystalline solids such as diamond and semiconductors such as silicon are good heat conductors but poor electrical conductors.

47. (d)

$$h = \frac{-k_f\left(\frac{dT}{dy}\right)_{y=0}}{(T_S - T_\infty)} = \frac{-k_f\left(E + 2Fy - 3Gy^2\right)_{y=0}}{(T_S - T_\infty)}$$

$$= \frac{-k_f E}{(T_S - T_\infty)} = \frac{k_f E}{(T_\infty - T_S)}$$

At $y = 0$, $T(0) = D = T_S$

$\therefore$
$$h = \frac{k_f E}{T_\infty - D}$$

48. (a)

$$Nu_x = \frac{h_x x}{k} = 0.04 \, Re_x^{0.9} \, Pr^{1/3}$$

$$\therefore \qquad h_x = \frac{(0.04)k}{x}\left(\frac{\rho V x}{\mu}\right)^{0.9} \cdot \Pr^{1/3}$$

$$= \left[0.04k\left(\frac{\rho V}{\mu}\right)^{0.9} \cdot \Pr^{1/3}\right] x^{0.9-1} = Cx^{-0.1}$$

where, $$C = 0.04k\left(\frac{\rho V}{\mu}\right)^{0.9} \cdot \Pr^{1/3}$$

At $x = L$, $h_L = CL^{-0.1}$ (Local heat transfer coefficient at $x = L$)

Average heat transfer coefficient, $$\bar{h} = \frac{1}{L}\int_0^L h_x dx = \frac{1}{L}\int_0^L Cx^{-0.1} dx = \frac{C}{L}\left[\frac{x^{0.9}}{0.9}\right]_0^L$$

$$\bar{h} = \frac{CL^{0.9}}{L \times 0.9} = \frac{CL^{-0.1}}{0.9} = \frac{h_L}{0.9}$$

$$\bar{h} = 1.11\, h_L$$

$$\frac{\bar{h}}{h_L} = 1.11$$

49. (d)

When one of the fluids in the heat exchanger is undergoing phase change then,

$$(\text{LMTD})_{\text{counter}} = (\text{LMTD})_{\text{parallel}}$$

$$\text{Effectiveness, } \varepsilon_{\text{parallel}} = \varepsilon_{\text{counter}} = 1 - e^{-\text{NTU}}$$

50. (d)

Heat transfer rate in the tubes can be enhanced by increasing the convection coefficient and/or by increasing the convection surface area. By increasing surface roughness or inserting a twisted tape, convection coefficient increases. By providing spiral fins or ribs, both convection coefficient and heat transfer area may be increased.

51. (b)

$$mc_pT_b = \int_{A_C} dm \cdot c_pT = \int_{A_C} (\rho \cdot dA \cdot v) \cdot c_pT$$

$$T_b = \frac{1}{\dot{m}}\int_{A_C} T\rho V \times d(A_C) = \frac{\int_0^R T\rho V 2\pi r dr}{\rho V_{avg}\pi R^2}$$

$$= \frac{2}{V_{avg}R^2}\int_0^R TVrdr$$

52. (b)

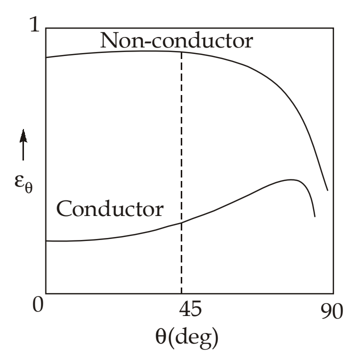
$$\text{Heat flux, } q_{\text{one shield}} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon}-1\right)+\left(\frac{1}{\varepsilon}+\frac{1}{\varepsilon_2}-1\right)} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1\right)+\left(\frac{2}{\varepsilon}-1\right)}$$

$$q_{\text{two shield}} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon}-1\right)+\left(\frac{1}{\varepsilon}+\frac{1}{\varepsilon}-1\right)+\left(\frac{1}{\varepsilon}+\frac{1}{\varepsilon_2}-1\right)} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1\right)+2\left(\frac{2}{\varepsilon}-1\right)}$$

$$q_{n\text{ shield}} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1\right)+n\left(\frac{2}{\varepsilon}-1\right)} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1}{\varepsilon_1}+\frac{2n}{\varepsilon}+\frac{1}{\varepsilon_2}-(n+1)\right)}$$

$\therefore \quad x = 2n, y = (n + 1)$

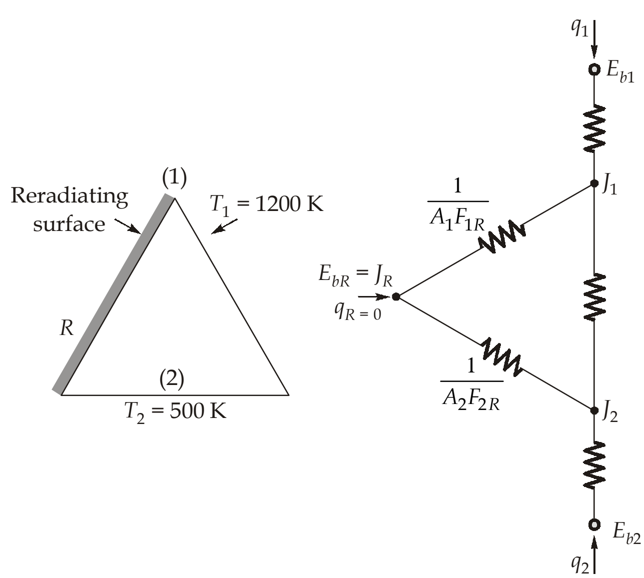
53. (d)



Based on the plot, both the statements are correct.

54. (d)

The insulated surface will be reradiating i.e. $q_R = 0$.



$$F_{12} = F_{1R} = F_{2R} = 0.5$$
$$A_1 = A_2 = A_3$$

From energy balance for reradiating surface,

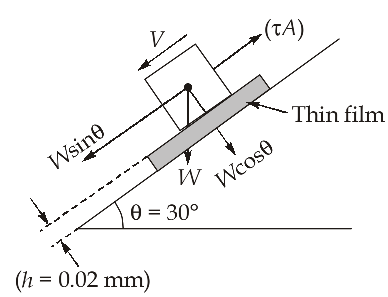
$$\frac{J_1 - J_R}{\frac{1}{A_1 F_{1R}}} = \frac{J_R - J_2}{\frac{1}{A_2 F_{2R}}}$$

$$J_R = \frac{J_1 + J_2}{2} = \frac{108323 + 59043}{2}$$

$$J_R = 83683 \text{ W/m}^2$$

55. (c)

$$\frac{du}{dy} = \frac{V}{h}$$



h (Thickness of oil film) = 0.02 mm

From Newton's law of viscosity:

$$\tau = \mu \frac{du}{dy} = \frac{\mu V}{h}$$

Viscous resistance force, $F = \tau A = \frac{\mu V}{h} \times A$

Where, A = Area of cubical block = 0.1 × 0.1 = 0.01 m^2

At terminal velocity, equilibrium occurs

$$\therefore \quad \frac{\mu V}{h} \times A = W \sin\theta$$

$$\frac{0.2 \times V}{0.02 \times 10^{-3}} \times 0.01 = 1000 \sin 30°$$

So, $V = 5 \text{ m/s}$

56. (b)

When $n > 1$, fluid is dilatant fluid. Sugar solution, starch suspension and high concentration sand suspension are typical examples of dilatant fluid.

