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ISRO

RAC ENGINEERING

Written Test of Scientist/Engineer Examination

Date of Test : 12-01-2020

Set-E

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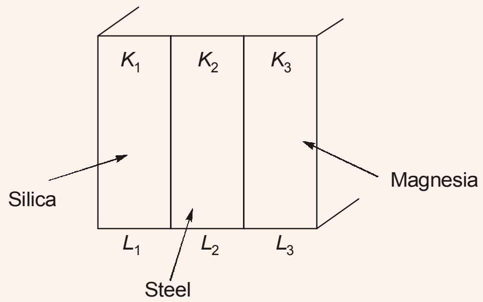
ISRO (Scientist/Engineer) Examination
Refrigeration and Air-Conditioning : Paper Analysis
Exam held on 12.01.2020

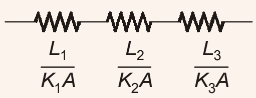
Sl.	Subjects	No. of Qs.	Level of Difficulty
1	Heat Transfer	4	Easy (Same as ESE)
2	RAC	12	Moderate (Same as ESE)
3	Engineering Mechanics	4	Moderate
4	IC Engine	1	Moderate
5	Strength of Material	11	Easy (Mostly repeated)
6	Production Engineering	7	Easy, Theoretical
7	Machine Design	2	Moderate
8	Power Plant	8	Easy
9	Fluid Mechanics + Turbo Machinery	11	Moderate
10	Thermodynamics	9	Easy
11	Engineering Mathematics	10	Moderate
12	Theory of Machines	1	Easy

Q.1 A furnace wall made of steel plate 10 mm thick and thermal conductivity 15 kcal/m-hr-°C is lined inside with silica brick of 150 mm thick of thermal conductivity 1.75 kcal/m-hr-°C and on outside with magnesia bricks of 200 mm thick with thermal conductivity of 4.5 kcal/m-hr-°C. The total resistance of the composite wall will be

(a) 0.13 °C-hr/kcal
(b) 0.23 °C-hr/kcal
(c) 0.03 °C-hr/kcal
(d) 0.33 °C-hr/kcal

Ans. **(a)**





Let $A = 1\ m^2$

$$R_{total} = \frac{0.15}{1.75} + \frac{0.01}{15} + \frac{0.2}{4.5} = 0.13°\text{C-hr/Kcal}$$

End of Solution

Q.2 A water turbine delivering 10 MW power is to be tested with the help of a geometrically similar 1:10 model which runs at the same speed and efficiency. The power developed by the model will be

(a) 10 W
(b) 100 W
(c) 1000 W
(d) 10000 W

Ans. **(b)**

$P_p = 10$ MW, $P_M = ?$

$$N_m = N_p$$

$$\frac{D_M}{D_P} = \frac{1}{10}$$

$$\left.\frac{P}{D^5N^3}\right|_P = \left.\frac{P}{D^5N^3}\right|_M$$

$$P_M = P_P \times \left(\frac{D_M}{D_P}\right)^5 \times \left(\frac{N_M}{N_P}\right)^3 \qquad (\because N_M = N_P)$$

$$P_M = 10 \times 10^6 \times \left(\frac{1}{10}\right)^5$$

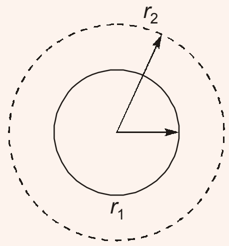
$$P_M = 100 \text{ W}$$

End of Solution

Q.3 A hot fluid is flowing through a long pipe of 4 cm outer diameter and covered with 2 cm thick insulation. It is proposed to reduce the conduction heat loss to the surroundings to one third of the present rate by increasing the same insulation thickness. The additional thickness of insulation required will be

(a) 2 cm (b) 6 cm
(c) 9 cm (d) 12 cm

Ans. **(d)**



$$Q = \frac{\Delta T}{R_{th}}$$

$$Q \propto \frac{1}{R_{th}}$$

$$\frac{Q_2}{Q_1} = \frac{R_1}{R_2}$$

$d_2 = 4 + 2 \times 2 = 8$ cm, $r_2 = 4$ cm
$d_1 = 4$ cm, $r_1 = 2$ cm

For cylindrical surface, $R_{th} = \dfrac{\ln(r_2/r_1)}{2\pi k l}$

$$\frac{Q_2}{Q_1} = \frac{\ln(r_2/r_1)}{2\pi k l} \times \frac{2\pi k l}{\ln(r_2'/r_1)}$$

$$\frac{1}{3} = \frac{\ln(r_2/r_1)}{\ln(r_2'/r_1)}$$

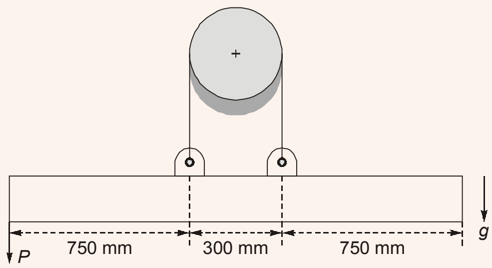
$$\frac{r_2'}{r_1} = \left(\frac{r_2}{r_1}\right)^3 = 2^3$$

$$r_2' = 8 \times 2 = 16 \text{ cm}$$

increment $r_2' - r_2 = 16 - 4 = 12$ cm

End of Solution

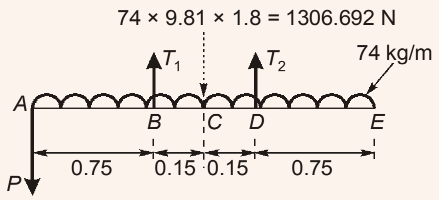
Q.4 A uniform beam of mass density 74 kg/m and length 1.8 m is suspended symmetrically as shown in figure. Calculate the maximum force *P* that can be supported without tipping the beam. Take the coefficient of static friction between the cord and the cylinder to be 7/22.



(a) 100.7 N (b) 200.9 N
(c) 150.8 N (d) 50.2 N

Ans. (a)

$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{\frac{22}{4} \times \pi} = e^1 = 2.718$$



$$\Sigma V = 0$$

$\Rightarrow$ $$T_1 + T_2 = P + 1306.692$$

$$P = 3.718 T_2 - 1306.692 \quad \text{...(I)}$$

$$\Sigma M_A = 0$$

$$-T_1 \times 0.75 - T_2 \times 1.05 + 1306.692 \times 0.9 = 0$$

$$\Rightarrow 2.718 T_2 \times 0.75 + T_2 \times 1.05 = 1176.0228$$

$\Rightarrow$ $$T_2 = \frac{1176.0228}{3.0885} = 380.7747 \text{ N}$$

$$T_1 = 2.718 T_2 = 1034.945 \text{ N}$$

from (I), $P = 109.028$ N

if $1\ kgf = 10$ N

then, $P = 111.1417$ N

End of Solution

Q.5 For which of the following situations, zeroth law of thermodynamics will not be applicable?

(a) 50 cc of water at 25°C is mixed with 150 cc of water at 25°C
(b) 500 cc of milk at 15°C is mixed with 100 cc of water at 15°C
(c) 5 kg of wet stream at 100°C is mixed with 50 kg of dry and saturated steam at 100°C
(d) 10 cc of water at 20°C is mixed with 10 cc of sulphuric acid at 20°C.

Ans. (c)

As the wet steam at 100°C and dry and saturated steam at 100°C are not in thermal equilibrium as heat transfer will take place between them. So zeroth law of thermodynamics will not be applicable.

