DETAILED SOLUTIONS

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ESE 2023 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 24

Full Syllabus Test 8 : Paper-II

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

DETAILED EXPLANATIONS

1. (c)

A homogeneous system is of single phase whereas a heterogeneous system consists of two or more phases.

3. (b)

Since pressure remains constant,

$$\therefore \quad \rho_1 T_1 = \rho_2 T_2$$

$$\therefore \quad \rho_2 = \rho_1 \times \frac{T_1}{T_2} = \frac{0.75}{0.5} \times \frac{300}{900}$$

$$\rho_2 = 0.5 \text{ kg/m}^3$$

4. (a)

For rigid vessel, volume is constant

$$\therefore \quad \frac{T_2}{T_1} = \frac{P_2}{P_1}$$

$$T_2 = T_1 \times \frac{P_2}{P_1} = 300 \times 2 = 600\,\text{K}$$

$$\therefore \quad \text{Internal energy, } du_{1\text{-}2} = mc_v(T_2 - T_1)$$

$$du_{1\text{-}2} = 20 \times 0.65(600 - 300)$$

$$du_{1\text{-}2} = 3900 \text{ kJ}$$

$$\therefore \quad \text{Heat interaction, } Q_{1\text{-}2} = W_{1\text{-}2} + du_{1\text{-}2}$$

$$\therefore \quad Q_{1\text{-}2} = du_{1\text{-}2} = 3900 \text{ kJ} \qquad [\because W_{1\text{-}2} = 0]$$

5. (a)

$$T_1 = 627 + 273 = 900 \text{ K}$$

$$T_2 = 127 + 273 = 400 \text{ K}$$

Here,

$$\oint \frac{\delta Q}{T} = \frac{Q_1}{T_1} - \frac{Q_2}{T_2}$$

$$= \frac{2500}{900} - \frac{900}{400} = 0.527 > 0$$

Thus, the cycle is impossible from the concept of Clausius inequality.

6. (c)

Assuming the direction of heat interactions as shown in figure, and noting that the engine is reversible,

$$\oint \frac{\delta Q}{T} = 0$$

$$\frac{Q_1}{T_1} - \frac{Q_2}{T_2} + \frac{Q_3}{T_3} = 0$$

$$\frac{1200}{400} - \frac{Q_2}{300} + \frac{Q_3}{200} = 0$$

or $$300 - \frac{Q_2}{3} + \frac{Q_3}{2} = 0$$

$\therefore$ $$-2Q_2 + 3Q_3 = -1800 \quad \text{...(i)}$$

Also from first law,

$$Q_1 + Q_3 - Q_2 = W$$

$$1200 + Q_3 - Q_2 = 200$$

$\therefore$ $$Q_2 = Q_3 + 1000 \quad \text{...(ii)}$$

From (i) and (ii),

$$-2(Q_3 + 1000) + 3Q_3 = -1800$$

$\therefore$ $$-2Q_3 - 2000 + 3Q_3 = -1800$$

$\therefore$ $$Q_3 = 200 \text{ kJ and } Q_2 = 1200 \text{ kJ}$$

7. (d)

$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}}$$

$$0.6 = 1 - \frac{1}{r^{1.5-1}}$$

$\therefore$ $$\frac{1}{r^{0.5}} = 0.4$$

$$r = \left(\frac{1}{0.4}\right)^2 = 6.25$$

9. (a)

Rough surfaces gives diffused reflections. Reflections from highly polished and smooth surface have regular (specular) characteristics.

10. (d)

$$q_{1\text{-}2} = \frac{\sigma\left[T_1^4 - T_2^4\right]}{\frac{1-\varepsilon_1}{A_1\varepsilon_1} + \frac{1}{A_1F_{12}} + \frac{1-\varepsilon_2}{A_2\varepsilon_2}}$$

$\Rightarrow$ $$q_{1\text{-}2} = \frac{5.67\times10^{-8}\left[200^4 - 100^4\right]}{\frac{0.2}{0.8} + 1 + \frac{0.2}{0.8}}$$

$$q = \frac{5.67\times10^{-8}\left[16\times10^8 - 10^8\right]}{1.5}$$

$$q = \frac{5.67\times9\times15}{1.5}$$

$$q = 56.7 \text{ W/m}^2$$

15. (a)

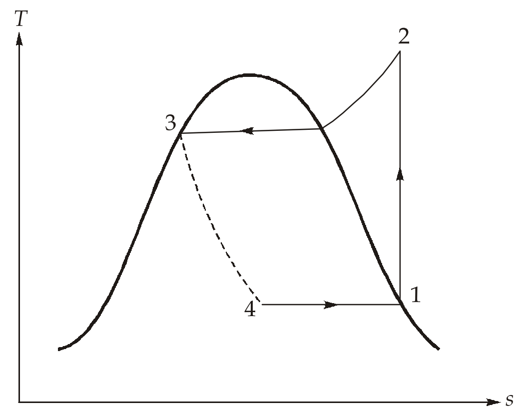
$$\frac{E_A}{E_B} = \frac{(\sigma A T^4)_A}{(\sigma A T^4)_B} = \frac{(R_A^2 \cdot T_A^4)}{(R_B^2 \cdot T_B^4)}$$

$$\frac{E_A}{E_B} = \left(\frac{2}{4}\right)^2 \times \left(\frac{6000}{2000}\right)^4 = \frac{1}{4} \times (3)^4$$

$$\frac{E_A}{E_B} = \frac{81}{4}$$

$\Rightarrow$ $$E_A > E_B$$

17. (c)



$$\dot{w} = h_2 - h_1$$
$$= 120 \text{ kJ/kg}$$

$$\dot{w}_{actual} = \frac{120}{(1-0.2)} = 150 \text{ kJ/kg}$$

$$\text{COP}_{\text{actual}} = \frac{h_1 - h_4}{\dot{w}_{actual}} = \frac{h_1 - h_3}{\dot{w}_{actual}}$$

$$= \frac{240}{150} = 1.6$$

18. (d)

Gibb's rule gives,

$$P + F = C + 2$$

Here, $P = 1$; $C = 2$

$$F = 2 + 2 - 1 = 3$$

19. (b)

Let n be the number of depth, of coil required,

$$0.5^n = 0.62$$

$n = 3$ $\Rightarrow$ $x = 0.5^3 = 0.125$

$n = 4$ $\Rightarrow$ $x = 0.5^4 = 0.625$

So, $n = 4$ as bypass factor should be less than or equal to the required.