When $n < 1$, fluid is pseudo-plastic fluid. Gelatine, milk and blood are typical examples of pseudo-plastic fluid.

57. (a)

Let h_f is head loss between any of two section. At steady state, V = Velocity of liquid in the pipe (constant).

Applying energy equation between 1 and B we get,

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + Z_B + h_f \qquad [V_1 = V_B = V, Z_1 = Z_B]$$

$$h_1 = h_f \text{ (All heads are in gage pressure)}$$

Now again applying energy equation between A and B we get,

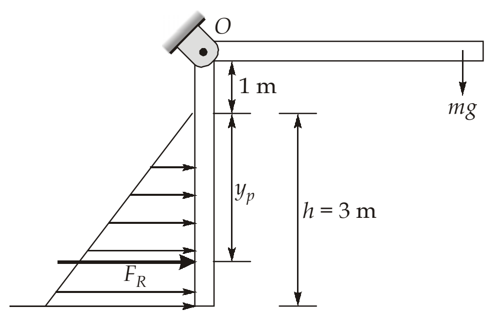
$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + Z_B + h_f + h_f + h_f$$

$$h_3 = \frac{V^2}{2g} + 3h_f = \frac{V^2}{2g} + 3h_1$$

$$V = \sqrt{2g(h_3 - 3h_1)} = \sqrt{2 \times 10(0.35 - 0.30)}$$

$$V = \sqrt{20 \times 0.05} = 1 \text{ m/s}$$

58. (c)



$$h = 3 \text{ m}, \quad \bar{h} = \frac{h}{2} = \frac{3}{2} \text{ m}$$

$$F_R = \rho g A\bar{h} = 1000 \times 10 \times 3 \times 1 \times \frac{3}{2} = 45000 \text{ N}$$

Centre of pressure, y_p = Centroid of triangular prism = $\frac{2}{3}h = \frac{2}{3} \times 3 = 2$ m

$\Sigma M_o = 0$, $\quad mg \times 6 = F_R\,(y_p + 1)$

$$m = \frac{45000 \times 3}{10 \times 6} = 2250 \text{ kg}$$

60. (b)

$$D = 6.81 \text{ cm} = 6.81 \times 10^{-2} \text{ m}, f = 0.025$$

Total minor head loss, $h_L = (k_{L1} + k_{L2} + k_{L3} + k_{L4} + k_{L5})\frac{V^2}{2g}$

$$= (1 + 0.78 + 0.22 + 1.5 + 0.9)\frac{V^2}{2g} = 4.4\left(\frac{V^2}{2g}\right)$$

For equivalent length of pipe, $(h_L) = f\frac{L_{equiv}}{D}\frac{V^2}{2g}$

$$4.4\frac{V^2}{2g} = f\frac{L_{equiv}}{D}\frac{V^2}{2g}$$

$$L_{equiv} = \frac{4.4 \times 6.81 \times 10^{-2}}{0.025} = \frac{11 \times 4 \times 68.1 \times 2}{5 \times 100}$$

$$L_{equiv} = \frac{11 \times 544.8}{500} = \frac{59.928}{5} = 11.98 \text{ m} \approx 12 \text{ m}$$

61. (c)

$$u(y) = a + b\left(\frac{y}{\delta}\right) + c\left(\frac{y}{\delta}\right)^3 \quad \text{... (i)}$$

Boundary condition are:

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

At $y = \delta$, $u = U$

At $y = \delta$, $\frac{du}{dy} = 0$

Applying above boundary condition in equation (i), we get

$$a = 0,\ b + c = U$$

$$b + 3c = 0$$

Solving we get, $b = +\frac{3U}{2}, \quad c = -\frac{U}{2}$

62. (b)

In the vicinity of the wall, Prandtl's mixing length (l_m) is nearly proportional to the distance from wall.

$$l_m = ky$$

where, k = Karman's coefficient = 0.4

At the wall of a pipe, l_m is zero.

63. (c)

Average velocity, $V = \left(-\frac{\partial P}{\partial x}\right)\frac{B^2}{12\mu}$

Shear stress at the boundary, $\tau_o = \left(-\frac{\partial P}{\partial x}\right)\frac{B}{2}$

$$\tau_o = \frac{12\mu V}{B^2} \times \frac{B}{2} = \frac{6\mu V}{B}$$

$$\therefore \quad \tau_o = \frac{6\mu V}{B}$$

64. (d)

Ideal gas equation: $pV = mRT$

$$p \propto T$$

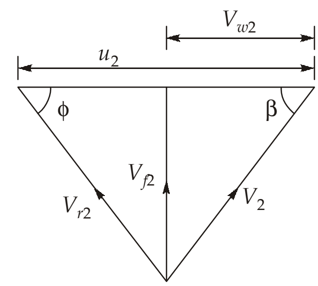
$$\frac{p_2}{p_1} = \frac{T_2}{T_1} \Rightarrow \frac{(15+1)}{(2+1)} = \frac{T_2}{300}$$

$$\Rightarrow \quad \frac{16}{3} \times 300 = T_2$$

$$T_2 = 1600 \text{ K}$$

65. (a)

As per given data:



$$u_2 = 22.77 \text{ m/s}$$

$$\frac{P_d - P_s}{\rho g} = H_m = 25 \text{ m}$$

From outlet velocity triangle,

$$V_{f2} = 2.5 \text{ m/s}, \qquad \phi = 30°$$

$$V_{w2} = u_2 - V_{f2} \cot\phi$$

$$= 22.77 - 2.5 \times 1.732$$

$$= 22.77 - 4.33$$

$$V_{w2} = 18.44 \text{ m/s}$$

$$\eta_{mano} = \frac{H \times g}{V_{w2} u_2} = \frac{10 \times 25}{18.44 \times 22.77} = 59.54\% \approx 59\%$$

67. (a)

Different mountings are:

1. Water level indicator
2. Safety valves
3. High steam and low water safety valves
4. Fusible plug
5. Pressure gauge
6. Stop valve
7. Feed check valve
8. Blow off cock
9. Manhole and mud box

Various boiler accessories are:

1. Superheater 2. Economiser
3. Air preheater 4. Feed pump

Fusible plug: It is a safety device used for preventing the level of water from going down below a critical point and thus avoids overheating. Fusible plug is mounted at crown plate of combustion chamber.