End of Solution

Q.6 A system undergoes a change of state during which 100 kJ of heat is transferred to it and it does 50 kJ of work. The system is brought back to its original state through a process during which 120 kJ of heat is transferred to it. The work done by the system in kJ is

(a) 50 (b) 70
(c) 170 (d) 200

Ans. (d)

End of Solution

Q.7 90 kilograms of ice at 0°C is completely melted. Find the entropy change in kJ/K, if final temperature is 0°C.

(a) 0 (b) 85
(c) 45 (d) 105

Ans. (d)

$\because$ Heat transfer, $Q = m \times LH$

$= 90 \text{ kg} \times 335 \text{ kJ/kg} = 30150 \text{ kJ}$

and thus heat transfer will take place at constant temperature,

$T = 0 + 273 = 273 \text{ K}$

So,Change in entropy $(\Delta S) = \dfrac{Q}{T} = \dfrac{30150}{273} = 110.44 \text{ kJ/K}$

Nearest value to the solution is option (d).

End of Solution

Q.8 For a heat engine operating on Carnot cycle, the work output is 1/4th of the heat transferred to the cold system. The efficiency of the Engine is

(a) 20% (b) 25%
(c) 75% (d) 50%

Ans. (a)

$$W = \frac{1}{4}Q_R$$

$$Q_s = W + Q_R$$

$$Q_s = \frac{1}{4}Q_R + Q_R$$

$$Q_s = \frac{5}{4}Q_R$$

$$\eta = \frac{W}{Q_s} = \frac{\frac{1}{4}Q_R}{\frac{5}{4}Q_R} = 20\%$$

End of Solution

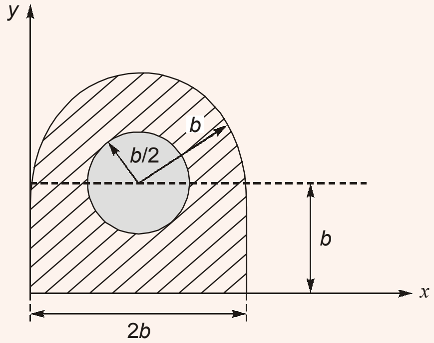
Q.9 Ideal Diesel cycle consists of

(a) Two adiabatic and two constant volume processes
(b) Two adiabatic and two constant pressure processes
(c) Two adiabatic, one constant pressure and one constant volume processes
(d) Two isothermal, one constant pressure and one constant volume processes

Ans. (c)

End of Solution

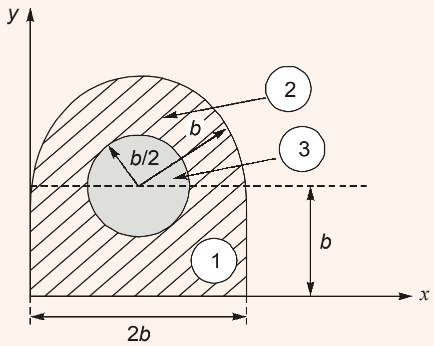
Q.10 Determine the centroid (x_c, y_c) of the shaded area as shown in figure with respect to given coordinate axes



(a) $\left(b, \dfrac{28+3\pi}{3(8+\pi)}b\right)$ (b) $\left(\dfrac{b}{2}, \dfrac{12+2\pi}{4(2+\pi)}b\right)$

(c) $\left(b, \dfrac{5}{(8+\pi)}b\right)$ (d) $\left(b, \dfrac{1+2\pi}{2(8+\pi)}b\right)$

Ans. (*)



1 → Rectangle ($2b \times b$)
2 → Semi-circle of radius $2b$

3 → Circle of radius $\dfrac{b}{2}$

$$x_c = \frac{2b}{2} = b \quad \text{(by Symmetry)}$$

$$y_c = \frac{A_1y_1 + A_2y_2 - A_3y_3}{A_1 + A_2 - A_3}$$

$$= \frac{(2b \times b) \times \frac{b}{2} + \frac{\pi b^2}{2} \times \left(b + \frac{4b}{3\pi}\right) - \pi\left(\frac{b}{2}\right)^2 \times b}{2b \times b + \frac{\pi b^2}{2} - \pi\left(\frac{b}{2}\right)^2}$$

$$= \frac{b + \frac{\pi}{2}\left(b + \frac{4b}{3\pi}\right) - \frac{\pi}{4}b}{2 + \frac{\pi}{2} - \frac{\pi}{4}} = \frac{b + \frac{\pi b}{2} + \frac{\pi}{2} \times \frac{4b}{3\pi} - \frac{\pi b}{4}}{2 + \frac{\pi}{4}}$$

$$= \frac{b + \frac{\pi b}{4} + \frac{2b}{3}}{2 + \frac{\pi}{4}} = \frac{\frac{20b + 3\pi b}{12}}{\frac{8 + \pi}{4}}$$

$$y_c = \frac{(20 + 3\pi)b}{3(8 + \pi)}$$

Centroid of shaded region, $\left(b, \frac{(20 + 3\pi)b}{3(8 + \pi)}\right)$

End of Solution

Q.11 The operating temperatures of a single stage Vapour Absorption Refrigeration System (VARS) are : Generator 90°C, condenser and absorber 40°C, evaporator 0°C. If the pump work is negligible, find the ideal COP of this VARS.

(a) 0.94
(b) 1.4
(c) 0.84
(d) 2.4

Ans. (a)

$$\text{COP}\Big|_{\text{VARS}} = \frac{T_G - T_o}{T_G} \times \frac{T_R}{T_O - T_R}$$

$$T_G = 90°\text{C} = 363\text{K}$$
$$T_o = 40°\text{C} = 313\text{K}$$
$$T_R = 0°\text{C} = 273\text{K}$$

$$\text{COP}\Big|_{\text{VARS}} = \frac{363 - 313}{363} \times \frac{273}{313 - 273}$$

$$\text{COP}\Big|_{\text{VARS}} = 0.94$$

End of Solution

Q.12 One of the Eigen vectors of the matrix $\begin{bmatrix} -5 & 2 \\ -9 & 6 \end{bmatrix}$ is

(a) $\begin{bmatrix} -1 \\ 1 \end{bmatrix}$

(b) $\begin{bmatrix} -2 \\ 9 \end{bmatrix}$

(c) $\begin{bmatrix} 2 \\ -1 \end{bmatrix}$

(d) $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$

Ans. (d)

$$A = \begin{bmatrix} -5 & 2 \\ -9 & 6 \end{bmatrix}$$

If x is eigen vector $\rightarrow Ax = \gamma x$, where γ is a constant.