21. (b)

When critical temperature is high, compressor superheat is small, flash gas losses are low and vapour pressure will be low. So COP will be high but volumetric capacity will be low.

25. (c)

$$E = -14.3 \text{ min}$$
$$\text{Solar time} = \text{Standard time} \pm 4(L_{st} - L_{loc})(\text{min}) + E(\text{min})$$
$$\text{Solar time} = 11{:}30 \text{ hrs} - 4 \times (81°44' - 77°12')(\text{min}) - 14.3 \text{ min}$$
$$= 11{:}30 - 31.58 \text{ min}$$
$$= 10{:}58.42 \text{ hours}$$

27. (d)

- In Mohs test, capability of one material to scratch other is measured.
- Scleroscope is an instrument in which a diamond tipped indentor is dropped on specimen and hardness of specimen is determined by rebound of indentor.
- In Rockwell test, indentor is pressed on surface first with minor load and then with major load. The difference in depth of penetration is measure of hardness.
- In Vickers test, area of indentation is measured.

28. (d)

High carbon steel is used to make cold chisels and rock drills, while medium carbon steel is used to make connecting rods.

29. (b)

$$\text{Intercepts} = 2 \;;\; 3 \;;\; 1$$
$$\text{Reciprocal} = \frac{1}{2} \;;\; \frac{1}{3} \;;\; 1$$
$$\text{Integers} = 3 \;;\; 2 \;;\; 6$$

$\therefore$ Miller indices of the plane is (3 2 6)

30. (a)

- By heating the pearlity microstructure, the Fe_3C wants to reduce the surface energy due to the thin layers of the eutectoid microstructure. It reduces the amount of surface area by changing from sheets to balls of Fe_3C giving the spheroidite microstructure. The new microstructure has much less surface area per unit volume to act as pinning centres and therefore is less able to prevent dislocation motion, leading to a lower yield strength and hardness.
- Bainite is harder and stronger than fine pearlite.

31. (d)

For safe design,

$$P_{\text{effective load}} < P_{\text{wear strength}}$$

or
$$P_{\text{effective load}} < DbQk$$

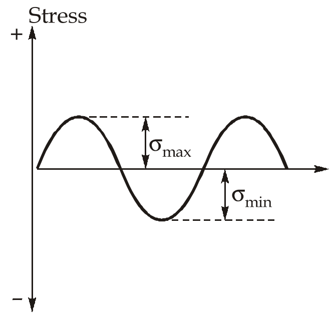
where b is face width gear tooth

D is diameter of pinion

Q is ratio factor

k is load stress factor

32. (d)



For a completely reversed stress condition,

As, $$\sigma_{max} = \sigma_{min}$$

So, $$\sigma_{amp} = \frac{\sigma_{max} + \sigma_{min}}{2} = \sigma_{max}$$

33. (a)

The coefficient of friction in needle bearing is almost four times as that of cylindrical roller bearing so statement 3 is not correct.

34. (d)

$$U_d = \left(\frac{1+\mu}{6E}\right)\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]$$

where

$$U_d = U - U_v$$

and U = Total strain energy per unit volume

U_v = Strain energy corresponding to distortion of element with no change of volume.

35. (b)

$$P = hl\sigma_t$$
$$= 10 \times 250 \times 80$$
$$= 200 \text{ kN}$$

36. (a)

$$T_e = \sqrt{(k_b M)^2 + (k_t T)^2}$$
$$= \sqrt{(1.5 \times 140)^2 + (280)^2}$$
$$= 350 \text{ Nm}$$

37. (b)

$$\tau = \left(1 + \frac{1}{2C}\right)\left(\frac{8WD}{\pi d^3}\right)$$

$$= \left(1 + \frac{4}{2 \times 16}\right)\left(\frac{8 \times 314 \times 16}{3.14 \times 4^3}\right)$$

$$= 225 \text{ N/mm}^2$$

38. (c)

$$\varepsilon = \left(1 - \frac{h_0}{c_1}\right)$$

$$0.2 = \left(1 - \frac{0.04}{c_1}\right)$$

$$c_1 = 0.05 \text{ mm}$$

$$R - r = c_1$$

$$R = 0.05 + 25$$

$$= 25.05 \text{ mm}$$

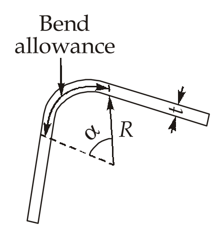
39. (c)

$$\text{Contact length} = \sqrt{R\Delta h}$$

So as size of roller decreases, contact length decreases.

40. (c)

$$\text{Bend allowance} = \alpha(R + kt)$$



41. (d)

$$T = \left(\frac{1-n}{n}\right)(TCT)$$

$$= \left(\frac{1-0.25}{0.25}\right) \times 2 = 6 \text{ min}$$

43. (d)

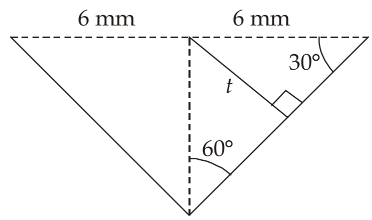
Chances of gas defects increases with

- High pouring temperature as it increases the amount of gas absorbed.
- Low permeability as it causes less air to escape.
- Poor gating design such as straight sprue in unpressurised casting as it causes air aspiration.

44. (b)

It is also known as direct current electrode negative as workpiece is made anode in straight polarity.

45. (c)



$$t = 6 \sin 30°$$
$$= 3 \text{ mm}$$

46. (b)

$$\text{Maximum size of hole} = 20 \text{ mm}$$
$$\text{Maximum size of shaft} = 20 - 0.03 = 19.97 \text{ mm}$$
$$20 - 19.97 = 0.03 \text{ mm}$$

47. (a)

$$t = \frac{w}{f}\left(\frac{l}{v_c} + \frac{l}{v_r}\right)$$
$$= \frac{1000}{1.01}\left(\frac{2.02}{20} + \frac{2.02}{40}\right)$$
$$= 150 \text{ minutes}$$

48. (a)

$$\text{Number of equivalent binary joints, } j = 5$$
$$\text{Number of links, } l = 5$$
$$\text{Number of higher pairs, } h = 1$$
$$F = 3(l-1) - 2j - h$$
$$= 3(5-1) - 2 \times 5 - 1$$
$$= 1$$

49. (a)

Crank and slotted lever mechanism and Whitworth mechanism are inversions of single slider crank chain.