68. (d)

Given: m = 18 kg air per kg of fuel, h_w = 20 mm, T_a = 27 + 273 = 300 K, T_g = 300 + 273 = 573 K

Draught in terms of water column,

$$h_w = 353H\left[\frac{1}{T_a} - \left(\frac{m+1}{m}\right) \times \frac{1}{T_g}\right] \text{ mm of water}$$

$$20 = 353H\left[\frac{1}{300} - \left(\frac{18+1}{18}\right) \times \frac{1}{573}\right]$$

$$H = 37.99 \text{ m} \approx 38 \text{ m}$$

$$\text{Height of chimney} = 37.99 \text{ m} \approx 38 \text{ m}$$

69. (d)

- Ramjet engine is the simplest of jet engines having no moving parts.
- Ramjet is a typically shaped duct, open at both ends with air being compressed merely due to forward motion of engine.
- Fuel is subsequently added for combustion and thus high pressure, high temperature gases exit from exhaust nozzle.
- High pressure air is continuously available as engines keeps on moving forward.
- These ramjet engines are extensively used for high speed aircrafts.

70. (b)

- In these condensers the steam to be condensed and cooling fluid (water) do not come in contact with one another, instead the heat transfer occurs between two fluids through surface in between.
- These condensers are preferred in the locations where large quantity of poor quality cooling fluid (impure water) is available and condensate is to be recirculated.
- Steam is admitted from the top. Cooling water may be picked directly from river/pond/cooling tower. For extraction of air the provision is made for air pump. Thus, this type of condenser has three pumps i.e. one for circulating cooling water, second for condensate extraction and third for air extraction.

71. (a)

C_p - Power coefficient which is fraction of available power in wind that can be extracted.
a - Interference factor which is ratio of decrease in velocity of air in wind turbine to inlet air

$$a = \frac{u_1 - u_2}{u_1}$$

$$C_p = 4a(1 - a)^2$$

$$C_p = 4 \times 0.22\,(1 - 0.22)^2$$

$$C_p = 0.5354$$

72. (b)

The normal incidence pyrheliometer, uses a long collimator tube to collect beam radiation whose field of view is limited to a solid angle of 5.5° by appropriate diaphragms inside the tube. The inside of the tube is blackened to absorb any radiation incident at angles outside the collection solid angle.
At the base of tube a wire wound thermopile having a sensitivity of approximately 8 μV/W/m^2 and output impedence of approx 200 Ω is provided. Tracker is needed if continuous readings are desired.

74. (d)

Both horizontal and vertical axis wind mills are used to harness wind energy. Typically wind speed from 5 to 25 m/s are most favourable.

75. (d)

Hot-wire anemometer measures the wind speed by recording cooling effect of wind on hot air. Anemometer measures wind speed.

76. (b)

For leap year,

$$n = 73 \text{ for 13 March}$$

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

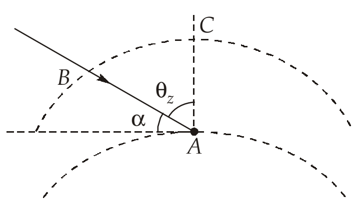
$$I_{sc} = 1367 \text{ W/m}^2$$

$$I_{ex} = 1367\left[1 + 0.033\cos\left(\frac{360 \times 73}{365}\right)\right]$$

$$= 1367 [1 + 0.033 \cos 72°]$$

$$I_{ex} = 1381 \text{ W/m}^2$$

77. (b)



$$m = \text{Air mass}$$

$$m = \frac{\text{Path length transversed by beam radiation}}{\text{Vertical path length of atmosphere}}$$

$$= \frac{1}{\cos\theta_z}$$

For overhead sun, $\theta_z = 0$

∴ $m = 1$

78. (d)

Thermal cracking subjects the large hydrocarbon molecules to high temperature and pressure and they are decomposed into smaller, lower boiling point molecules.

79. (c)

With spark at TDC, the peak pressure is low due to expansion of gases. If the spark is advanced (> 35°) to achieve complete combustion close to TDC, additional work is required to compress the burning gases. In either case, viz., with or without spark advance the work area is less and the power output and efficiency are are lowered. Therefore, a moderate or optimum spark advance (15° - 30°) is the best compromise resulting in minimum losses on both the compression and expansion strokes.

81. (a)

The supercharger takes 10% of total power, so power that should be produced by supercharged engine = $\frac{270}{0.9} = 300\text{ kW}$

$$\text{Mass of air required, } \dot{m}_a = 300 \times \frac{0.3}{60} \times 18 = 27\text{ kg/min}$$

$$\text{Mass of air per cycle} = \frac{27 \times 2}{N} = \frac{27 \times 2}{2000} = \frac{27}{1000}\text{ kg/cycle} \quad [\frac{N}{2}\text{ for 4-stroke cycle}]$$

$$\text{Volumetric efficiency: } \eta_v = \frac{m_v \times v_2}{V_s} = \frac{27}{100} \times \frac{RT}{P \times V_s}$$

$$P = \frac{27}{1000} \times \frac{0.287 \times 10^3 \times (273 + 37)}{0.0287 \times 0.9} \times 10^{-5}$$

$$P = 0.93\text{ bar}$$

$$\text{Pressure increase required} = 0.93 - 0.7 = 0.23\text{ bar}$$

82. (a)

We know that for retardation test, frictional torque is given by

$$T_f = \frac{t_3}{t_2 - t_3} \times T_{1/2} = \left(\frac{3}{8 - 3}\right) \times 80 = 48\text{ N-m}$$

Where t_2 and t_3 be the time of fall at no load and half load respectively.

83. (b)

Rich mixture does not have enough oxygen to react with all the carbon and hydrogen, and both HC and CO emission increases. The generation of NO_x emissions is a function of the combustion temperature, highest near stoichiometric conditions when temperature are at the peak value. Maximum NO_x emissions occur at slightly lean conditions where the combustion temperature is high and there is an excess of oxygen to react with the nitrogen.

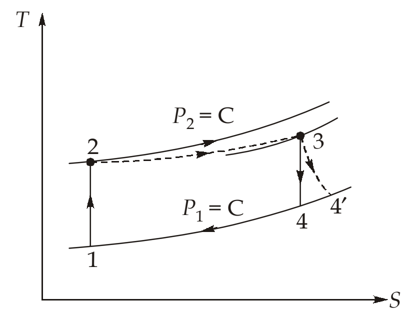
84. (d)

When a converter in good working order is operated at a fully warmed temperature of 400°C or above, it will remove 98-99% of CO, 95% of NO_x and more than 95% of HC from exhaust flow emissions.