(a) $\begin{bmatrix} -5 & 2 \\ -9 & 6 \end{bmatrix}\begin{bmatrix} -1 \\ 1 \end{bmatrix} = \begin{bmatrix} 7 \\ 15 \end{bmatrix}$

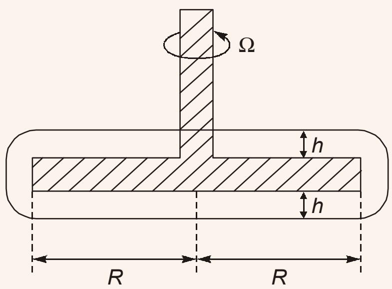
(b) $\begin{bmatrix} -5 & 2 \\ -9 & 6 \end{bmatrix}\begin{bmatrix} -2 \\ 9 \end{bmatrix} = \begin{bmatrix} 28 \\ 72 \end{bmatrix}$

(c) $\begin{bmatrix} -5 & 2 \\ -9 & 6 \end{bmatrix}\begin{bmatrix} 2 \\ -1 \end{bmatrix} = -12\begin{bmatrix} 1 \\ 2 \end{bmatrix}$

(d) $\begin{bmatrix} -5 & 2 \\ -9 & 6 \end{bmatrix}\begin{bmatrix} 1 \\ 1 \end{bmatrix} = -3\begin{bmatrix} 1 \\ 1 \end{bmatrix}$

End of Solution

Q.13 A disc of radius R rotates at an angular velocity Ω inside a disc shaped container filled with oil of viscosity μ, as shown in figure. Assuming a linear velocity profile and neglecting shear stress on the outer disc edges, the formula for viscous torque on the disc is



(a) $\dfrac{\pi\mu\Omega R^2}{h}$

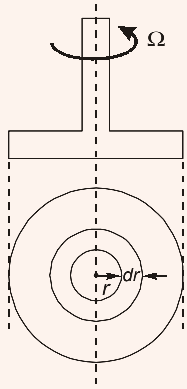
(b) $\pi\mu\Omega h R^3$

(c) $\dfrac{\pi\mu\Omega R^5}{h^2}$

(d) $\dfrac{\pi\mu\Omega R^4}{h}$

Ans. (d)

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



Consider a strip of thickness dr at radius r.
Friction force on strip, $dF_f = \tau \cdot 2\pi r dr$
Frictional torque on strip $dT_f = dF_f \times r$
Surface

$$dT_f = \tau 2\pi r dr \cdot r$$

$$dT_f = \frac{\mu r \Omega}{h} 2\pi r^2 dr$$

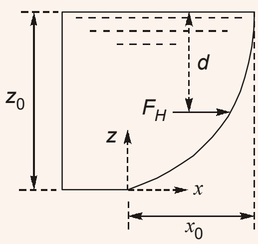
$$\int dT_f = \frac{2\pi\mu\Omega}{h} \int_0^R r^3 dr$$

One surface torque, $T_f = \dfrac{\pi\mu\Omega R^4}{2h}$

So top and bottom surfaces torque, $T_f = \dfrac{\pi\mu\Omega R^4}{h}$

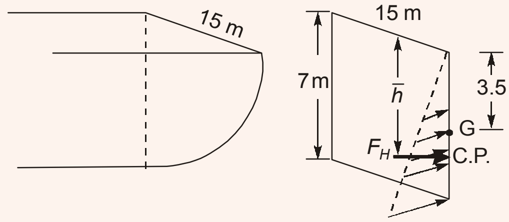
End of Solution

Q.14 A dam has a parabolic shape $\dfrac{z}{z_0} = \left(\dfrac{x}{x_0}\right)^2$ as in shown in figure with x_0 = 3 m and z_0 = 7 m. The fluid is water (specific weight = 9810 N/m^3) and atmospheric pressure may be omitted. Compute the horizontal force F_H and its line of action from surface of water 'd'. Assume width of dam is 15 m.



(a) F_H = 3605 kN, d = 1.16 m
(b) F_H = 3505 kN, d = 4.66 m
(c) F_H = 4300 kN, d = 4.66 m
(d) F_H = 4300 kN, d = 1.16 m

Ans. (b)

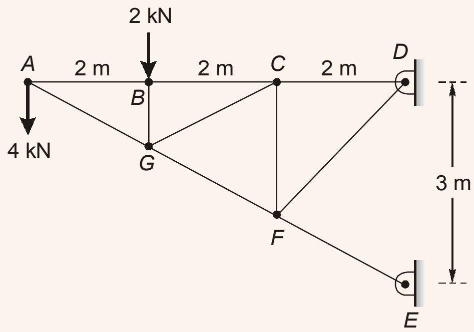


$$F_H = \gamma A_p \bar{x}$$
$$= 9810 \times (15 \times 7) \times 3.5 = 3605.17 \text{ kN}$$

Location $\bar{h} = \frac{2}{3} \times 7 = 4.66 \text{ m}$

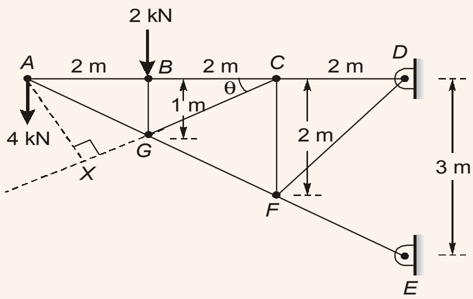
End of Solution

Q.15 Calculate the forces in the members *CG* and *CF* for the truss shown.



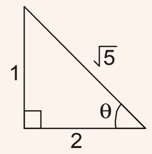
(a) $F_{CG} = \sqrt{5}$ kN, $F_{CF} = 1$ kN
(b) $F_{CG} = \sqrt{3}$ kN, $F_{CF} = 2$ kN
(c) $F_{CG} = 2$ kN, $F_{CF} = \sqrt{3}$ kN
(d) $F_{CG} = \sqrt{5}$ kN, $F_{CF} = 2$ kN

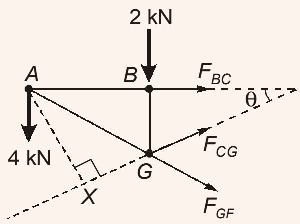
Ans. (a)



$$\Sigma M_A = 0$$
$$2 \times 2 = F_{CG} \times AX$$

In ΔBGC, $\tan\theta = \frac{1}{2}$





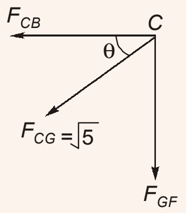
So $$\sin\theta = \frac{1}{\sqrt{5}}$$

In ΔAXC,

$$AX = AC\sin\theta = 4\times\frac{4}{\sqrt{5}}$$

$\Rightarrow$ $$F_{CG} = \frac{2\times 2}{AX}$$

and in joint C,



$$F_{GF} = F_{CG}\sin\theta$$

$$= \sqrt{5}\times\frac{1}{\sqrt{5}} = 1 \text{ kN} = 1 \text{ kN}$$

End of Solution

Q.16 Which of the following statement regarding centrifugal compressor is true?

(a) Conversion of dynamic pressure into static pressure takes place in the volute casing due to its convergent shape.

(b) In multi stage centrifugal compressor, the width of the blades reduces progressively in the direction of flow.

(c) In multi stage centrifugal compressor, the width of the blades increases progressively in the direction of flow.

(d) Multi staging in centrifugal compressors is commonly used for high refrigerant capacity applications.

Ans. (b)

Multistage centrifugal compressor is used for high compression ratio so the width of blades reduces progressively in the direction of flow so as to get constant mass flow rate.

End of Solution

Q.17 Which one of the following statements is true?

(a) Compared to reciprocating compressor, the performance of centrifugal compressor is less sensitive to speed.

(b) Surging in centrifugal compressor takes place as evaporator pressure increases and condenser pressure decreases.

(c) Surging in centrifugal compressor takes place as evaporator pressure decreases and condenser pressure increases.

(d) For a given flow rate, frictional losses decrease as the number of blades increases.

Ans. **(c)**

Surging increases as condenser pressure increases and evaporator pressure decreases.