51. (d)

Rayleigh method is also known as static deflection method,

$$\omega_n = \sqrt{\frac{g}{\delta}}$$

53. (d)

When spring is cut into half then new spring stiffness will be $2k$.

$$\omega_2 = \sqrt{\frac{4k}{m}} = 2\sqrt{\frac{k}{m}}$$

$$\frac{\omega_2 - \omega_1}{\omega_1} = \frac{2\sqrt{\frac{k}{m}} - \sqrt{\frac{k}{m}}}{\sqrt{\frac{k}{m}}} = \frac{2-1}{1} \times 100 = 100\%$$

54. (b)

Secondary crank concides with actual crank at inner dead centre and its length is $\frac{r}{4n}$.

55. (a)

As arm is fixed so there is no arm effect on gear train.

$$\therefore \quad \frac{N_S}{N_R} = -\frac{T_R}{T_S} = -\frac{120}{20} = -6$$

$$N_S = -54 \text{ rpm}$$

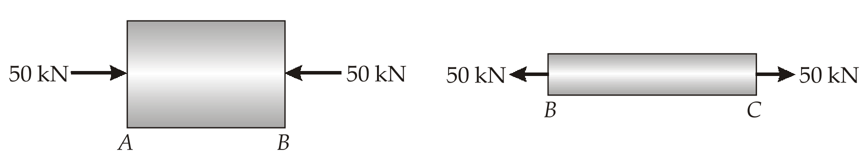
56. (d)

$$a_c = 2\omega V$$
$$= 2 \times 2 \times 3 = 12 \text{ m/s}^2$$
$$a_n = \omega^2 r$$
$$= 2^2 \times 1.25 = 5 \text{ m/s}^2$$
$$a_s = \sqrt{12^2 + 5^2} = 13 \text{ m/s}^2$$

57. (d)

$$\Delta E = I\omega^2 C_s$$
$$8100 = I \times (30)^2 \times 0.03$$
$$I = 300 \text{ kg-m}^2$$

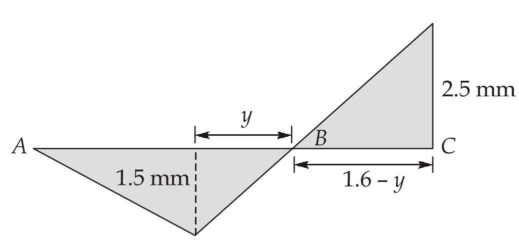
58. (a)



$$\delta_{AB} = \frac{50 \times 10^3 \times 1200}{200 \times 200000} = 1.5 \text{ mm}$$

$$\delta_{BC} = \frac{50 \times 10^3 \times 1600}{100 \times 200000} = 4 \text{ mm}$$

Deflection diagram,



$$\frac{1.5}{y} = \frac{2.5}{1.6 - y}$$

$$y = 0.6 \text{ m}$$

So, deflection is zero at x = 1.8 m.

59. (d)

$$\sigma_N = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\theta$$

$$\sigma_N = \left(\frac{120}{2}\right) + \left(\frac{120}{2}\right)\cos 120 = 30 \text{ MPa}$$

$$F_N = 30 \times \frac{300}{\sin 30°}$$

$$F_N = 30 \times \frac{300}{0.5} = 18 \text{ kN}$$

60. (c)

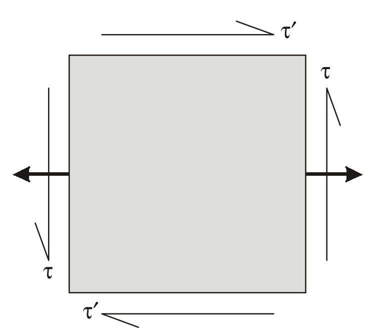
$$I = Ak^2$$

$$\frac{a^4}{12} = a^2 \times k^2$$

$$k = \frac{a}{2\sqrt{3}}$$

$$\text{Slenderness ratio, } r = \frac{L_e}{k} = \frac{900 \times 2\sqrt{3}}{2 \times 15} = 103.92$$

61. (a)



In simple shear, $\tau = \tau'$

So simple shear in given direction cannot exist without balancing shear stress of equal intensity in direction right angle to it.

62. (c)

$$\frac{dM}{dx} = V$$

- In region AB shear force 'V' is positive so slope of BMD is positive in region AB.
- Shear force decreases for portion AB and increases for portion BC so slope of BMD decreasing type for region AB and is of increasing type for region BC.

63. (c)

$$\varepsilon_x = \frac{P}{AE} = \frac{160 \times 10^3}{20 \times 20 \times 200 \times 10^3} = 0.002$$

$$\varepsilon_y = \frac{\Delta t}{t} = \frac{0.0124}{20} = 6.2 \times 10^{-4}$$

$$\mu = \frac{6.2 \times 10^{-4}}{0.002} = 0.31$$

64. (b)

$$U = \frac{M^2 l}{2EI} = \left(\frac{EI}{R}\right)^2 \frac{l}{2EI} = \frac{E \times I \times l}{2R^2}$$

$\Rightarrow$ $$U_1 = kwt^3$$

and $$U_2 = k \times 0.5w \times 1.5^3\, t^3$$

So, $$\frac{U_2}{U_1} = 0.5 \times 1.5^3 = 1.6875$$

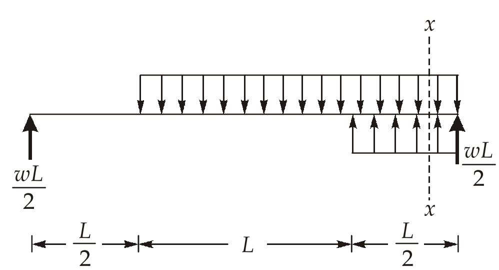
65. (b)

- Maximum shear stress for circular cross-section beam is $\frac{4}{3}\frac{F}{A}$

  and shear stress for triangular cross-section beam is $\frac{3}{2}\frac{F}{A}$

  So it is same for both beams.
- In triangular cross-section beam, maximum shear does stress not occur at neutral axis.

