Answer Key's

1	A	**2**	D	**3**	B	**4**	A	**5**	C	**6**	C	**7**	D
8	B	**9**	C	**10**	C	**11**	D	**12**	B	**13**	D	**14**	C
15	D	**16**	B	**17**	A	**18**	C	**19**	A	**20**	A	**21**	D
22	D	**23**	B	**24**	B	**25**	C	**26**	A	**27**	B	**28**	A
29	D	**30**	B	**31**	B	**32**	C	**33**	C	**34**	C	**35**	D
36	B	**37**	C	**38**	B	**39**	B	**40**	B	**41**	B	**42**	C
43	D	**44**	D	**45**	C	**46**	C	**47**	D	**48**	C	**49**	C
50	B	**51**	A	**52**	C	**53**	C	**54**	C	**55**	A	**56**	A
57	B	**58**	A	**59**	D	**60**	C	**61**	A	**62**	C	**63**	C
64	B	**65**	A	**66**	C	**67**	B	**68**	B	**69**	D	**70**	D
71	A	**72**	C	**73**	B	**74**	A	**75**	D	**76**	A	**77**	A
78	A	**79**	C	**80**	B	**81**	D	**82**	A	**83**	B	**84**	C
85	A												

Explanation:-

7. Option (a) is not correct because if heat flows from the system, entropy of the system will decrease, and the entropy of environment will increase. Sum of the entropy of system and environment i.e. the entropy of universe can not be negative but entropy of system can be negative

8. $dy = \left(1 - \frac{1}{x^2+1}\right)dx$, Integrating, $y = x - \tan^{-1}x + C, y(0) = 0 \quad \therefore C = 0, \therefore \quad f(1) = 1 - \tan^{-1}1, = 1 - \frac{\pi}{4}$

9. A and B are independent events

$P(A \text{ or } B) = P(A) + P(B) - P(A \cap B) = P(A) + P(B) - P(A)P(B) = \frac{6}{36} + \frac{6}{36} - \frac{6}{36} \times \frac{6}{36} = \frac{11}{36}$

10. $\begin{vmatrix} \lambda & 3 & -5 \\ 2 & -4\lambda & \lambda \\ -4 & 18 & 7 \end{vmatrix} = 0, \lambda = -3 \text{ or } 1$

11. $\underset{x \to 1^+}{\text{Lt}} \frac{x^2-1}{|x-1|} = 2$, $\underset{x \to 1^-}{\text{Lt}} \frac{x^2-1}{|x-1|} = -2$ doesn't exist

13. $\lambda = 9/5 = 1.8 \quad \mu = 10/5 = 2$, $L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} = 8.1$

14. $q_0 = \sqrt{\frac{2C_3R}{C_1}} = 1000$ units, Length of cycle $= t_0 = \frac{1000}{100} = 10$ days

As lead time is 13 days and cycle length is 10 days

Reorder point $= (13 - 10) \times 100 = 300$ units

17. Option b is not correct because, it does not include open cycle gas turbines which also consider as IC engines where combustion takes place in separate combustion chamber. So the most appropriate answer is (a)

19. Unit power, $P_u = \frac{P}{H^{3/2}}$, Unit discharge, $Q_u = \frac{Q}{\sqrt{H}}$

Ratio = $\frac{P_u}{Q_u} = \frac{P \times \sqrt{H}}{H^{3/2} \times Q} = \frac{P}{QH} = 4000$

20. Mach Velocity, $C = \sqrt{\frac{K}{\rho}} = \sqrt{\frac{15600 \times 9.81 \times 10^4}{0.8 \times 1000}} = 1383 m/s$

21. $$\begin{vmatrix} -1 & \cos C & \cos B \\ \cos C & -1 & \cos A \\ \cos B & \cos A & -1 \end{vmatrix} \xrightarrow[R_{31}(\cos B)]{R_{21}(\cos C)} \begin{vmatrix} -1 & \cos C & \cos B \\ 0 & 0 & \cos A + \cos C \cos B \\ 0 & \cos B \cos C + \cos A & \cos^2 B - 1 \end{vmatrix}$$

$$= -\left[\sin^2 B \sin^2 C - \left\{\left(-\cos(B+C) + \cos B \cos C\right)\right\}^2\right], [\because A + B + C = \pi] = -\left[\sin^2 B \sin^2 C - \sin^2 B \sin^2 C\right] = 0$$