End of Solution

Q.18 Three cards were drawn from a pack of 52 cards. The probability that they are a king, a queen and a jack is

(a) $\frac{16}{5525}$ (b) $\frac{64}{2197}$

(c) $\frac{3}{13}$ (d) $\frac{8}{16575}$

Ans. **(a)**

$$\frac{4c_1 \cdot 4c_1 \cdot 4c_1}{52c_3} = \frac{4\times4\times4}{\frac{52\times51\times50}{3\times2\times1}} = \frac{16}{5525}$$

End of Solution

Q.19 General solution of the equation $(x^3 + 3xy^2)dx + (3x^2y + y^3)dy = 0$ is (c is a constant)

(a) $\frac{1}{4}(x^4 + 6x^2y^2 + y^4) = c$ (b) $\frac{1}{5}(8x^4 + 6x^3y + y^3) = c$

(c) $\frac{1}{12}(x^3 + 6xy^2 + y^4) = c$ (d) $(x^2 + y^2) = c$

Ans. **(a)**

$$\underset{\downarrow M}{(x^3 + 3xy^2)}dx + \underset{\downarrow N}{(3x^2y + y^3)}dy = 0$$

$$M_y = 6xy$$
$$N_x = 6xy$$
$$M_y = N_x \qquad \text{Exact DE}$$

GS

$$\underset{(y_{\text{const}})}{\int(x^3 + 3xy^2)dx} + \underset{(\text{Terms independent of } x)}{\int(3x^2y + y^3)dy} = C$$

$$\frac{x^4}{4} + \frac{3x^2y^2}{2} + \frac{y^4}{4} = C$$

$$\Rightarrow \frac{1}{4}\left[x^4 + 6x^2y^2 + y^4\right] = C$$

End of Solution

Q.20 Let $f(t) = \sin^2 t$, find the Laplace transform of $f(t)$

(a) $\dfrac{2}{s^2+4}$

(b) $\dfrac{2}{s(s^2+4)}$

(c) $\dfrac{2s}{s^2+4}$

(d) $\dfrac{2}{s(s^2-4)}$

Ans. **(b)**

$$L\{\sin^2 t\} = L\left\{\frac{1-\cos 2t}{2}\right\} = \frac{1}{2}\left\{\frac{1}{s}-\frac{s}{s^2+4}\right\} = \frac{1}{2}\left[\frac{s^2+4-s^2}{s(s^2+4)}\right] = \frac{2}{s(s^2+4)}$$

End of Solution

Q.21 Find the particular solution for the initial value problem

$2\sin(y^2)dx + xy\cos(y^2)dy = 0$, if $y(2) = \sqrt{\left(\frac{\pi}{2}\right)}$

(a) $x^4 \sin(y^3) = 28$

(b) $x^3 \sin(y^2) = 8$

(c) $x^4 = 16$

(d) $x^4 \sin(y^2) = 16$

Ans. **(d)**

$$\underset{M}{\underbrace{2\sin(y^2)dx}} + \underset{N}{\underbrace{xy\cos(y^2)dy}} = 0$$

$$M_y = 2\cos(y^2)2y\ ; \quad N_x = y\cos(y^2) = 4y\cos(y^2)$$

$$M_y \neq N_x$$

$$\frac{M_y - N_x}{N} = \frac{3y\cos(y^2)}{xy\cos(y^2)} = \frac{3}{x} = f(x)$$

$$\text{IF} = e^{\int \frac{3}{x}dx} = x^3$$

G.S

$$\int_{y\text{ const}} 2x^3\sin(y^2)dx + \int_{(\text{Terms independent of } x)} x^4 y\cos(y^2)dy = 0$$

$$\frac{x^4}{2}\sin(y^2) = C$$

$$y(2) = \sqrt{\frac{\pi}{2}}$$

$$\frac{2^4}{2}\sin\left(\frac{T}{2}\right) = C \Rightarrow C = 8$$

$$\frac{x^4}{2}\sin(y^2) = 8$$

$$x^4\sin(y^2) = 16$$

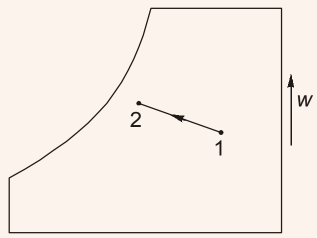
End of Solution

Q.22 When the air is passed through an insulated chamber having sprays of water maintained at a temperature higher than the dew point temperature of entering air but lower than the dry bulb temperature, then the air is said to be

(a) cooled and dehumidified
(b) cooled and humidified
(c) heated and humidified
(d) heated and dehumidified

Ans. (b)

Cooled and Humidified.



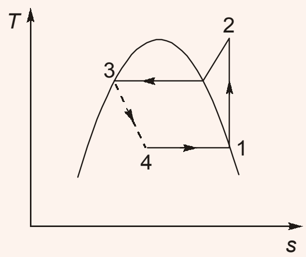
End of Solution

Q.23 In an ideal vapour compression refrigeration cycle, the specific enthalpy of refrigerant in kJ/kg at the following states is given as

Inlet of condenser : 283
Exit of condenser : 116
Exit of evaporator : 232
The COP of the cycle is

(a) 2.27
(b) 2.75
(c) 3.27
(d) 3.75

Ans. (a)



h_1 = 232 kJ/kg, h_2 = 283 kJ/kg, h_3 = 116 kJ/kg.

$$h_3 = h_4$$

$$\text{COP} = \frac{h_1 - h_4}{h_2 - h_1} = 2.27$$

End of Solution

Q.24 A 10 kg solid at 100°C with a specific heat of 0.8 kJ/kg°C is immersed in 40 kg of 20°C liquid with a specific heat of 4.0 kJ/kg°C. The temperature of the solid after a long time if the container is insulated will be

(a) 30.8 °C
(b) 27.8 °C
(c) 26.3 °C
(d) 23.8 °C

Ans. (d)

$m_1 = 10$ kg; $m_2 = 40$ kg; $t_1 = 100°C$; $t_2 = 20°C$;
$(C_p)_1 = 0.8$ kJ/kg°C; $(C_p)_2 = 4$ kJ/kg°C,
Let final temperature is t°C

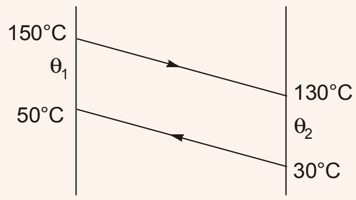
$$Q_{net} = 0$$
$$\Rightarrow \quad 10 \times 0.8(100 - t) = 40 \times 4 \times (t - 20)$$
$$\Rightarrow \quad 800 - 8t = 160t - 3200$$
$$\Rightarrow \quad 168t = 3200 + 800$$
$$\Rightarrow \quad t = \frac{4000}{160} = 23.8°C$$

End of Solution

Q.25 In a counter flow heat exchanger, cold fluid enters at 30°C and leaves at 50°C, whereas the hot fluid enters at 150 °C and leaves at 130°C. The mean temperature difference for this case is

(a) 20°C
(b) 80°C
(c) 100°C
(d) 120°C

Ans. (c)



$$\text{LMTD} = \frac{\theta_1 - \theta_2}{\ln\left(\frac{\theta_1}{\theta_2}\right)}$$

$$\theta_1 = 150 - 50 = 100°C$$
$$\theta_2 = 130 - 30 = 100°C$$

As $\theta_1 = \theta_2$ in counter flow so it is balanced type so $\theta_1 = \theta_2 = \theta_m = 100°C$.

End of Solution

Q.26 Find the change in height (h) in a circular tube (of radius $R = 1$ mm) filled with liquid (water) with surface tension T = 0.073 N/m. Contact angle of water-air-glass interface is 0°.