66. (c)



$$M_{x\text{-}x} = \frac{wLx}{2} - \frac{w}{2}\left\langle x - \frac{L}{2}\right\rangle^2 + \frac{w}{2}\left\langle x - \frac{3L}{2}\right\rangle^2$$

$$EI\frac{d^2y}{dx^2} = M_{x\text{-}x}$$

$$EI\frac{dy}{dx} = \frac{wL}{2}\frac{\langle x\rangle^2}{2} - \frac{w}{6}\left\langle x - \frac{L}{2}\right\rangle^3 + \frac{w}{6}\left\langle x - \frac{3L}{2}\right\rangle^2 + C_1$$

Slope at $x = L$ is zero

$$0 = \frac{wL^3}{4} - \frac{wL^3}{48} + 0 + C_1$$

$$C_1 = \frac{-11}{48}wL^3$$

Slope at $x = 0$

$$EI\frac{dy}{dx} = 0 - 0 + 0 - \frac{11}{48}wL^3$$

So, $$\theta_A = \frac{-11wL^3}{48EI}$$

67. (b)

$$T_A + T_B = T_0$$

$$\frac{80 \times 300}{GJ} = \frac{T_B \times 100}{GJ}$$

$$T_B = 240 \text{ Nm}$$

$$T_0 = 80 + 240 = 320 \text{ Nm}$$

68. (d)

$$\alpha L\Delta T + \alpha L\Delta T = \frac{\sigma_{AB}L}{E} + \frac{\sigma_{BC}L}{E}$$

$$2\Delta TE = \sigma_{AB} + \sigma_{BC} \quad ...(i)$$

$$\sigma_{AB} \times (d^2) = \sigma_{BC} \times \left(\frac{3}{2}d\right)^2$$

$$\sigma_{AB} = \frac{9}{4}\sigma_{BC} \quad ...(ii)$$

From (i) and (ii),

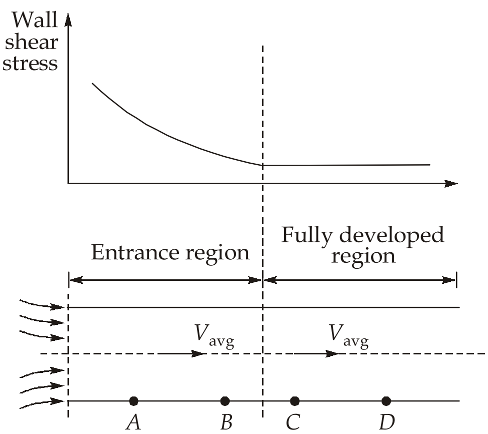
$$2\alpha\Delta TE = \frac{9}{4}\sigma_{BC} + \sigma_{BC}$$

$$\sigma_{BC} = \frac{8}{13}\alpha\Delta TE$$

$$\sigma_{AB} = \frac{9}{4} \times \frac{8}{13}\alpha\Delta TE$$

$$= \frac{18}{13}\alpha\Delta TE$$

69. (a)



So, $\tau_C = \tau_D$

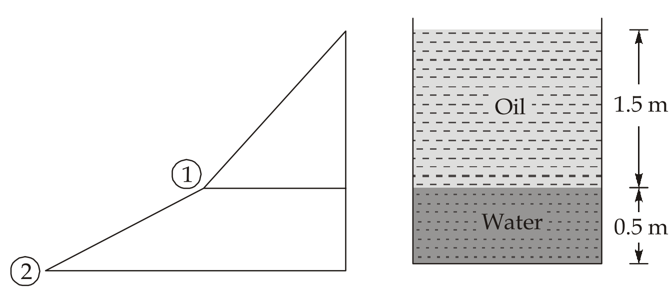
70. (c)

In laminar boundary layer pressure varies along direction of flow, but is constant in direction perpendicular to plate since its thickness is very less.

71. (a)

By streamlining friction drag increases due to increase in surface area. The pressure drag is proportional to frontal area and to the difference between the pressures acting on the front and back of the immersed body.

72. (c)



$$P_1 = 8000 \times 1.5 = 12000 \text{ N/m}^2$$

$$P_2 = P_1 + 1000 \times 10 \times 0.5 = 12000 + 5000 = 17000 \text{ N/m}^2$$

Hydrostatic force = Volume of pressure prism

$$= \frac{1}{2} \times 12000 \times 1.5 \times 2 + \frac{1}{2} \times [(12000 + 17000) \times 0.5] \times 0.2$$

$$= 32500 \text{ N}$$

73. (d)

$$\text{Froude law} = \frac{V_p}{\sqrt{gL_p}} = \frac{V_m}{\sqrt{gL_m}}$$

$$V_r = \sqrt{L_r}$$

$$\Rightarrow \quad Q_r = L_r^{2.5}$$

$$\frac{1944}{Q_m} = (9)^{2.5}$$

$$Q_m = 8 \text{ m}^3/\text{s}$$

74. (c)

For a 2 dimensional flow,

$$\frac{\partial \phi}{\partial x} = \frac{\partial \psi}{\partial y}; \qquad \frac{\partial \phi}{\partial y} = \frac{-\partial \psi}{\partial x}$$

$$\frac{\partial \phi}{\partial x} = 2x + 6y$$

$$\phi = \frac{2x^2}{2} + 6xy + f(y)$$

$$\frac{\partial \phi}{\partial y} = 6x + f'(y) \qquad \text{...(i)}$$

$$\frac{\partial \psi}{\partial x} = 2y - 6x \qquad \text{...(ii)}$$

Comparing (i) and (ii),

$$6x + f'(y) = -2y + 6x$$

$$f(y) = \frac{-2y^2}{2} + c$$

$$\phi = x^2 + 6xy - y^2 + c$$

75. (d)

$$\text{Re} = \frac{\rho V d}{\mu} = \frac{800 \times 1.5 \times 0.1}{8 \times 10^{-2}} = 1500$$

$$f' = \frac{16}{\text{Re}} = \frac{16}{1500}$$

$$h_L = 4 \times \frac{16}{1500} \times \frac{200}{20} \times \frac{(1.5)^2}{0.1}$$

$$= 9.6 \text{ m}$$

76. (d)

$$\text{Work done per second} = \rho A(V - u)^2 \times u$$

$$= \rho A(10 - 4)^2 \times 4$$

$$= 144\rho A$$

$$\text{Kinetic energy of jet} = \frac{1}{2}\rho A V^3$$

$$= \frac{1}{2}\rho A \times 10^3 = 500\rho A$$

$$\eta = \frac{144\rho A}{500\rho A} = 28.8\%$$

77. (b)

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

$$\tau = 0.9 \times (0.8 - 2.2y)$$

$$\tau = 0.9 \times (0.8 - 2.2 \times 0.3)$$

$$\tau = 0.126 \text{ N/m}^2$$

78. (c)

$$\text{Theoretical discharge, } Q = \frac{ALN}{60},$$

$$\therefore \quad Q = \frac{\frac{\pi}{4}(0.14)^2 \times 0.3 \times 60}{60} = 4.6 \times 10^{-3} \text{m}^3/\text{s}$$

Now,

$$Q_{act} = \frac{240 \times 10^{-3}}{60} = 4 \times 10^{-3} \text{m}^3/\text{sec}$$

$$\therefore \quad \%\text{slip} = \left(1 - \frac{4 \times 10^{-3}}{4.6 \times 10^{-3}}\right) \times 100$$

$$\%\text{slip} \simeq 13\%$$

80. (d)

$$\text{Overall efficiency, } \eta_0 = \frac{P}{\rho g Q H}$$

$$Q = \frac{10000}{9.81 \times 0.8 \times 20}$$

$$\therefore \quad Q = 63.71 \text{ m}^3/\text{sec}$$

83. (b)

The function of the inlet casing is to deliver air to the impeller eye with minimum loss and to provide a uniform velocity profile at the eye.