85. (d)

The orifice method can be used if pressure pulsations could be damped out by some means. In IC engine, the satisfactory mesurement of air consumption is quite difficult because the flow is pulsating due to the cyclic nature of the engines and because the air is a compressible fluid. The usual method of damping out pulsations is to fit an air box of suitable volume (500 to 600 times the swept volume in single cylinder engines and less in the case of multi-cylinder engines) to the engine with an orifice placed in the side of the box remote from the engine.

86. (b)



In combustion chamber,

$$\dot{m}_f \times \text{Calorific value} \times \eta_{\text{combustion}} = (\dot{m}_a + \dot{m}_f)c_{pg}T_3 - \dot{m}_a c_{pa} T_2$$

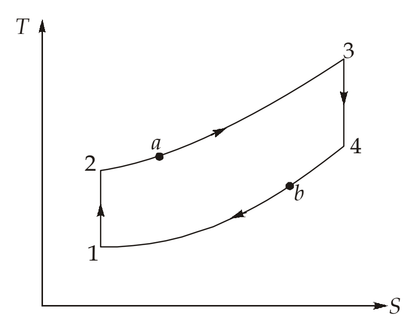
$$42000 \times 0.98 = \left(\frac{\dot{m}_a}{\dot{m}_f} + 1\right) 1.1 \times 1500 - \frac{\dot{m}_a}{\dot{m}_f} \times 650$$

$$42000 \times 0.98 = \frac{\dot{m}_a}{\dot{m}_f}\left(C_{pg}T_3 - C_{pa}T_2\right) + C_{pg}T_3$$

$$\frac{41160 - 1.1 \times 1500}{1.1 \times 1500 - 650} = \frac{\dot{m}_a}{\dot{m}_f}$$

$$\frac{\dot{m}_a}{\dot{m}_f} = 39.51$$

87. (d)



$$\text{Effectiveness of regenerator, } \dot{\varepsilon} = \left(\frac{T_a - T_2}{T_4 - T_2}\right)$$

Effectiveness of ideal regenerator, $\varepsilon = 1$

$$T_a = T_4 \text{ and } T_b = T_2$$

$$\eta_{thermal} = 1 - \frac{Q_R}{Q_S} = 1 - \left(\frac{T_b - T_1}{T_3 - T_a}\right) = 1 - \left(\frac{T_2 - T_1}{T_3 - T_4}\right)$$

$$= 1 - \frac{T_1\left(\frac{T_2}{T_1} - 1\right)}{T_4\left(\frac{T_3}{T_4} - 1\right)} = 1 - \frac{T_1}{T_4} \qquad \left[\frac{T_3}{T_4} = \frac{T_2}{T_1} = (r)^{\frac{\gamma-1}{\gamma}}\right]$$

$$\Rightarrow \qquad \eta = 1 - \frac{T_1}{T_4} \times \frac{T_3}{T_3} = 1 - \frac{T_1}{T_3} \times \left(\frac{T_3}{T_4}\right)$$

$$\eta_{thermal} = 1 - \frac{T_1}{T_3}(r)^{\frac{\gamma-1}{\gamma}} \qquad \left[\frac{T_3}{T_4} = \frac{T_2}{T_1} = (r)^{\frac{\gamma-1}{\gamma}}\right]$$

88. **(c)**

William's line equation,

$$w_s = 25000 + 4 \times L$$

At rate load,

$$L = 100 \times 10^3 \text{ kW}$$

$$w_s = 25000 + 4 \times 100000$$

$$= 425000 \text{ kg/hour}$$

89. **(c)**

The back work ratio compares the work required by the compressor to the work developed by the turbine.

$$\text{Back work ratio} = \frac{\text{Compressor work}}{\text{Turbine work}}$$

90. **(c)**

As we know,

$$\eta_{overall} = \eta_{stage} \times \text{Reheat factor}$$

$$= 0.75 \times 1.071$$

$$= 0.80325$$

$$= 80.325\%$$

92. **(d)**

σ is Thoma cavitation parameter, it is a measure of how much the pressure at the discharge end of turbine differs from vapour pressure.

σ_c (Critical Thoma coefficient) represents the lower value of σ that can be allowed in the turbine without serious cavitation occuring in the turbine.

If $\sigma \geq \sigma_c$, then there will be no chances of cavitation.

If $\sigma < \sigma_c$, the turbine installation will suffer cavitation problem.

93. (d)

As per given data:

P = 22 MW, H = 25 m, η_o = 0.8, D_o = 4 m D_h = 2m

$$\text{Power} = \eta_o \rho Q g H$$

$$\Rightarrow \quad 22 \times 10^6 = 0.8 \times 1000 \times Q \times 10 \times 25$$

$$Q = \frac{22000}{0.8 \times 10 \times 25} = \frac{22000}{20 \times 10} = 110 \text{ m}^3/\text{s}$$

$$\therefore \quad Q = \frac{\pi}{4}\left(D_o^2 - D_h^2\right)V_{f1}$$

$$\Rightarrow \quad 110 = \frac{22}{7 \times 4}\left(4^2 - 2^2\right)V_{f1}$$

$$\Rightarrow \quad 5 \times 7 \times 4 = (16 - 4)V_{f1}$$

$$\Rightarrow \quad V_{f1} = \frac{5 \times 7 \times 4}{12} = \frac{35}{3} = 11.67 \text{ m/s}$$

$$\Rightarrow \quad V_{f1} = 11.67 \text{ m/s}$$

94. (c)

β_2 (Outlet blade angle): It is angle made by the relative velocity vector (V_{r2}) with the negative direction of the peripheral velocity (u_2):

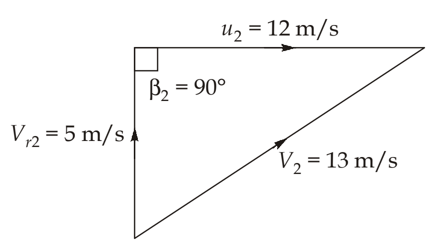
From given data:

$$V_2 = \sqrt{V_{r2}^2 + u_2^2}$$

$$13 = \sqrt{5^2 + 12^2}$$

So, outlet velocity triangle is right angled triangle and β_2 = 90°.

Obtained velocity triangle,



95. (b)

$$\text{Paddle wheel work, } W_{pw} = -mgh = -100 \times 9.81 \times 3$$
$$= -2943 \text{ J}$$

$$\text{Work done by gas on piston, } W_2 = p \times \Delta V = 200 \times 0.002 \times 1000$$
$$= 400 \text{ J}$$

$$\text{Net work done} = 400 - 2943 = -2543 \text{ J}$$

Negative sign shows that work is done on the system.