(a) 1.5 cm
(b) 2.5 cm
(c) 0.5 cm
(d) 0.15 cm

Ans. (a)

$$h = \frac{4\sigma\cos\theta}{\gamma d} = \frac{4 \times 0.073 \times 1}{9810 \times 2 \times 1 \times 10^{-3}} = 1.5 \text{ cm} \quad (\sigma = 0.073 \text{ N/m})$$

End of Solution

Q.27 Oil at 20°C (density = 870 kg/m^3) and viscosity = 0.104 kg/m-s) flows (laminar flow) at 1.1 m^3/hr through a horizontal pipe with diameter d = 2 cm and length L = 12 m. Find the power required to cause the flow

(a) 29.7 W
(b) 35.8 W
(c) 15.7 W
(d) 49.8 W

Ans. (a)

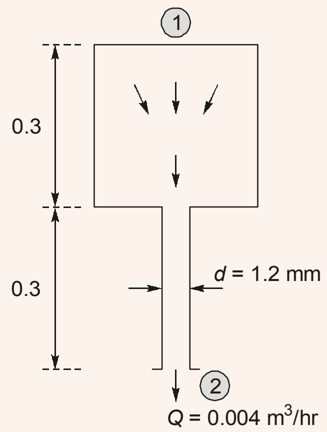
$$\text{Power} = \gamma Q h_f = \gamma Q \frac{32\mu u L}{\gamma d^2}$$

$$= \frac{32\mu Q^2 L}{\left(\frac{\pi d^2}{4}\right) d^2}$$

$$= \frac{32 \times 0.104 \times 1.1^2 \times 12}{\frac{\pi}{4} \times (0.02)^4 \times 3600^2} = 29.7$$

End of Solution

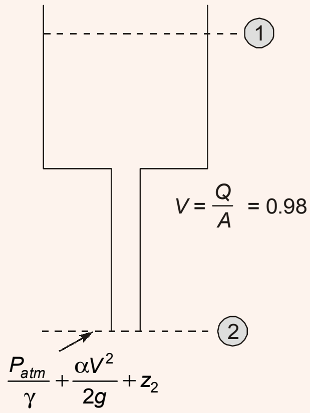
Q.28 A liquid of specific weight (ρg) = 9000 N/m^3 flow by gravity from a tank of 0.3 m height through a 1.2 mm diameter capillary tube at a rate of 0.004 m^3/hr as shown in figure. Sections 1 and 2 are at atmospheric pressure. Neglecting entrance effects and friction in the large tank, compute the viscosity of the liquid. Assume kinetic energy correction factor α = 2.0.



(a) 8.9×10^{-4} kg/m-s
(b) 10×10^{-4} kg/m-s
(c) 6.9×10^{-4} kg/m-s
(d) 3×10^{-3} kg/m-s

Ans. (c)

$$V = \frac{Q}{A} = \frac{0.004}{3600 \times \frac{\pi}{4} \times 1.2^2 \times 10^{-6}} = 0.98 \text{ m/s}$$



Applying energy equation between (1) and (2).

$$\frac{P_{atm}}{\gamma} + 0 + z_1 = \frac{P_{atm}}{\gamma} + \frac{\alpha V_2^2}{2g} + z_2 + h_f$$

$$h_f = (z_1 - z_2) - \frac{\alpha V_2^2}{2g}$$

Assuming laminar flow in Capillary tube

$$\frac{32\mu VL}{\gamma d^2} = (z_1 - z_2) - \frac{\alpha V_2^2}{2g}$$

$$\frac{32 \times \mu \times 0.98 \times 0.3}{9000 \times (0.0012)^2} = 0.6 - \frac{2 \times 0.98^2}{2 \times 10}$$

$$\mu = 6.9 \times 10^{-4} \text{ kg/m-s}$$

End of Solution

Q.29 An electric cable of Aluminium conductor of thermal conductivity 240 W/mK is to be insulated with rubber of thermal conductivity 0.15 W/mK. The cable is to be located in air of heat transfer coefficient of 6 W/m^{2}K. The critical thickness of insulation will be

(a) 25 mm
(b) 40 mm
(c) 150 mm
(d) 160 mm

Ans. (a)

$$r_{in} = \frac{k_{in}}{h} \text{ (cylindrical shape)} = \frac{0.15}{6} = 0.025 \text{ m} = 25 \text{ mm}$$

Although this is critical radius of insulation, critical thickness of insulation will be less than 25 cm as no option is less than 25 so most appropriate is *a*.

End of Solution

Q.30 The power per tonne of refrigeration (in kW) is

(a) 3.5/COP
(b) COP/3.5
(c) 3.5 × COP
(d) None of these

Ans. (a)

$$COP = \frac{RC}{W_{in}}$$

$$W_{in} = \frac{RC}{COP} = \frac{3.5}{COP}$$

$$RC = 1 \text{ TR} = 3.5 \text{ kW}$$

End of Solution

Q.31 A bag house is to be designed to handle 1000 m^3/min of air. The filtration takes place at constant pressure so that the air velocity through each bag decreases during the time between cleaning according to the relation $u = \frac{1}{0.267 + 0.08t}$ where, u is in m/min of cloth and t is the time in min. The bags are shaken in sequence row by row on a 30 min cycle. Each bag is 20 cm in diameter and 3 m height. The bag house is to be square in cross-section with 30 cm spacing between bags and 30 cm clearance from the walls. Calculate the minimum number of bags required.

(a) 663 (b) 753
(c) 553 (d) 853

Ans. **(c)**

$$V_{avg.} = \frac{1}{t}\int_0^t u\,dt = \frac{1}{t}\int_0^t \frac{dt}{0.267 + 0.08t}$$

$$A_t = \frac{Q_g}{V_{avg}}$$

$$A_b = \pi dL$$

$$N = \text{Number of bags} = \frac{A_t}{A_b}$$

Given: Ratio of flow rate air to cloth are (u) $= \frac{1}{0.267 + 0.08t}\left(\text{m}^3/\text{m}^2\ \text{min of cloth}\right)$

Time, t = 30 min, diameter of bag, d = 0.2 ; Length of bag, L = 3 m,
Flow rate, Q_g = 1000 m^3/min
Put the values in equation, we get the average velocity

$$V_{avg} = \frac{1}{30}\int_0^{30} \frac{dt}{0.267 + 0.08t} = \frac{28.78}{30} = 0.959 \text{ m/min}$$

$$A_t = \frac{1000}{0.959} = 1042.390 \text{ m}^2$$

$$A_b = \pi \times 0.2 \times 3 = 1.8849 \text{ m}^2$$

$$N = \frac{1042.390}{1.884} = 553.005 \simeq 553$$

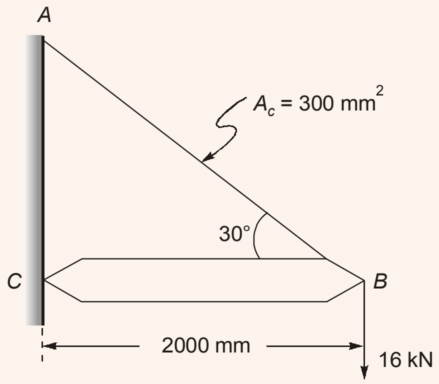
End of Solution

Q.32 The thermostatic expansion valve operates based on
(a) temperature of the evaporator
(b) pressure in the evaporator
(c) degree of superheat at exit of evaporator
(d) degree of super heat at exit of the compressor

Ans. (c)

End of Solution

Q.33 A jib crane consists of a rigid beam *BC* supported by an elastic rod *AB* and hinged at *C*. Determine the deflection of the point *B* when a load of 16 kN is applied. Take E = 200 GPa, area of cross-section (A_C) of elastic rod AB is 300 mm^2.