84. (b)

For maximum work done,

$$\eta_{max} = 1 - \sqrt{\frac{T_{min}}{T_{max}}}$$

$$= 1 - \sqrt{\frac{300}{1200}} = 0.5 \text{ or } 50\%$$

85. (b)

Some of the features of exponential smoothing method are:

1. The emphasis given to the most recent demand levels can be adjusted by changing the smoothing parameter.
2. Exponential smoothing is simple and requires minimal data.
3. Larger α values emphasize recent levels of demand and result in forecasts more responsive to changes in the underlying average.
4. Smaller α value treats past demand more uniformly and result in more stable forecasts.

86. (c)

First statement talks about the introduction phase while the fourth statement is concerned with the maturity phase of the product.

87. (b)

Assuming that the company purchases all its material and services including energy, machine and equipment. Then,

$$\text{Total factor productivity} = \frac{\text{Net output}}{(\text{Labour + Capital})\text{Input}}$$

$$= \frac{\text{Total output – Material and services purchased}}{(\text{Labour + Capital})\text{Input}}$$

$$= \frac{20000-(5000+6000+1000)}{12000}$$

$$= \frac{20000-12000}{12000} = \frac{8000}{12000} = 0.67$$

88. (c)

$$F_{\text{Apr}} = \alpha D_{Mar} + (1-\alpha)F_{Mar}$$
$$= 0.6 \times 400 + 0.4 \times 300$$
$$= 240 + 120 = 360 \text{ units}$$
$$F_{\text{May}} = \alpha D_{Apr} + (1-\alpha)F_{Apr}$$
$$= 0.6 \times 500 + 0.4 \times 360$$
$$= 300 + 144 = 444 \text{ units}$$

89. (b)

Linear speed of the particle at t = 2 second is

$$v = 2t^2 = 2 \times 2^2 = 8 \text{ m/s}$$

$\therefore$ Centripetal acceleration, $a_r = \frac{v^2}{R} = \frac{(8)^2}{4} = 16 \text{ m/s}^2$

$\therefore$ Tangential acceleration, $a_t = \frac{dv}{dt} = 4t$

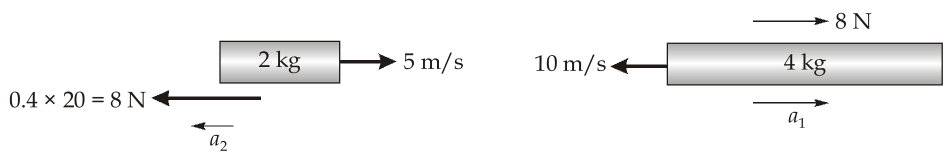
$$= 4 \times 2 = 8 \text{ m/s}^2$$

$\therefore$ Net acceleration, $a = \sqrt{a_r^2 + a_t^2} = \sqrt{16^2 + 8^2}$

$$= \sqrt{256 + 64} = \sqrt{320} \text{ m/s} = 8\sqrt{5} \text{ m/s}^2$$

90. (d)

Using relative motion between the blocks, the directions of friction force acting is



$\therefore$ $a_2 = -\frac{8}{2} = -4 \text{ m/s}^2$

$$a_1 = \frac{8}{4} = 2 \text{ m/s}^2$$

Relative motion will stop when,

$$v_1 = v_2$$

$\therefore$ $u_1 + a_1 t = u_2 + a_2 t$

$\Rightarrow$ $-10 + 2t = 5 - 4t$

$\Rightarrow$ $6t = -15$

$\Rightarrow$ $t = \frac{15}{6} = 2.5$ seconds

91. (d)

Applying work energy theorem,

Work done by all the forces $= \Delta K.E$

$$W_{mg} + W_{air} = \frac{1}{2}mv^2 - 0$$

$\Rightarrow$ $mgh + W_{air} = \frac{1}{2}mv^2$

$\Rightarrow$ $W_{air} = \frac{1}{2} \times 5 \times 256 - 5 \times 10 \times 40$

$$= 640 - 2000$$

$$= -1360 \text{ Joules}$$

92. (a)

Velocity of ball at 3 second is

$$v = u + at = 0 + a \times t$$

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

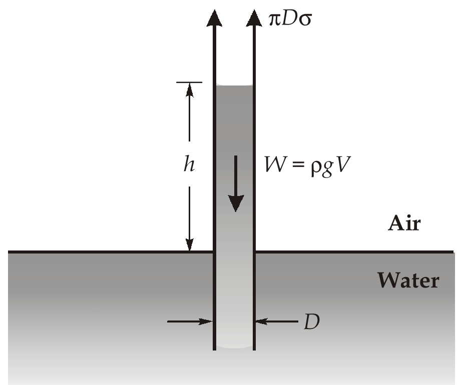
$\therefore$ Power $= \vec{F} \cdot \vec{v} = Fv\cos 0°$

$$= mgv$$

$$= 2 \times 10 \times 30$$
$$= 600 \text{ Watt}$$

93. (a)

The upward surface tension force is equal and opposite to the weight of water in the liquid column.



$$\therefore \quad \sigma\pi D = \rho g V$$

$$\Rightarrow \quad \sigma\pi D = \rho g \pi \frac{D^2}{4} h$$

$$\Rightarrow \quad h = \frac{4\sigma}{\rho g D} = \frac{4 \times 0.0741}{1000 \times 10 \times 4 \times 10^{-3}} = 7.41 \text{ mm}$$

94. (a)