22. The corresponding augmented matrix

$$\begin{pmatrix} 1 & -2 & 3 & 3 \\ 2 & 1 & -1 & 9 \\ -3 & -4 & 5 & -8 \end{pmatrix} \xrightarrow[3R_1+R_3]{-2R_1+R_2} \begin{pmatrix} 1 & -2 & 3 & 3 \\ 0 & 5 & -7 & 3 \\ 0 & -10 & 14 & 1 \end{pmatrix}$$

$$\downarrow 2r_2 + r_3$$

$$\begin{pmatrix} 1 & -2 & 3 & 3 \\ 0 & 5 & -7 & 3 \\ 0 & 0 & 0 & 7 \end{pmatrix}$$

The bottom row of the final matrix corresponds to the equation, $0.x + 0.y + 0.z = 7$, which has no solution

23. $\frac{dy}{dx} = \frac{2x}{y^2+1} \Rightarrow (y^2+1)dy - 2xdx = 0$, The above equation is exact.

Integrating we get, $\frac{y^3}{3} + y - x^2 = C$, At $(1, 2)$, $C = \frac{11}{3}$ $\therefore$ The int egral curve is $y^3 + 3y - 3x^2 = 11$

24. $P\left(X \le \frac{1}{3}\right) = F_x\left(\frac{1}{3}\right) = 1 + e^{\frac{2}{3}} = 2.95$

25. $\lim_{x\to\infty} \left(3^x + 3^{2x}\right)^{1/x}, = \lim_{x\to\infty}\left[9^x.\left(\frac{3^x}{9^x} + 1\right)\right]^{1/x} = \lim_{x\to\infty}\left[9\left\{\left(\frac{1}{3}\right)^x + 1\right\}^{1/x}\right] = 9$

26. $f(x) = 3x - \cos x - 1, f'(x) = 3 + \sin x, x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} = \frac{x_n \sin x_n + \cos x_n + 1}{3 + \sin x_n}$

Let $x_0 = 0.6$, First approximation: $x_1 = \frac{x_0 \sin x_0 + \cos x_0 + 1}{3 + \sin x_0} = \frac{0.6 \sin(0.6) + \cos(0.6) + 1}{3 + \sin(0.6)} = 0.6071$

Second approximation:

$x_2 = \frac{0.6071 \sin 0.6071 + \cos 0.6071 + 1}{3 + \sin(0.6071)} = 0.6071$

27. $L\left(\frac{f(t)}{t}\right) = \int_s^\infty \bar{f}(s)\,ds$ where $\bar{f}(s) = L(f(t))$, $L\left(\frac{\sin t}{t}\right) = \int_s^\infty \frac{1}{1+s^2}ds = \cot^{-1}s, L\left(e^t\left(\frac{\sin t}{t}\right)\right) = \cot^{-1}(s-1)$

28-29. From Merchant's circle

$$F_S = F_C\cos\phi - F_T\sin\phi = 248.3N, F_S = \frac{wt_1\tau_S}{\sin\phi} \Rightarrow t_1 = 0.14mm, \frac{\sin\phi}{\cos(\phi-\alpha)} = \frac{t_1}{t_2}, \therefore \alpha = 16.67^0$$

31-32. $\sum F_x = 0, \sum F_y = 0$

$$T_{AC}\cos 30^0 + F\cos\alpha = T_{BC}\cos 45^0,\ F\sin\alpha + T_{AC}\sin 30^0 + T_{BC}\sin 45^0 = 0$$

33. $\eta = \frac{P}{\rho g \times q \times H} \Rightarrow H = 7m$, Specific speed $N_S = \frac{N\sqrt{P}}{H^{\frac{5}{4}}}$