(a) 1.23 mm
(b) 4.56 mm
(c) 2.46 mm
(d) 5.23 mm

Ans. (a)

End of Solution

Q.34 The heat rejection factor in vapour compression refrigeration system will be
(a) equal to 1
(b) more than 1
(c) less than one
(d) depends on cooling medium of the condenser

Ans. (b)

$$\text{HRR} = 1 + \frac{1}{COP} = \frac{Q_{cond}}{RE}$$

Alternate Solution:

$$\text{HRR} = \text{Heat resection ratio} = \frac{Q_R}{Q_E}$$

Heat rejected in condensor is always more than heat absorbed in evaporator.

End of Solution

Q.35 The power consumption of Vapour Compression Refrigeration System (VCRS) with air cooled condenser compared to VCRS with water cooled system will be higher due to

(a) High discharge temperature
(b) High condensing temperature
(c) Low suction temperature
(d) High refrigeration load

Ans. (a)

End of Solution

Q.36 During turning a metallic rod at a given condition, the tool life was found to increase from 25 min to 50 min, when cutting velocity V_c alone was reduced from 141.4 m/min to 100 m/min. How much will be the life of that tool if machined at 353.5 m/min?

(a) 20 min
(b) 15 min
(c) 10 min
(d) 4 min

Ans. (d)

$$T_1 = 25 \text{ min}; \; V_1 = 141.4 \text{ m/min}$$
$$T_2 = 50 \text{ min}; \; V_2 = 100 \text{ m/min}$$

From Taylor's tool life equation,

$$V_1 T_1^n = V_2 T_2^n$$
$$141.4 \times 25^n = 100 \times 50^n$$
$$1.414 = 2^n$$
$$2^{1/2} = 2^n, \; n = 0.5$$
$$V_2 T_2^n = V_3 T_3^n$$
$$V_3 = 353.5 \text{ m/min}$$
$$100 \times 50^{0.5} = 353.5 \times T_3^{0.5}$$
$$T_3 = 4 \text{ min}$$

End of Solution

Q.37 Reciprocating motion of the cutting tool in shaping machines is accomplished by

(a) rack pinion mechanism
(b) crank and connecting rod mechanism
(c) cam and cam follower mechanism
(d) oscillating lever mechanism

Ans. (b)

Shaping machines:

Mechanism → Crank and slotted lever quick return motion mechanism (which is the inversion of single slider crank mechanism known as crank and connecting rod mechanism)

End of Solution

Q.38 The job reciprocates in which type of machine

(a) shaping machine
(b) planning machine
(c) slotting machine
(d) drilling machine

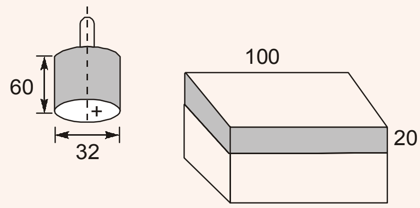
Ans. (b)

End of Solution

Q.39 Estimate the machining time that will be required to finish a vertical flat surface of length 100 mm and depth 20 mm by an 8 teeth HSS (High speed steel) end mill cutter of 32 mm diameter and 60 mm length in a milling machine. Assume cutting velocity (V_c) = 30 m/min and feed (s_0) = 0.12 mm/tooth. Take approach and run over both 2 mm.

(a) 0.4 minutes
(b) 0.6 minutes
(c) 0.8 minutes
(d) 1.0 minutes

Ans. (a)



z = 8 teeth

f_t = 0.12 mm/tooth

r = 30 m/min

$$N = \frac{30\times1000}{\pi\times32} = 318.3\times\frac{30}{32} = 298.41 \simeq 300 \text{ rpm}$$

$$t_m = \frac{104}{0.12\times8\times300} \simeq 0.4 \text{ min}$$

End of Solution

Q.40 Which of the following is not generally machined by Ultra Sonic Machining (USM)?

(a) Copper
(b) Glass
(c) Silicon
(d) Germanium

Ans. (a)

The following material is generally machined by USM

(i) Glass
(ii) Silicon
(iii) Germanium

Tool in USM is generally made of Steel

End of Solution

Q.41 The blade height of axial compressor decreases in axial direction to maintain

(a) maximum mass flow rate
(b) lower mass flow rate
(c) constant speed
(d) constant mass flow rate

Ans. (d)

End of Solution

Q.42 The T joint of steel plates which is subjected to 350 kN load is developed using intermitted 4 double fillet welds of length each of 40 mm at an interval of 100 mm. Allowable shear strength of the weld metal is 100 MPa. Determine the leg length of the weld.

(a) 12.45 mm (b) 15.45 mm
(c) 17.25 mm (d) 20.25 mm

Ans. (b)

$$P = 4 \times 2 \times 0.707\ tl\tau_{per}$$
$$350 \times 10^3 = 4 \times 2 \times 0.707t \times 40 \times 100$$
$$t = 15.45 \text{ mm}$$

End of Solution

Q.43 Shaping grey cast iron will produce

(a) Continuous chip with Built Up Edge (BUE)
(b) Continuous chip without Built Up Edge (BUE)
(c) Discontinuous chip of irregular size and shape
(d) Discontinuous chip of regular size and shape

Ans. (c)

Conditions for forming Discontinuous chip of irregular size and shape is that when work material is brittle (such as grey cast iron).

End of Solution

Q.44 For same tool-work materials and speed, feed and depth of cut, the average cutting temperature will decrease

(a) with the increase in principal cutting edge angle (ϕ)
(b) with the decrease in principal cutting edge angle (ϕ)
(c) with the increase in auxiliary cutting edge angle (ϕ_1)
(d) with the decrease in auxiliary cutting edge angle (ϕ_1)

Ans. (b)

Principal cutting edge = 90° – side cutting edge angle.

- At its increased value it will have more of its length in action for a given depth of cut.
- At its increased value it produce thinner and wider chip that will distribute the cutting .heat (increase tool life)

End of Solution

Q.45 Extreme Pressure Additive (EPA) is mixed with cutting fluid for improving its power of

(a) cooling (b) lubrication
(c) cleaning of cutting zone (d) protection of machined surface

Ans. (b)

Where high pressures and rubbing action are encountered, hydrodynamic lubrication cannot be maintained; so extreme pressure (EP) additives must be added to the chemical components such as boron, phosphorus, sulfur, chlorine, or combination of these. The compounds are activated by the higher temperature resulting from extreme pressure. As the temperature derivatives such as iron chloride or iron sulfide and forms a solid protective coating.

End of Solution

Q.46 Equation of the line normal to function $f(x) = (x - 8)^{2/3} + 1$ at $P(0,5)$ is

(a) $y = 3x - 5$
(b) $y = 3x + 5$
(c) $3y = x + 15$
(d) $3y = x - 15$

Ans. **(b)**

$$f(x) = (x - 8)^{2/3} + 1$$

$$\Rightarrow \quad f'(x) = \frac{2}{3}(x - 8)^{-1/3}$$

$$m = \left[f'(x)\right]_{(0,5)} = -\frac{1}{3}$$

Hence slope of normal = 3

Equation of normal:

$$y - 5 = 3(x - 0)$$

$$\Rightarrow \quad y = 3x + 5$$

End of Solution

Q.47 The area enclosed between the curves $y^2 = 4x$ and $x^2 = 4y$ is

(a) 16/3
(b) 8
(c) 32/3
(d) 16

Ans. **(a)**

Area bounded by parabolas

$$y^2 = 4ax \text{ and } x^2 = 4by \text{ is } \frac{16}{3}ab$$

In this question $a = 1$ and $b = 1$

So required area $= \frac{16}{3}(1)(1) = \frac{16}{3}$

End of Solution

Q.48 The Laplace transform of e^{i5t} where $i = \sqrt{-1}$, is

(a) $\frac{s-5i}{s^2-25}$
(b) $\frac{s+5i}{s^2+25}$
(c) $\frac{s+5i}{s^2-25}$
(d) $\frac{s-5i}{s^2+25}$