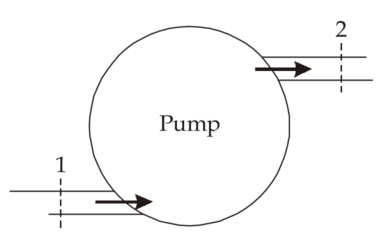
Using Bernoulli's equation between two

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} = \frac{v_2^2}{2g}$$

$$\Rightarrow \quad \frac{v_1^2}{2g} = 0.8 - 0.4 = 0.4$$

$$\Rightarrow \quad v_1 = \sqrt{2 \times 10 \times 0.4} = \sqrt{8} = 2\sqrt{2} \text{ m/s}$$

95. (b)



Applying Bernoulli's equation between points 1 and 2

$$H_p = \text{Head provided by pump}$$

$$H_p = \frac{P_2 - P_1}{\rho g} + (z_2 - z_1)$$

$$= \frac{500 \times 10^3}{1000 \times 10} + (1) = 51 \text{ m}$$

$$\therefore \quad W_p = \frac{\rho Q g H_p}{\eta_p} = \frac{1000 \times 0.17 \times 10 \times 51}{0.85}$$

$$\therefore \quad W_p = 102 \text{ kW}$$

96. (d)

Equating the pressures on both the limbs at the horizontal plane X-X

$$P_A + [0.12 + 0.15 + 0.1]\,\gamma_A = P_B + 0.15 \times \gamma_B + 0.1 \times \gamma_M$$

$$\Rightarrow \quad P_A + [0.37] \times 6000 = P_B + 0.15 \times 9000 + 0.1 \times 140000$$

$$\Rightarrow \quad P_A + 2220 = P_B + 1350 + 14000$$

$$\Rightarrow \quad P_A - P_B = 13130 \text{ Pa} = 13.13 \text{ kPa}$$

97. (c)

Diffusion is defined as a natural tendency of the molecule to flow from higher concentration to lower concentration. Diffusion along the edge dislocation is known as pipe diffusion.

98. (d)

Difference in diameter of two atoms should not be greater than 15 percent.

99. (a)

Densities:

$$\rho_{mg} = 1738 \text{ kg/m}^3 = 1.738 \text{ g/cm}^3$$

$$\rho_{mg} = 3650 \text{ kg/m}^3 = 3.65 \text{ g/cm}^3$$

Molecular weight,

$$M_{\text{mg}} = 24.5\text{g}$$

$$M_{\text{mgo}} = 24.5 + 16 = 40.5\text{g}$$

$$\frac{M_c}{\rho_c} = \frac{M_{mgo}}{\rho_{mgo}} = \frac{40.5}{3.65} = 11.095$$

$$\frac{M_m}{\rho_m} = \frac{M_{mg}}{\rho_{mg}} = \frac{24.5}{1.738} = 13.988$$

$$\because \quad \frac{M_c}{\rho_c} < \frac{M_m}{\rho_m}$$

$\therefore$ Porous film is formed, which is unprotective and insufficient to fully cover the metal surface.

100. (d)

Chemical nature of environment cause pitting corrosion for e.g. Brackish water, salt water, chloride bleaches etc.

103. (d)

In actual cycles, the major losses are due to

(i) Variation of specific heats with temperature.

(ii) Dissociation of the combustion product.

(iii) Progressive combustion.
(iv) Incomplete combustion of fuel.
(v) Heat transfer to walls of combustion chamber.

104. (c)

Time for injection will be,

$$t_{\text{inj}} = \frac{\theta}{360 \times \frac{N}{60}} = \frac{15 \times 60}{360 \times 1500}$$

$$t_{\text{inj}} = 1.67 \times 10^{-3} \text{ sec}$$

105. (c)

$$\text{B.P.} = \frac{2\pi NT}{60} = \frac{2\pi N \cdot WR}{60000}$$

$$\text{B.P.} = \frac{40 \times 9.81 \times 1600 \times 3}{60000} = 31.4 \text{ kW}$$

$$\eta_{\text{Bth}} = \frac{B.P.}{\dot{m}_f \times C.V.} \times 100 = \frac{31.4 \times 60}{0.2 \times 44000} \times 100 = 21.4\%$$

$$\therefore \quad \eta_{\text{ith}} = \frac{\eta_{Bth}}{\eta_{mech}} \times 100 = \frac{0.214}{0.8} \times 100 = 26.75\%$$

108. (c)

Output of the controller $= k_p e + m_0$

$= 10 \times 2 + 10 = 30\%$

110. (c)

Nyquist sampling rate states that the sampling rate should be at least twice the highest frequency of interest.

112. (b)

OR valve/shuttle valve requires at least one input device to be active in order to cause the output.

113. (b)

- The natural frequency is very high.
- These are useful for high input frequencies and their response is poor at low frequencies.

114. (c)

Erasable and programmable ROM (EPROM) : It is a specially designed PROM, and is programmed using a dedicated programmer, it can be reprogrammed after having been entirely erased with the use of an ultraviolet light source.

115. (c)

- Parity flag is set if the accumulator contains an even number of 1's.
- Zero flag is set when the result of an operation is zero.

117. (d)

- At present the cost of solar cells is high, making them economically uncompetitive with other conventional power sources.
- The efficiency of solar cells is low. As solar radiation density is also low, large area of solar cell modules are required to generate sufficient useful power.

118. (c)

The bottom layers of the brine reach 70-85°C while the top remains at 25°C. The hot brine from the bottom is slowly withdrawn in a laminar flow pattern from the pond and used to evaporate an organic working fluid in a heat exchanger and returned to the pond.

119. (a)

For diffuse radiation,

$$r_d = \frac{1+\cos\beta}{2}$$

For reflected radiation,

$$r_r = \rho\left(\frac{1-\cos\beta}{2}\right)$$

120. (c)

$$\frac{\bar{H}_g}{\bar{H}_0} = a + b\left(\frac{\bar{t}_d}{t_{d\max}}\right)$$

$$\therefore \quad \bar{H}_g = 36000\left[0.4 + 0.3 \times \frac{10}{12}\right] = 23400 \text{ kJ/m}^2$$

121. (d)

Power available in wind, $P_0 = \frac{1}{2}\rho A V^3$

$$P_0 = \frac{1}{2} \times 1.2 \times \frac{22}{7} \times 0.7^2 \times 6^3$$

$$P_0 = 199.584 \text{ Watt}$$

$\therefore$ Power extracted by rotor

$$P_T = C_P P_0$$

$$P_T = 0.4 \times 199.584$$

$$P_T = 79.83$$

$$P_T \simeq 80 \text{ Watt}$$

122. (c)

Methane forming bacteria works best in temperature ranges 20-55°C. Digestion at higher temperature proceeds more rapidly than at lower temperature, with gas yield rates doubling at about 5°C increase in temperature.