35. Heat transfer from oil = $C_h\Delta T = 2000(425-350) = 150KW$

for parallel flow arrangement

$\Delta T_1 = T_{hi} - T_{ci} = 400^0C$, $\Delta T_2 = T_{ho} - T_{co} = 150^0C$

$\Delta T_{\ell m} = \frac{\Delta T_1 - \Delta T_2}{\ell n(\Delta T_1/\Delta T_2)} = 254.88^0C$, Heat exchanger area $A_1 = \frac{Q}{U\Delta T_{\ell m}} = .735m^2$

For counter flow arrangements, $\Delta T_1 = T_{hi} - T_{co} = 225^0C, \Delta T_2 = T_{ho} - T_{ci} = 325^0C$

$\Delta T_{\ell m} = \frac{\Delta T_1 - \Delta T_2}{\ell n \Delta T_1/\Delta T_2} = 271.94^0C, A_2 = \frac{Q}{u\Delta T_{\ell m}} = .689m^2, A_1/A_2 = 1.067$

(Area required in parallel flow heat exchanger is always more than counter flow heat exchanger. Here only 1 option has the ratio more than 1. So it can be attempted without solving the whole problem)

37. Co-efficient of steadiness = $\frac{N_1+N_2}{2(N_1-N_2)}$, where N_1 =maximum speed

N_2 = minimum speed, Maximum fluctuation of speed = $N_1 - N_2 = 30.61$ rpm

38-39. f_P = Permissible stress for pinion = 140

y_P = tooth factor for pinion = $.154 - \frac{.912}{50} = .13576$

Strength factor for Pinion = $f_P \times y_P = 140 \times .13576 = 19$

Similarly $f_G = 115N/mm^2$

$y_G = .154 - \frac{.912}{75} = .14184$

Strength factor for gear = $f_G \times y_G = 115 \times .14184 = 16.31$

So, Lewis equation will be used for gear since strength factor is low.

40. $\varepsilon = 1 - \frac{2h_0}{c}c = D - d$

41. $\theta = 270^0 = 4.712 \text{ rad}$, $\frac{T_1}{T_2} = e^{\mu\theta} = 3.25$, $T_1 = 3.25\ T_2$, $T_B = (T_1 - T_2) r_e$

$re = r + \frac{t}{2} = 300 + .005 \times \frac{600}{2} = 300.15\text{Nmm}$, $1575 = (3.25T_2 - T_2) \times 300.15 \times 10^{-3}$

42. $\frac{\ell}{K} = 75$ for both ends hinged, $\frac{L}{K} = \frac{\ell}{\sqrt{2}K}$ for one end fixed and one hinged length = $\frac{\ell}{\sqrt{2}}$

$\underset{\text{(decrease)}}{\%\ \text{change}} = \frac{75 - \frac{75}{\sqrt{2}}}{75} \times 100 = 29.28\%$

43. e_1 = circumferential strain = $\frac{\delta d}{d} = \frac{3}{100} = .03$, e_2 = longitudial strain = $\frac{\delta \ell}{\ell} = \frac{5}{100} = .05$

change in volume $\delta v = v(e_2 + 2e_1) = 8.25\text{cm}^3$

46. For 1-2-3-5-7-9-10 to be critical path, summation of time for all the activities along the path should be maximum.

47. $\sigma^2 = \left(\frac{t_P - t_o}{6}\right)^2 = \left(\frac{10-4}{6}\right)^2 = 1$

50. $\frac{\partial T}{\partial x} = -75 + 16x + 36x^2 - 28x^3$

Heat energy stored in unit time = Heat entering - Heat leaving

Heat entering, $Q_0 = -kA\left(\frac{\partial T}{\partial x}\right)_{x=0} = 450\text{W}$,

Heat leaving, $Q_2 = -kA\left(\frac{\partial T}{\partial x}\right)_{x=1.2} = 314.054\text{W}$