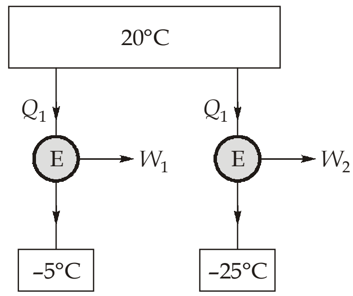
96. (b)

$$\text{Thermal efficiency, } \eta = \frac{W}{Q} = 1 - \frac{T_2}{T_1}$$

$$W = Q\left(1-\frac{T_2}{T_1}\right) = Q\left(\frac{T_1-T_2}{T_1}\right)$$

Case 1:

$$W_1 = Q_1\left(\frac{20-(-5)}{20+273}\right) = \frac{25}{293}Q_1$$



Case 2:

$$W_2 = Q_1\left(\frac{20-(-25)}{20+273}\right) = \frac{45}{293}Q_1$$

$$\text{\% increase in work output} = \frac{W_2-W_1}{W_1}\times 100 = \frac{\frac{45}{293}Q_1 - \frac{25}{293}Q_1}{\frac{25}{293}Q_1}\times 100$$

$$= \left(\frac{45}{25}-1\right)\times 100 = \frac{4}{5}\times 100 = 80\%$$

97. (d)

An optical method is adopted for measuring temperature higher than the gold point (1063°C). The intensity of radiation of any conveneint wavelength is compared with the intensity of radiation of the same wavelength emitted by a black body at the gold point. The temperature is then determined with the help of Planck's law of thermal radiation.

98. (d)

$$\eta_m = \frac{\text{Heat of melting}}{\text{Heat supplied}} = \frac{H_m}{H_s}$$

$$= \frac{15\times\frac{\pi}{2}\times 5^2\times 200}{\frac{2}{3}\times 200\times 10^3} = 0.8835 = 88.35\%$$

99. (c)

Let final temperature be 'T_2'

Energy balance:

$$mc_p\,(T_2 - 27) = I^2Rt$$

$$\Rightarrow \quad \frac{50}{1000}\times 800\times (T-27) = 5^2 \times 100 \times 4.8$$

$$T_2 - 27 = \frac{25 \times 100 \times 4.8}{40}$$

$$T_2 = 300 + 27 = 327°C$$
$$= 327 + 273 = 600 \text{ K}$$

Entropy change of resistor, $\Delta S_{res} = mc_p \ln\left(\frac{T_2}{T_1}\right) = \frac{50}{1000} \times 800 \ln\left(\frac{600}{300}\right)$

$$= 40 \ln 2 = 40 \times 0.693 = 27.92 \text{ J/K}$$

Entropy change of surrounding,

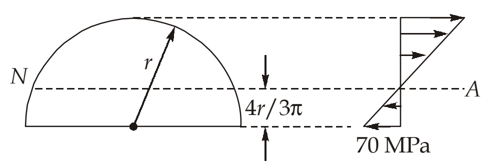
$$\Delta S_{surr} = 0 \quad [\because \text{ No heat transfer}]$$

Entropy change of universe,

$$\Delta S_{uni} = \Delta S_{res} + \Delta S_{surr}$$
$$= 27.72 + 0 = 27.72 \text{ J/K}$$

100. (c)

As we know, $\sigma \propto y$



$$\frac{\sigma_{top}}{\sigma_{bottom}} = \frac{y_{top}}{y_{bottom}} \Rightarrow \frac{\sigma_{top}}{70} = \frac{\left(r - \frac{4r}{3\pi}\right)}{\frac{4r}{3\pi}}$$

$$\sigma_{top} = 70 \times \left(\frac{3\pi}{4} - 1\right) = 70 \times \left(\frac{3 \times 22}{4 \times 7} - 1\right)$$

$$= 70 \times \left(\frac{33}{14} - 1\right) = 70 \times (2.357 - 1)$$

$$\sigma_{top} = 70 \times (1.357) = 95 \text{ MPa}$$

101. (b)

Since strain energy stored by the two rods is same,

$$\frac{\sigma_A^2}{2E_A} \times A_A \times L_A = \frac{\sigma_B^2}{2E_B} \times A_B \times L_B$$

$$\left(\frac{\sigma_A}{\sigma_B}\right)^2 = \frac{A_B}{A_A}$$

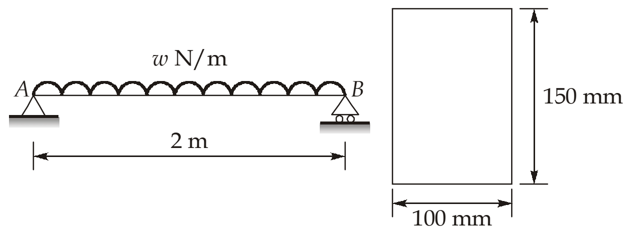
$[E_A = E_B$ ($\because$ Same material), $L_A = L_B$ (Same length)]

$$\frac{\sigma_A}{\sigma_B} = \sqrt{\frac{100^2}{\frac{\pi}{4} \times 100^2}} = \sqrt{\frac{4}{\pi}} = \frac{2}{\sqrt{\pi}} = 1.128$$

102. (b)

Maximum shear force,

$$F_{max} = R_A = R_B = \frac{wL}{2} = \frac{w \times 2}{2} = w \text{ N}$$



Maximum shear stress in the beam for rectangular cross section,

$$\tau_{max} = \frac{3}{2}\tau_{avg} = \frac{3}{2}\frac{F_{max}}{bd} = \frac{3}{2} \times \frac{w}{100 \times 150}$$

$$\tau_{max} = w \times 10^{-4} \text{ MPa}$$

For safe design, $\tau_{max} \leq \tau_{per}$

$\Rightarrow$ $w \times 10^{-4} \leq 2$

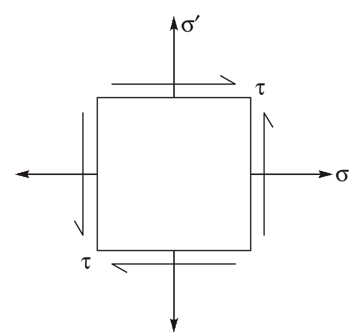
$$w \leq 2 \times 10^4 \text{ N/m}$$

$$w \leq 20 \text{ kN/m}$$

103. (b)

Minor principal stress, $\sigma_2 = \frac{\sigma + \sigma'}{2} - \sqrt{\left(\frac{\sigma - \sigma'}{2}\right)^2 + \tau^2} = 0$

$\Rightarrow$ $\frac{\sigma + \sigma'}{2} = \sqrt{\left(\frac{\sigma - \sigma'}{2}\right)^2 + \tau^2}$



$$\left(\frac{\sigma + \sigma'}{2}\right)^2 - \left(\frac{\sigma - \sigma'}{2}\right)^2 = \tau^2$$

$$\frac{1}{4}\left[\sigma^2 + \sigma'^2 + 2\sigma\sigma' - \sigma^2 - \sigma'^2 + 2\sigma\sigma'\right] = \tau^2$$