Ans. **(b)**

We know that $L\{e^{at}\} = \frac{1}{s-a}$

So $$L\{e^{i5t}\} = \frac{1}{s-5i} = \frac{s+5i}{s^2-(5i)^2} = \frac{s+5i}{s^2+25}$$

End of Solution

Q.49 If $y = f(x)$ is the solution of $\frac{d^2y}{dx^2} = 0$, with the boundary conditions $y = 5$ at $x = 0$ and $\frac{dy}{dx} = 2$ at $x = 10$, $f(15) =$

(a) 15
(b) 25
(c) 35
(d) 5

Ans. (c)

$$\frac{d^2y}{dx^2} = 0 \Rightarrow \frac{dy}{dx} = c_1 \Rightarrow y = c_1x + c_2$$

using $\left(\frac{dy}{dx}\right)_{x=10} = 2 \Rightarrow c_1 = 2$

Again using y (0) = 5

$\Rightarrow$ $c_2 = 5$

$\therefore$ $y = 2x + 5$

Hence $f(15) = 2 \times 15 + 5 = 35$

End of Solution

Q.50 Given two complex numbers $z_1 = 5 + (5\sqrt{3})i$ and $z_2 = \frac{2}{\sqrt{3}} + (2)i$, the argument of z_1/z_2 in degree is

(a) 0
(b) 30
(c) 60
(d) 90

Ans. (a)

$$z_1 = 5 + (5\sqrt{3})i$$

$$\Rightarrow \quad \theta_1 = \tan^{-1}\left(\frac{5\sqrt{3}}{5}\right) = 60°$$

$$z_2 = \frac{2}{\sqrt{3}} + (2)i$$

$$\Rightarrow \quad \theta_2 = \tan^{-1}\left(\frac{2}{\frac{2}{\sqrt{3}}}\right) = 60°$$

So $$Arg\left(\frac{z_1}{z_2}\right) = arg(z_1) - arg(z_2)$$

$$= \theta_1 - \theta_2$$

$$= 60° - 60° = 0°$$

End of Solution

Q.51 Two cantilever beams, '*A*' carrying pointed load of '*W*' at free end and the other '*B*' carrying uniformly distributed load totaling to '*W*'. The ratio of maximum deflection of beam *A* to that of beam *B* is

(a) $\frac{3}{8}$ (b) $\frac{8}{3}$

(c) $\frac{6}{15}$ (d) $\frac{15}{6}$

Ans. (b)

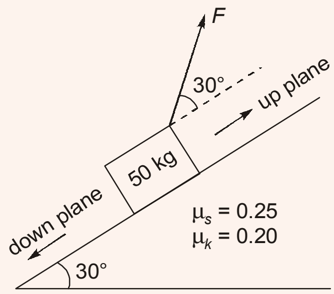
$$\delta_A = \frac{WL^3}{3EI}$$

$$\delta_B = \frac{WL^3}{8EI}$$

$$\therefore \quad \frac{\delta_A}{\delta_B} = \frac{8}{3}$$

End of Solution

Q.52 A force *F* is used to pull a 50 kg block, as shown in figure. Determine the magnitude and direction of the friction force when *F* = 400 N.



(a) 45 N up the plane (b) 80 N up the plane
(c) 45 N down the plane (d) 80 N down the plane

Ans. (c)

Let, $g = 10 \text{ m/s}^2$

Normal reaction, N = Wcos30° –Fsin30°
= 0.866 × 50 × 10 – 400 × 0.5
= 433 – 200 = 233 N

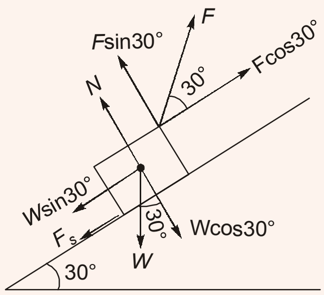
Static friction force, $F_s = \mu_s N = 0.25 \times 233 = 58.25$ N

kinetic friction force $F_k = \mu_k N = 0.20 \times 233 = 46.6$ N

Net force along the inclined plane = Fcos30° – Wsin30°

$$= 400 \times \frac{\sqrt{3}}{2} - 500 \times \frac{1}{2} = 346.4 - 250 = 96.4 \text{ N}$$

Hence, friction force will be 46.6 N down the plane.



End of Solution

Q.53 When a beam is subjected to bending moment alone, the bending stress at any point from the neutral axis

(a) equal
(b) varies directly proportional with respect to distance from neutral axis
(c) varies inversely proportional with respect to distance from neutral axis
(d) stress is independent of the distance

Ans. (b)

End of Solution

Q.54 A fabric filter is to be constructed using bags that are 0.1 m in diameter and 5.0 m long. The bag house is to receive 5 m^3/s of air. Filtering velocity is 2.0 m/min. Determine the minimum number of bags required for a continuous removal of particulate matter.

(a) 96 (b) 106
(c) 78 (d) 88

Ans. (a)

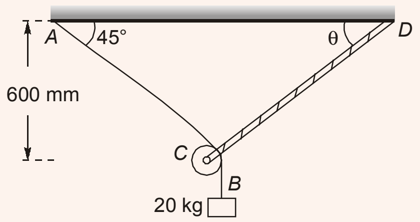
$$d = 0.1 \text{ m}$$
$$l = 5 \text{ m}$$
$$Q = 5 \text{ m}^3/\text{s}$$
$$V = 2 \text{ m/min}$$
$$A_{bag} = \pi dh = \pi \times 0.1 \times 5 = 1.5708 \text{ m}^2$$

$$A_c = \frac{Q}{V} = \frac{5}{\left(\frac{2}{60}\right)} = \frac{5 \times 60}{2} = 150 \text{ m}^2$$

$$\text{Number of bags required} = \frac{A_c}{A_b} = \frac{150}{1.5708} = 95.4927$$

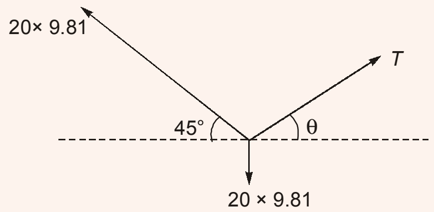
End of Solution

Q.55 A load of 20 kg is supported as shown in figure. Assuming the pulley to be ideal and the equilibrium configuration as shown in figure, determine the tension in cable CD



(a) 250 N (b) 200.4 N
(c) 150.2 N (d) 100 N

Ans. (c)



$\because \quad \Sigma F_x = 0$

$$20 \times 9.81 \cdot \cos 45° = T \cdot \cos\theta$$

$\Rightarrow \quad T \cdot \cos\theta = 138.73 \text{ N} \quad \text{...(i)}$

and $\Sigma F_y = 0$

$\Rightarrow \quad T \cdot \sin\theta = 20 \times 9.81 - (20 \times 9.81 \sin 45°)$

$$= 20 \times 9.81 (1 - \sin 45°)$$

$$T\sin\theta = 57.4656 \quad \text{...(ii)}$$

Squaring and adding equations (i) and (ii), we get

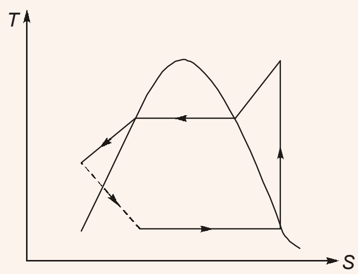
$$T^2 = 138.73^2 + 57.4656^2$$

$$T = 150.16 \text{ N} \simeq 150.2 \text{ N}$$

End of Solution

Q.56 Liquid sub cooler in Vapour Compression Refrigeration System will
(a) Prevent the entry of liquid into compressor
(b) Increases Net Refrigeration Effect
(c) Reduce work of compression
(d) Increase work of compression

Ans. (b)



Liquid sub-cooler always increases the refrigeration effect (RE) of cycle.