Heat energy stored $= 73.728\text{W}$, $\frac{\partial^2 T}{\partial x^2} = 16 + 72x - 84x^2$

rate of temperature change at entry side k, $\frac{\partial T}{\partial t} = \alpha\left(\frac{\partial^2 T}{\partial x^2}\right)_{x=0} = 28.32 \times 10^{-3}\ ^0\text{C/h}$

rate of temperature change at exit side, $\frac{\partial T}{\partial t} = \alpha\left(\frac{\partial^2 T}{\partial x^2}\right)_{x=1.2} = -32.85 \times 10^{-3}\ ^0\text{C/h}$

for rate of heating or cooling to be maximum

$\frac{\partial}{\partial x}\left(\frac{\partial T}{\partial t}\right) = 0$, $\alpha\frac{\partial}{\partial x}\left(\frac{\partial^2 T}{\partial x^2}\right) = 0$, i.e. $\frac{\partial^3 T}{\partial x^3} = 0$, $\Rightarrow 72 - 168x = 0$, $x = 0.428\text{m}$

51. $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^2$, $P_2 = \left(\frac{6000}{2000}\right)^2 \times 100 = 900\text{kPa}$, $dw = \int_{v_1}^{v_2} P dv$, $Pv^2 = c$, $P = \frac{c}{V^2}$, $dw = \int_{v_1}^{v_2} \frac{c}{V^2} dv = c\left[-\frac{1}{v}\right]_{v_1}^{v_2}$

$w = P_1V_1 - P_2V_2 = (100 \times 6000 \times 10^3 \times 10^{-6} - 900 \times 10^3 \times 2000 \times 10^{-6}) = -1200\text{J} = -1.2\text{kJ}$

53. $(\Delta U)_{ACB} = (\Delta U)_{ADB}$, $\Delta Q = \Delta U + \Delta w$

55. $0.4 = W / Q_1$, $W = 0.4Q_1$, $COP = Q_3 / W$, $COP = 2Q_1 / 0.4Q_1 = 5$

56. $\delta - \Delta = \frac{P\ell}{A \in}$, $\delta\ell\Delta T = \Delta + \frac{P\ell}{A \in}$ $P = \sigma A, \ell\alpha\Delta T = \Delta + \frac{\sigma\ell}{\in}, \Delta T = \frac{\Delta}{\ell\alpha} + \frac{\sigma}{\in \alpha}$, $\Delta T = 70.6^0C, T = \Delta T + T_0 = 50.6^0C$

57. for 1st bar, stress = $\frac{P}{\frac{\pi}{4}(2d)^2} = \frac{P}{\pi d^2}$,strain energy stored = $\frac{F^2}{2E} \times$ vol of bar $= \frac{P^2\ell}{2E\pi d^2}$

2nd bar, $AB = F_1 = \frac{4P}{\pi d^2}, BC = F_2 = \frac{P}{\pi d^2}$

stress energy = AB+BC=$\frac{f_1^{\,2}}{2E} \times$ vol. of AB $+ \frac{f_2^{\,2}}{2E} \times$ vol. of BC $= \frac{\pi^2\ell}{E\pi d^2}$, ratio $\rightarrow 1/2$

59. $\omega_n = \sqrt{\frac{s}{m}} = 24.49\,\text{rad/sec}, \frac{x_o}{x_2} = \frac{x_o}{x_1} \times \frac{x_1}{x_2} = \left(\frac{x_o}{x_1}\right)^2, \frac{x_o}{x_1} = \left(\frac{x_o}{x_2}\right)^{1/2} = \left(\frac{45}{8}\right)^{1/2} = 2.37$

$\frac{2\pi\xi}{\sqrt{1-\xi^2}} = \ell n 2.37 = 0.867, \Rightarrow \xi = 0.136, C = 2m\omega_n\xi = 0.4\,\text{N/mm/sec}.$

60. Cycle $\eta = \frac{Q - 0.56Q}{Q} = 44\%$

Gen.output $= 0.92 \times 0.94 \times 0.44 \times 0.95Q$ & net output $= (1 - 0.06)$ gen.output
overall $\eta = 0.92 \times 0.94 \times 0.95 \times 0.94 \times 0.44 = 0.34 \Rightarrow 34\%$