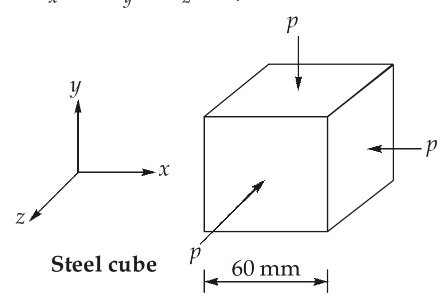
$$\frac{1}{4}[4\sigma\sigma'] = \tau^2$$

$$\tau^2 = \sigma\sigma'$$

$$\tau = \sqrt{\sigma\sigma'}$$

104. (c)

$$\sigma_x = \sigma_y = \sigma_z = -p = -100 \text{ MPa}$$



Strain in x-direction,

$$\varepsilon_x = \frac{1}{E}\left[\sigma_x - \mu\sigma_y - \mu\sigma_z\right]$$

$$= \frac{1}{200 \times 10^3}\left[-100 + \frac{1}{4} \times 100 + \frac{1}{4} \times 100\right]$$

$$= \frac{100}{200 \times 10^3}\left[-1 + \frac{1}{4} + \frac{1}{4}\right] = -0.25 \times 10^{-3} \text{ mm/mm}$$

Change in dimension, $\Delta_x = \varepsilon_x \times a = -0.25 \times 10^{-3} \times 60$

$= -0.015$ mm

Negative sign shows that there is contraction of dimension.

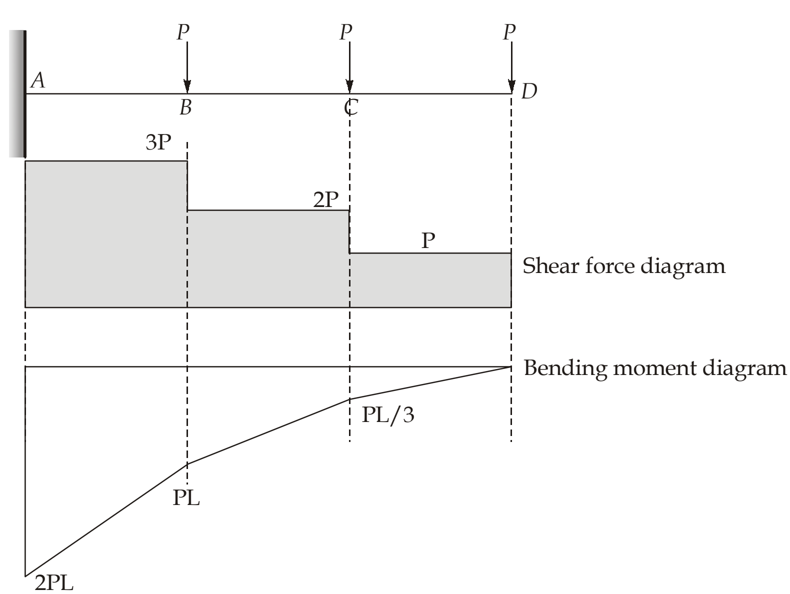
105. (c)

At pinned support, $y = 0$ and $\theta \neq 0$

At free end, $y \neq 0$

At fixed support, $y = 0$ and $\theta = 0$

106. (b)



Mohr's Ist theorem:

$$\theta_C - \theta_A = \text{Area of } \frac{M}{EI} \text{ diagram between point C and A}$$

$$\theta_C = \frac{1}{EI}\left[\frac{L}{3\times 2}\left(PL+\frac{PL}{3}\right)+\frac{L}{3\times 2}(2PL+PL)\right] \quad [\theta_A = 0, \text{ fixed end}]$$

$$= \frac{1}{EI}\left[\frac{2PL^2}{9}+\frac{PL^2}{2}\right] = \frac{13}{18}\frac{PL^2}{EI}$$

107. **(b)**

$$T = 0.3 \text{ N-m}$$

$$G = 75 \text{ GPa}$$

As we know,

$$\frac{\theta}{L} = \frac{T}{GJ} = \frac{0.3\times 10^{12}}{75\times 10^9 \times \frac{\pi}{32}\times 4^4}$$

$$= \frac{0.3\times 10^3\times 32}{75\times\pi\times 16\times 16} = \frac{1}{2\pi}\text{ rad/ m}$$

$$= \frac{1}{2\pi}\times\frac{180}{\pi} = 9.11^\circ / \text{m}$$

109. **(b)**

Number of variable $= n \times m = 3 \times 2 = 6$

Number of equation $= n + m - 1 = 3 + 2 - 1 = 4$

Number of alternate basic solutions $= {}^{n\times m}C_{n+m-1}$

$= {}^6C_4 = 15$

110. **(c)**

1 unit of product X requires 3 units of A, 5 units of B and 2 units of C.

So 400 units of product X requires 1200 units of A, 2000 units of B and 800 units of C.

And 1 unit of component A requires 3 units of components D.

So, for 1200 units of components A, 3600 units of sub-component D is required.

And 1 unit of component C requires 4 units of sub-component F.

So for 800 units of component C, 3200 units of sub components F is required.

Requirement of sub-component, D = 3600 units

Requirement of sub-component, F = 3200 units

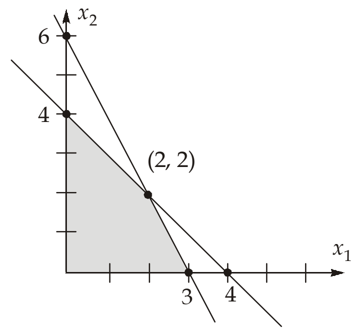
111. **(c)**

It is an assignment problem.

$$\begin{bmatrix}12 & 17\\ 15 & 19\end{bmatrix} \rightarrow \begin{bmatrix}0 & 5\\ 0 & 4\end{bmatrix} \rightarrow \begin{bmatrix}0 & 1\\ 0 & 0\end{bmatrix} \rightarrow \begin{bmatrix}\boxed{0} & 1\\ 0 & \boxed{0}\end{bmatrix}$$

Least cost = 12 + 19 = 31

112. (c)



$$x_1 + x_2 \le 4$$
$$2x_1 + x_2 \le 6 \qquad [x_1 = 2, x_2 = 2]$$

By subtracting, $x_1 = -2$

$$Z(x_1 = 0, x_2 = 4) = 24$$
$$Z(x_1 = 3, x_2 = 0) = 21$$
$$Z(x_1 = 2, x_2 = 2) = 26$$

113. (c)

Arrival rate, λ = 4 machines/hr

Service rate, μ = 5 machines/hr

Channel efficiency, $\rho = \frac{\lambda}{\mu} = \frac{4}{5} = 0.8$

Number of machines in system, $L_S = \frac{\rho}{1-\rho} = \frac{0.8}{1-0.8} = \frac{0.8}{0.2} = 4$

Total queuing cost = L_S × Cost of ideal machines/hr + Repairman charges

= 4 × 200 + 100 = ₹900 per hour

114. (a)

FTA is cause-oriented while ETA (Event Tree Analysis) is consequence oriented.