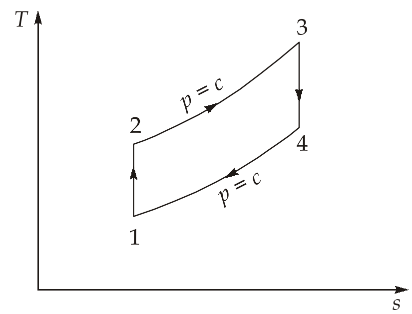
123. (c)

$$P_{av} = \frac{\frac{1}{2}\rho A g R^2}{22350} = 0.225 \times A \times R^2 \text{ Watts} \quad \text{where } \rho = 1025 \text{ kg/m}^3$$

124. (b)

- It can be operated below atmospheric pressure.
- Wide variety of working fluid can be used because the products of combustion do not enter the turbine.

125. (d)



Given :

Pressure ratio, r_p = 6

Entry pressure, P_1 = 1.01 bar

Entry temperature, T_1 = 25°C = 298 K

Work ratio, r_w = 0.6

$$r_w = \frac{w_T - w_c}{w_T} = 1 - \frac{w_c}{w_T}$$

[w_T = work output from turbine; w_c = work input to compressor]

$$0.6 = 1 - \frac{w_c}{w_T}, \frac{w_c}{w_T} = 0.4$$

$$\Rightarrow \quad w_T = \frac{w_c}{0.4} \quad \text{...(i)}$$

For process 1-2,

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \quad T_2 = T_1 (r_p)^{\frac{\gamma-1}{\gamma}} = 298 \times 1.67 = 497.66 \text{ K}$$

So,

$$w_c = c_p (T_2 - T_1) = 1.005(497.66 - 298)$$

$$= 200.658 \text{ kJ/kg}$$

From equation (i),

$$w_T = \frac{200.658}{0.4} = 501.645 \text{ K}$$

$$\Rightarrow \quad w_T = c_p(T_3 - T_4) = 501.645$$

$$T_3 - T_4 = 499.15 \quad \text{...(ii)}$$

For process 3-4,

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_4 = \frac{T_3}{(r_p)^{\frac{\gamma-1}{\gamma}}} = \frac{T_3}{1.67} = 0.5988T_3$$

From equation (ii)

$$T_3 - 0.5988T_3 = 499.15$$

$$T_3 = 1244.15 \text{ K}$$

126. (d)

Given :

$$\text{mass flow rate, } \dot{m} = 4 \text{ kg/min}$$

$$\text{Entry pressure, } P_1 = 1 \text{ bar}$$

$$\text{Entry temperature, } T_1 = 300 \text{ K}$$

$$n = 1.5$$

$$R = 0.3 \text{ kJ/kgK}$$

$$P_H = 512 \text{ bar}$$

$$P_L = P_1 = 1 \text{ bar}$$

$$\text{Per stage pressure ratio } (r_p) = \left(\frac{P_H}{P_L}\right)^{1/3}$$

$$r_p = \left(\frac{512}{1}\right)^{1/3} = 8$$

We know,

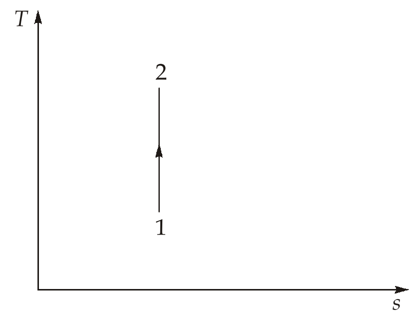
$$W_{\text{input/stage}} = \frac{n}{n-1}\dot{m}RT\left[(r_p)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{1.5}{0.5} \times \frac{4}{60} \times 0.3 \times 300\left[(8)^{\frac{0.5}{1.5}} - 1\right]$$

$$\dot{W}_{\text{input/stage}} = 18 \text{ kW}$$

$$\dot{W}_{\text{input}} = 18 \times 3 = 54 \text{ kW}$$

127. (c)



Given,

$$D = 0.4 \text{ m}$$
$$N = 6000 \text{ rpm}$$
$$\text{Slip factor, } \sigma = 0.8$$
$$\text{Work input factor, } \psi = 0.9$$
$$\text{No whirl at inlet, } V_{w_1} = 0$$

$$W_{\text{input/kg}} = V_{w_2}u_2 - V_{w_1}u_1 = c_p(T_2 - T_1) \quad \text{...(i)}$$

$$W_{\text{input/kg}} = V_{w_2}u_2 = \sigma\psi u_2^2$$

$$= 0.8 \times 0.9 \times \left(\frac{\pi \times D \times N}{60}\right)^2$$

$$W_{\text{input/kg}} = 0.72 \times \left(\frac{\pi \times 0.4 \times 6000}{60}\right)^2 = 11369.784 \text{ J/kg}$$

From equation (i),

$$11369.784 = c_p(T_2 - 300)$$

$$T_2 = 300 + \frac{11369.784}{1000} = 311.369 \text{ K}$$

128. (a)

Given,

$$\text{Inlet blade angle, } \beta_1 = 45°$$
$$\text{Outlet blade angle, } \beta_2 = 10°$$
$$\text{Blade velocity, } v = 200 \text{ m/s}$$
$$\text{Axial velocity, } V_F = 170 \text{ m/s}$$

We know, Degree of reaction, $R_D = \frac{V_F}{2u}(\tan\beta_1 + \tan\beta_2)$

$$R_D = \frac{170}{2 \times 200}(\tan 45° + \tan 10°)$$

$$R_D = 0.5 = 50\%$$

129. (c)

Heat transfer is mainly due to radiation effect in radiant superheater.