63. $A_S = A_C$, $4\pi r^2 = 6a^2 \Rightarrow r^2 = \frac{6}{4\pi}a^2$, $(t_S)_{sphere} = k\left(\frac{V_s}{A_s}\right)^2$ $(t_S)_{cube} = k\left(\frac{V_C}{A_c}\right)^2, \frac{(t_S)_S}{(t_S)_C} = \left(\frac{4}{3}\pi\right)^2 \frac{(r^2)^3}{(a^2)^3} = 1.9$

65. $L = \sqrt{R(h_o - h_f)} = 1.55\text{in}$, true strain $\varepsilon = 1n\left(\frac{1.00}{0.80}\right) = 0.223$, roll force $F = Lwy_{average} = 1.6\text{MN}$

Power $= \frac{2\pi FLN}{33,000} = 670\text{kW} \times$ two rolls $= 1340\text{kW}$

66. dQ=dU+dW is only valid for closed system and gas turbine and steam turbines are open systems.

67. Average BP for 3 cylinder $= \frac{2\pi NT}{60000} = 13.82\text{kW}$, average IP with 1 cylinder $= 20 - 13.82 = 6.18\text{kW}$

total $I.P = 4 \times 6.18 = 24.72\text{kW}, ISFC = bsfc \times \frac{BP}{I.P} = 291.26\,\text{g/kWh}$, fuel consumption $= \frac{ISFC \times IP}{360 \times 1000} = 2 \times 10^{-3}\,\text{kg/S}$

69. It must be remembered that velocity and pressure head behave in reverse fashion. Thus velocity will be maximum for least area and pressure will be minimum. $\therefore$D → 3, 1, 2, 4.

70. Torque = Shear stress × Surface area × Torque arm

$0.88 = t(2\pi r \times 0.3)r, t = \frac{0.467}{r^2}, \frac{dV}{dy} = \frac{t}{\mu} = \frac{0.467}{\mu r^2}, \int_{V_{outer}}^{V_{inner}} dV = \frac{0.467}{\mu}\int_{0.13}^{0.12} -\frac{dr}{dr^2}, V_{inner} - V_{outer} = \frac{0.467}{\mu}\left[\frac{1}{r}\right]_{0.13}^{0.12}$

$V_{inner} = 2\pi \times 0.12 = 0.754$ m/s.$(0.754\text{-}0) = \frac{0.467}{\mu}\left[\frac{1}{0.12} - \frac{1}{0.13}\right], \Rightarrow \mu = 0.397$ Pas

71. Displacement thickness = $\int_0^\delta \left(1-\frac{u}{U}\right)dy = \int_0^\delta \left[1-\frac{2y}{\delta}+\left(\frac{y}{\delta}\right)^2\right]dy = \frac{\delta}{3}$

73. Mass of flywheel rim, $m_r = \frac{2KE}{r^2\left(\omega_1^2-\omega_2^2\right)} = \frac{2\times 0.90\times 207\times 10^3}{(0.915)^2\left[\left(\frac{2\pi\times 200}{60}\right)^2-\left(\frac{2\pi\times 180}{60}\right)^2\right]} = 69.6kg$

Total mass of flywheel = 1.15×69.6=80kg.

74. Co-efficient of speed fluctuation is $C_S = \frac{\omega_1-\omega_2}{\omega} = 0.105$

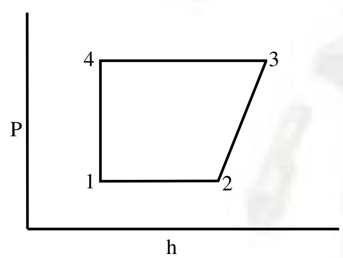
76-77. $L_1+L_2+L_3 = 18 \Rightarrow k+2k+3k = 18, k = 3$