The general direction of logical flow in FTA is up to down.

Six basic units of fault tree diagram are:

AND gate, OR gate, basic event, intermediate event, transfer and undeveloped event.

116. (c)

By comparing frame matrix with,

$$F_{\text{object}} = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

where n, o, a three unit vectors, which are perpendicular to each other.

$$n \cdot a = 0$$
$$\left(0.707\hat{i} + x\hat{j} + o\hat{k}\right)\cdot\left(0.707\hat{i} - 0.707\hat{j} + 0\hat{k}\right) = 0$$
$$(0.707)^2 - 0.707x = 0$$
$$x = 0.707$$

117. (a)

For rotation about fixed frame, we do pre-multiplication and for rotation about moving frame i.e. [noa], we do post multiplication.

$$P_{xyz} = R_x(\alpha) \cdot R_z(\gamma) \cdot R_o(\beta) \cdot P_{noa}$$

118. (d)

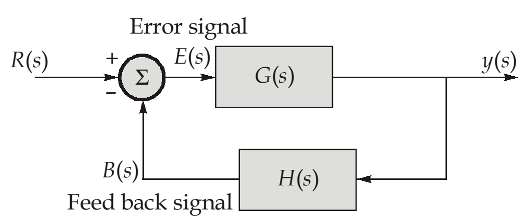
$$^2T_1 = \left[\begin{array}{ccc|c} & ^1R_2^T & & -^1R_2^T\,{}^1D_2 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

$$^1R_2 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.5 & -0.866 \\ 0 & 0.866 & 0.5 \end{bmatrix} \Rightarrow -^1R_2^T = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -0.5 & -0.866 \\ 0 & 0.866 & -0.5 \end{bmatrix}$$

$$-^1R_2{}^T \times {}^1D_2 = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -0.5 & -0.866 \\ 0 & 0.866 & -0.5 \end{bmatrix}\begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} = \begin{bmatrix} -1 \\ -1.866 \\ 1.232 \end{bmatrix}$$

$$^2T_1 = \begin{bmatrix} 1 & 0 & 0 & -1 \\ 0 & 0.5 & 0.866 & -1.866 \\ 0 & -0.866 & 0.5 & 1.232 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

119. (d)



$$y(s) = E(s)\ G(s) \text{ and}$$

$$B(s) = y(s)\ H(s) = E(s)\ G(s)\ H(s)$$

Open loop transfer function, (OLTF) = $\dfrac{B(s)}{E(s)} = \dfrac{E(s)G(s)H(s)}{E(s)}$

$$(\text{OLTF}) = G(s)\ H(s)$$

$$= \frac{1}{s(s+2)} \times \frac{1}{s} = \frac{1}{s^2(s+2)}$$

120. (d)

Velocity of piston × Area of piston = Volume flow rate of liquid

$$v \times \frac{\pi}{4} \times (0.05)^2 = 0.3\ \text{m}^3/\text{min}$$

$$v = \frac{0.3 \times 4}{\pi \times 0.05 \times 0.05 \times 60} = 2.54\ \text{m/s}$$

121. (c)

$$\text{Production rate, } p = 50 \text{ items per day}$$
$$\text{Demand, } d = 25 \text{ items per day}$$
$$\text{Setup cost, } C_o = ₹100 \text{ per setup}$$
$$\text{Holding cost, } C_h = 0.01 \text{ per unit per day}$$

$$Q^* = \sqrt{\frac{2DC_o}{C_h\left(\frac{p-d}{p}\right)}} = \sqrt{\frac{2 \times 25 \times 100}{0.01\left(\frac{50-25}{50}\right)}}$$

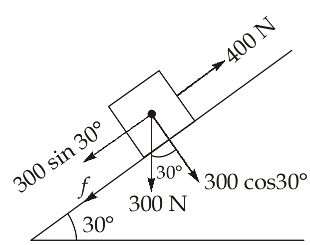
$$= \sqrt{\frac{2 \times 25 \times 100 \times 100}{0.5}} = 1000 \text{ items}$$

122. (a)

Inventory carrying cost includes:
- Capital tied up in inventories
- Cost of storage space
- Depreciation and deterioration costs
- Pilferage cost
- Obsolesence cost
- Handling costs
- Administrative cost
- Taxes and insurance cost

123. (c)

Let final velocity be 'v'.



Work done by forces along the plane results in change in kinetic energy of body, i.e.,

$$(400 - f - 300 \sin 30°) \times 5 = \frac{1}{2} \times \frac{300}{10} \times (v^2 - 1^2)$$

$$(400 - 0.2 \times 300 \times \cos 30° - 300 \sin 30°) \times 5 = 15\,(v^2 - 1^2) \qquad [\because f = \mu N = \mu W \cos\theta]$$

$$400 - 300 \times 0.6732 = 3 \times (v^2 - 1)$$

$$\frac{198.04}{3} + 1 = v^2$$

$$\Rightarrow \quad v = \sqrt{67.01} = 8.18 \text{ m/s}$$

124. (b)

For hollow shaft,

$$\text{Strain energy, } U = \frac{1}{2}T\theta = \frac{1}{2}\left[\tau \times \frac{\pi}{16} \times \frac{(D^4 - d^4)}{D}\right] \times \left[\frac{2\tau l}{GD}\right]$$

$$= \frac{\tau^2}{4G}\left[\frac{\pi}{4}(D^2 - d^2)l\right] \times \frac{D^2 + d^2}{D^2}$$

$$= \frac{\tau^2}{4G} \times \text{Volume} \times \frac{D^2 + d^2}{D^2}$$

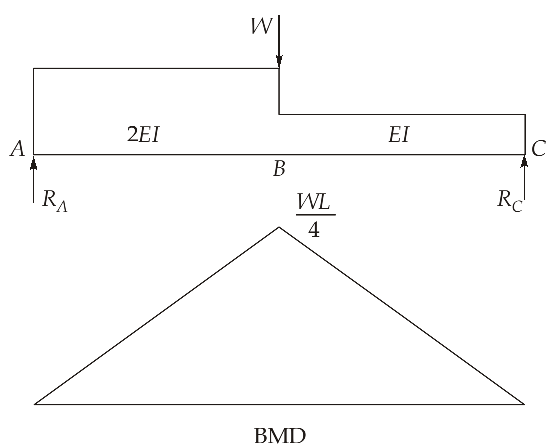
So, strain energy per unit volume, $u = \dfrac{\tau^2}{4G}\dfrac{(D^2 + d^2)}{D^2}$

125. (b)

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

$$M_A = M_C = 0$$

$$M_B = R_A \times \frac{L}{2} = \frac{W}{2} \times \frac{L}{2} = \frac{WL}{4}$$



126. (b)

$$W = p(V_2 - V_1) = 2 \times (0.05 - 0.02) \times 1000$$
$$= 60 \text{ kJ}$$
$$Q = 90 \text{ kJ}$$

From I[st] law of thermodynamics,

$$Q = W + \Delta U$$

$\Rightarrow$ $$90 = 60 + \Delta U$$

$\Rightarrow$ $$\Delta U = 90 - 60 = 30 \text{ kJ}$$

127. **(a)**

A change in an instrument's reading or set point value over extended periods due to factors such as time, line voltage, or ambient temperature effects. Drift is an indication of the loss of perfect repeatability or reproduction of a measured value by an instrument.