130. (c)

Given,

$$\text{S.S.C.} = 7.2 \text{ kg/kW}\cdot\text{hr}$$

$$\text{Heat input } (Q_s) = 2000 \text{ kJ/kg}$$

We know,

$$\text{S.S.C.} = \frac{3600}{w_{net}} \text{ kg/kW}\cdot\text{ hr}$$

$$\Rightarrow \quad w_{\text{net}} = \frac{3600}{7.2} = 500 \text{ kJ/kg}$$

$$\text{Heat rate} = \frac{1}{\text{Efficiency } (\eta)} = \frac{1}{\frac{w_{net}}{Q_s}}$$

$$\text{Heat rate} = \frac{Q_s}{w_{net}} = \frac{2000}{500} = 4$$

131. (a)

Given:

$$(\Delta h)_{\text{M.B}} = \frac{1}{3}\left[(\Delta h)_{F.B} - (\Delta h)_{M.B}\right]$$

$$\Rightarrow \quad \frac{4}{3}(\Delta h)_{M.B.} = \frac{(\Delta h)_{F.B.}}{3}$$

$$\Rightarrow \quad (\Delta h)_{\text{F.B.}} = 4(\Delta h)_{\text{M.B.}}$$

We know,

$$\text{D.O.R.} = \frac{(\Delta h)_{M.B.}}{(\Delta h)_{M.B.} + (\Delta h)_{F.B.}} = \frac{(\Delta h)_{M.B.}}{(\Delta h)_{M.B.} + 4(\Delta h)_{M.B.}}$$

$$= \frac{1}{5} = 0.2$$

133. (a)

The energy loss due to friction is proportional to the square of the velocity of fluid (steam). Since the fluid velocity is the highest for a 2-row Curtis stage and lowest in the 50% reaction stage, so the energy loss due to friction in the reaction stage is the least while that in Curtis stage is the highest. The energy loss in the impulse stage will be in between these two values.

Therefore, the efficiency of the reaction stage will be the highest and that of the Curtis stage will be the lowest, while that of impulse stage will lie in between.

135. (c)

Given,

Vehicle velocity through the air,

$$V_a = 300 \text{ m/s}$$

$$\text{Air flow rate, } \dot{m}_a = 5 \text{ kg/s}$$

$$\text{Exit velocity of gas, } V_g = 900 \text{ m/s}$$

So, Thrust power, $TP = \dot{m}_a (V_g - V_a) V_a$ Watt

$$TP = 5(900 - 300) \times 300 = 9 \times 10^5 \text{ Watt}$$
$$= 900 \text{ kW}$$

136. (b)

Given, Maximum temperature, $T_H = 1600$ K

Minimum temperature, $T_L = 400$ K

$$\text{Maximum work, } w_{max} = c_p \left[\sqrt{T_H} - \sqrt{T_L}\right]^2$$

$$w_{max} = 1\left[\sqrt{1600} - \sqrt{400}\right]^2$$
$$= 400 \text{ kJ/kg}$$

$$\text{Optimum pressure ratio } ((r_p)_{opt}) = \left(\frac{T_H}{T_L}\right)^{\frac{\gamma}{2(\gamma-1)}}$$

$$(r_p)_{opt} = \left(\frac{1600}{400}\right)^{\frac{1.5}{2\times 0.5}} = 8$$

138. (b)

Given, $P_H = 800$ kPa

$P_L = 100$ kPa

$V_C = 6\%$ of V_S

$$\Rightarrow \quad V_C = \frac{6}{100} V_S$$

$$\frac{V_C}{V_S} = C = 0.06$$

So, Volumetric efficiency,
$$\eta_v = 1 + c - c\left(\frac{P_H}{P_L}\right)^{\frac{1}{n}}$$

$$= 1 + 0.06 - 0.06\left(\frac{800}{100}\right)^{\frac{1}{1.5}}$$
$$= 0.82 = 82\%$$

139. (c)

Given, Inlet blade angle, $\beta_1 = 60°$

Outlet blade angle, $\beta_2 = 45°$

Blade velocity, $v = 100$ m/s

Axial flow velocity, $V_F = 70$ m/s

Number of stage, $n = 3$

$$\text{Work input} = nUV_F(\tan\beta_1 - \tan\beta_2)$$

$$= 3 \times 100 \times 70\left(\tan(60°) - \tan(45°)\right)$$

$$\text{Work input} = 15373 \text{ J/kg}$$

$$\text{Work input} = 15.373 \text{ kJ/kg}$$

140. (b)

Given,

$$\text{Blade speed, } u = 100 \text{ m/s}$$

$$\text{Enthalpy drop, } \Delta h = 80 \text{ kJ/kg}$$

$$\text{Exit velocity from nozzle, } V = \sqrt{2 \times (\Delta h) \times 1000}$$

$$= \sqrt{2 \times 80 \times 1000} = 400 \text{ m/s}$$

We know,

$$\rho = \text{Blade speed ratio} = \frac{U}{V} = \frac{\cos\alpha}{2} \quad \begin{bmatrix}\text{for maximum} \\ \text{efficiency}\end{bmatrix}$$

$$\Rightarrow \quad \frac{100}{400} = \frac{\cos\alpha}{2}$$

$$\Rightarrow \quad \cos\alpha = 0.5$$

$$\text{Maximum efficiency, } \eta_{max} = \cos^2\alpha$$

$$\eta_{max} = (0.5)^2 = 0.25 = 25\%$$

141. (b)

- At surging point mass flow rate is minimum and pressure ratio is maximum.
- At choking point mass flow rate is maximum and the valve of mach number is 1.

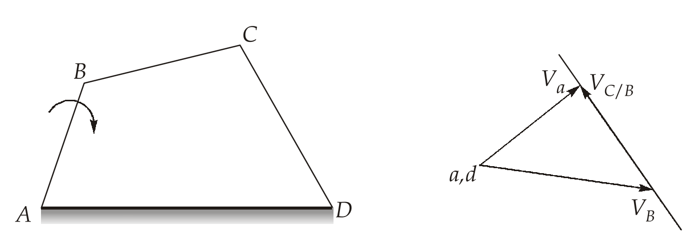
143. (a)

$$\text{Strain in beam, } \varepsilon = \frac{y}{R}$$

or

$$\varepsilon \propto y$$

144. (a)



Points a and d given on fixed link are represented by a single point as shown in velocity diagram.

145. (b)

To avoid collision of electrons with air molecules, this process is carried out in vacuum. So maintaining the vacuum on a large workpiece is very difficult.

146. (b)

For thin pressure vessel, we ignore the radial stress component since our limiting assumption of $\frac{r}{t} = 10$ results in principal stress σ_2, σ_1 being respectively 5 and 10 times higher than the maximum radial stress $(\sigma_3)_{max} = p$.

147. (a)

$$h = \frac{895}{N^2}$$

As height is inversely proportional to square of speed, beyond 60 rpm height of governor is very less.

148. (c)

In pressure compounding or Rateau staging, pressure drop occur in nozzles only.

149. (a)

During quenching surface converts immediately to martensite but core is still austenite but after some time, when core converts into martensite it expands and cracks are produced.

150. (c)

Adiabatic exponent for ammonia is high (1.31) as compared to fluorocarbons, resulting in high discharge temperature. Thus, water cooling is required.