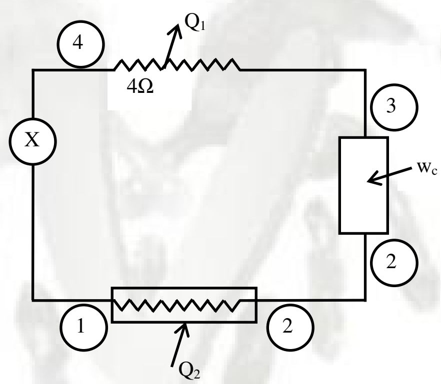
$L_1 = 3, L_2 = 6, L_3 = 9$, $d_1\times d_2\times d_3 = 20250 \Rightarrow 3k\times 2k\times k = 20250, k = 15$

$d_1 = 15mm, d_2 = 30mm, d_1 = 45mm$, $Q_1 = A_1V_1 = \frac{\pi}{4}d_1^2\times V_1 \Rightarrow V_1 = \frac{4Q_1}{\pi d_1^2}$, Similarly $V_2 = \frac{4Q_2}{\pi d_2^2}$ and $V_3 = \frac{4Q_3}{\pi d_3^2}$

Head loss due to friction $\frac{4fL_1V_1^2}{d_1\times 2g} = \frac{4fL_2V_2^2}{d_2\times 2g}+\frac{4fL_3V_3^2}{d_3\times 2g}$, On solving above equation we get $\frac{Q_3}{Q_2} = \frac{17}{3}$

78.





$h_1 = 80kJ/kg,\; h_2 = 200kJ/kg, h_3 = 220kJ/kg,$

$\therefore\; h_4 = h_1 = 80kJ/kg,$ mass flow rate $= \frac{5}{200-80} = 0.0417kg/sec$

79. Heat given by refrigerant in condenser= m(h3-h4)= 0.0417*(220-80)

80. $D = \frac{mg\ell^3}{48I}$, $I = \frac{\pi}{64}\times(24)^4 = 16.3\times 10^{-9}m^4$,

$D = \frac{12\times 9.81\times(1)^3}{48\times 2\times 10^{11}\times 16.9\times 10^{-9}} = 0.000752m, \omega_n = \sqrt{\frac{g}{D}} = 114.2$ rad/sec.

81. Amplitude

$y = \frac{e}{\left(\frac{\omega_n}{\omega}\right)^2-1}, \omega = \frac{2\pi\times 2400}{60} = 251.32$ rad/sec.,e=0.11,y=0.139mm

82. $9\times 2.5+12\times 6\times 3=6\times R_B$

$R_B=37.75kN$
$R_A+R_B=12\times 6+9$
$R_A=41.25kN$

Shear force in section AC = 41.25 – 12x

For maximum BM

41.25 – 12x = 0,x = 3.4375, x = 3.4375 does not lie in section AC

Consider section BC

$S_F=41.25-12\times -9$

For Maximum B.M. $SF=0$

x = 2.6875

Now BM at x = 2.6875= 65.85 kNm

83. $M=z\sigma, z=\dfrac{M}{\sigma}=\dfrac{65.83\times 10^6}{8}=8.2287\times 10^6, z=\dfrac{1}{6}bd^2=\dfrac{1}{6}b(2b)^2=\dfrac{2b^3}{3}$

$\dfrac{2b^3}{3}=8.2286\times 10^6, b=231mm, d=462mm$ $\therefore$ cross sectional area = 6 × d = 0.231 × 0.462 = 0.11 m^2

84. $\beta = \tan^{-1}\mu = \tan^{-1}(0.4) = 21.8°, \alpha = 15°$

using equation , $2\phi+\beta-\alpha=\dfrac{\pi}{2}\Rightarrow 2\phi=90°-21.8°+15°=83.2°\Rightarrow \phi=41.6°$

85. $F_S=\dfrac{wt_1\tau_S}{\sin\phi}=\dfrac{10\times 0.1\times 300}{\sin 41.6°}=451.86N$, $R=\dfrac{F_S}{\cos(\phi+\beta-\alpha)}=\dfrac{451.86}{\cos(41.6+21.8-15)}=680.2N$

$F_C=R\cos(\beta-\alpha)=680.2\times\cos(21.8-15)=675.4N$, $F_\tau=R\sin(\beta-\alpha)=680.2\times\sin(21.8-15)=80.54N$