128. **(a)**

Random Access Memory (RAM):
- Used to store temparory data.
- Information can be write and read from the memory.
- It is also known as volatile memory.

Read Only Memory (ROM):
- Used as permanent storage data.
- Information can be only read but cannot be write.
- It is also known as non-volatile memory.

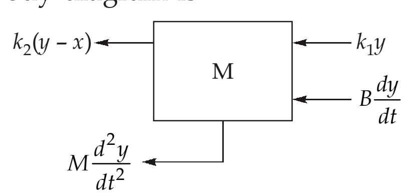
Programmable Read Only Memory (PROM):
- Special type ROM, allow to write only once.

Erasable and Programmable ROM (EPROM):
- Specially designed PROM, in which can be reprogrammed by erasing entire programme with the use of an ultraviolet light source.

Electrically Erasable and Programmable ROM (EEPROM)
- It is non-volatile memory that can be erased using electrical pulses.

129. **(c)**

For the given system the free body diagram is



From equation of motion

$$M\frac{d^2y}{dt^2}+k_2(y-x)+k_1y+B\frac{dy}{dt}=0$$

So, option (c) is correct.

131. **(d)**

Exergy is the maximum useful work obtainable from a system as it reaches to dead state. So, exergy depends on state of system as well as state of surrounding. If the system is allowed to undergo spontaneous change from the given state to dead state, exergy will be destroyed.

132. **(c)**

Statement II is true about SDE analysis,

where S stands for scarce items, D stands for difficult items, E stands for easily available items,

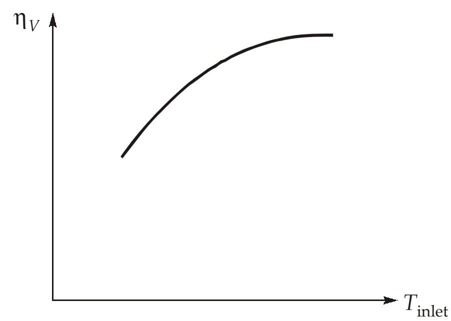
In S-OS analysis, S stands for seasonal items and OS represents off-seasonal.

134. (b)

Statement I is the explanation of statement II but not vice versa.

136. (d)

The air capacity does not increase with increase in inlet temperature, in fact reduces resulting in lower power output.



Mass of air m_a is proportional to $\rho_i \times \eta_v$. When inlet temperature increases, η_v does not increases enough to compensate for the reduction in ρ_i and hence the product $\rho_i \times \eta_v$ has a lower value.

137. (a)

Simple compressible system is free of surface, magnetic, gravitational, motion and electrical effects. The only work mode is that due to pressure acting on a moving boundary. If other work modes are present, such as work mode due to an electric field, then additional independent variables would be necessary, such as the electric field intensity.

138. (d)

A pure substance may exist in more than one phase but each phase must have the same chemical composition.

Mixture of liquid and gaseous air is not a pure substance because chemical composition is not same throughout.

139. (a)

- $$\Delta S = c_v \ln\left(\frac{T_2}{T_1}\right) > 0$$

$\therefore$ $$T_2 > T_1$$

- $$e_{\text{mech loss, piping}} = u_2 - u_1 - q_{\text{net in}} = c_v (T_2 - T_1) > 0$$

- $$\text{Head loss, } h_L = \frac{e_{\text{mech. loss piping}}}{g} > 0$$

140. (a)

Initially the rate of cooling or heating of body is very high due to high convection heat transfer rate prevailing between body and fluid because of large temperature difference existing between them. But with the time this rate of cooling or heating of body keeps on decreasing due to lesser and lesser heat transfer rate occuring between fluid and body because of lesser temperature difference existing between them.

141. **(a)**

FMS technology can be applied in production situations similar to those identified for cellular manufacturing:

- Presently the plant either produces parts in batches or uses manned GT cells, and management wants to automate.
- It is possible to group a portion of the parts made in the plant into part families, whose similarities permit them to be processed on the machines in the flexible manufacturing system. Part similarities can be interpreted to mean that (A) the parts belong to a common product and or (B) the parts possesses similar geometries. In either case, the processing requirements of the parts must be sufficiently similar to allow them to be made on the FMS.

143. **(d)**

The physical space that can be swept by a manipulator with wrist and end effector, may be more or less than the arm end point work space.

144. **(a)**

The stress strain behaviour of brittle ceramics is not usually ascertained by tensile test because:

1. It is difficult to prepare and test specimens having required geometry.
2. It is difficult to grip brittle materials without fracturing them.
3. Ceramics fail after only about 0.1% strain, which necessitates that tensile specimens be perfectly aligned to avoid the presence of bending stresses, which are not easily calculated.

145. **(d)**

In pneumatic system, the shuttle valve performs 'OR' logic operation

147. **(a)**

Although we get very large force or torque at output but energy or power remain conserved.

$$\text{Power} = Fv = T\omega$$

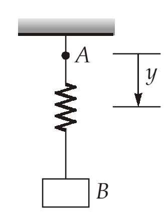
Output velocity tends to zero, as force or torque approaches infinity.

148. **(a)**

Consider the spring mass shown in the figure.

Velocity of A = 0

Velocity of B = V (V is velocity of point mass)



Velocity at a distance y from fixed end = $\frac{V}{l}y$

$$\text{Kinetic energy of the element} = \frac{1}{2}\left(\frac{m}{l}dy\right)\left(\frac{V}{l}y\right)^2$$

$$\text{Kinetic energy of spring} = \int_0^l \frac{mV^2}{2l^3}\left(y^2 dy\right) = \frac{mV^2}{6} = \frac{1}{2}\left(\frac{m}{3}\right)V^2$$

Here m is mass of sprinng and $\left(\frac{m}{3}\right)$ is considered to be eqivalent mass at free end.

149. (d)

$$\text{Swaying couple} = (1 - C) m r \omega^2 (\cos\theta + \sin\theta)\frac{l}{2}$$

As $C\uparrow$, swaying couple decreases.

150. (d)

Certainly, there will be gyroscopic effect in locomotive while turning, as happens in automobile. Generally, the radius of curvature while turning is quite large and hence the precession speed is less which result in less gyroscopic couple.

Inner and outer wheels rotate at different radius while turning to avoid slipping, as there is no differential gear in locomotive.