End of Solution

Q.57 A pump having an efficiency of 68% delivers 3 L/s of water against a head of 22 m. Compute the power requirement of the pump in W

(a) 952 (b) 850
(c) 1050 (d) 752

Ans. (a)

$$SP = \frac{\rho g Q H_m}{\eta_0}$$

$$SP = \frac{1000 \times 9.81 \times 0.003 \times 22}{0.68}$$

$$SP = 952 \text{ W}$$

End of Solution

Q.58 A heat engine is supplied heat at the rate of 1700 kJ/min and gives an output of 9 kW. The thermal efficiency will be around

(a) 31.76% (b) 35.76%
(c) 42.85% (d) 45.85%

Ans. (a)

$$\eta = \frac{9}{\left(\frac{1700}{60}\right)} = 0.3176 \text{ or } 31.76\%$$

End of Solution

Q.59 A Carnot cycle which operates between the temperatures of 400 K and 300 K. If 20000 kcal/hr of heat is supplied, the work output will be

(a) 3000 kcal/hr (b) 4000 kcal/hr
(c) 5000 kcal/hr (d) 6000 kcal/hr

Ans. (c)

$$\eta = 1 - \frac{300}{400} = \frac{W_{output}}{20000}$$

$$W_{output} = 5000 \text{ kcal/hr}$$

End of Solution

Q.60 A solid shaft of diameter '*D*' carries a twisting moment that develops maximum shear stress τ. If this shaft is replaced by a hollow one of outside diameter *D* and inside diameter D/2, then the maximum shear stress will be

(a) $1.067\,\tau$ (b) 1.145τ
(c) 1.335τ (d) $2\,\tau$

Ans. (a)

For solid shaft, $\tau = \dfrac{16T}{\pi D^3}$

For hollow shaft, $\tau_H = \dfrac{16T}{\pi D_0^3\left[1-\left(\dfrac{D_i}{D_0}\right)^4\right]}$

$$\tau_H = \frac{16T}{\pi D^3\left[1-\left(\frac{1}{2}\right)^4\right]}$$

$$= \frac{16T}{\pi D^3} \times \frac{16}{15}\tau = 1.066\tau$$

End of Solution

Q.61 A square beam and a circular beam of same material have the same length, same allowable stress and the same bending moment. The ratio of weights of the square beam to that of circular beam is

(a) $\dfrac{1}{2}$

(b) 1

(c) $\dfrac{1}{1.12}$

(d) $\dfrac{1}{3}$

Ans. (c)

Bending stress, $\sigma = \dfrac{M}{Z}$

For same stress and moment,

$$Z_S = Z_{cir}$$

$$\frac{b^3}{6} = \frac{\pi}{32}d^3$$

$$b^3 = \frac{3}{16}\pi d^3$$

$$b = \left(\frac{3\pi}{16}\right)^{1/3} \cdot d$$

now, $$\frac{W_s}{W_{cir}} = \frac{A_s}{A_{cir}} = \frac{b^2}{\frac{\pi}{4}d^2} = \frac{4}{\pi}\left(\frac{b}{d}\right)^2 = \frac{4}{\pi}\left(\frac{3\pi}{16}\right)^{2/3} = \frac{1}{1.12}$$

End of Solution

Q.62 A circular shaft subjected to torsion undergoes a twist of 1° in a length of 120 cm. If the maximum shear stress induced is limited to 1000 kg/cm^2 and if the modulus of rigidity, $G = 0.8 \times 10^6$ kg/cm^2, then the radius of shaft in cm should be

(a) $\frac{\pi}{18}$ (b) $\frac{\pi}{27}$

(c) $\frac{18}{\pi}$ (d) $\frac{27}{\pi}$

Ans. **(d)**

$$\text{Angle of twist, } \theta = \frac{T \cdot L}{J \cdot G}$$

$$\theta = \frac{\tau}{r} \cdot \frac{L}{G}$$

$$\therefore \quad r = \frac{\tau \cdot L}{\theta \cdot G} = \frac{1000 \times 120}{\frac{\pi}{180} \cdot 0.8 \times 10^6}$$

$$= \frac{27}{\pi} \text{ cm}$$

End of Solution

Q.63 Air flows isentropically through a duct. At a section, the area is 0.05 m^2, velocity v = 180 m/s and temperature T = 470 K. Compute the stagnation temperature T_o

(a) 486K (b) 286K

(c) 556K (d) 508K

Ans. **(a)**

For isentropic process,

$$v_1 = 180 \text{ m/s}; \quad c_p = 1.005 \text{ kJ/kgK}$$

$$h_o = h_1 + \frac{v_1^2}{2000}$$

$$c_p T_o = c_p \cdot T_1 + \frac{v_1^2}{2000}$$

$$T_o = T_1 + \frac{v_1^2}{1000 c_p}$$

$$T_o = 470 + \frac{180^2}{2000 \times 1.005}$$

$$T_o = 486.119 \text{ K}$$

Alternate:

$$\frac{T_o}{T_1} = 1+\left(\frac{\gamma-1}{2}\right)M^2 \quad \text{...(i)}$$

$$M = \frac{v}{c} = \frac{v}{\sqrt{\gamma RT}}$$

$$M = \frac{180}{\sqrt{1.4\times 287\times 470}} = 0.4142$$

$$T = 470 \text{ K}$$

$$\gamma = 1.4$$

Use in eq. (i)

$$T_o = 486.12\text{K}$$

End of Solution

Q.64 Which of the following element in the refrigerant is the main contributing factor for ozone depletion of the stratosphere?

(a) Carbon
(b) Chlorine
(c) Fluorine
(d) Hydrogen

Ans. (b)

End of Solution

Q.65 A fan running at 720 rpm develops static pressure of 12 mm. If the speed of the fan is doubled the static pressure developed will be

(a) 24 mm
(b) 12 mm
(c) 48 mm
(d) 96 mm

Ans. (c)

$$\left.\frac{H_m}{D^2N^2}\right|_1 = \left.\frac{H_m}{D^2N^2}\right|_2$$

$$D_1 = D_2$$

$$\left.\frac{12}{720^2}\right|_1 = \left.\frac{H_m}{1440^2}\right|_2$$

$$\Rightarrow \quad H_{m2} = 48 \text{ cm}$$

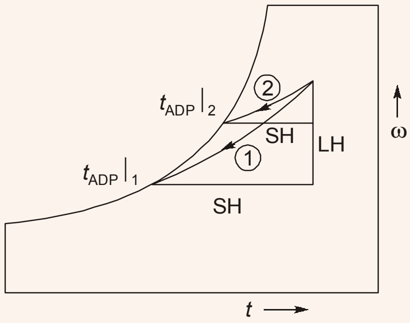
End of Solution

Q.66 The Apparatus Dew Point (ADP) for the cooling coil of an air conditioning system with high latent load compared to a system with high sensible load will be

(a) More
(b) Less
(c) Remains same
(d) Depends on air flow through the coil

Ans. (b)

Process (1) ⇒ ADP with High latent load.
Process (2) ⇒ ADP with High sensible load.
ADP of process (1) is lower than ADP of process (2)



End of Solution

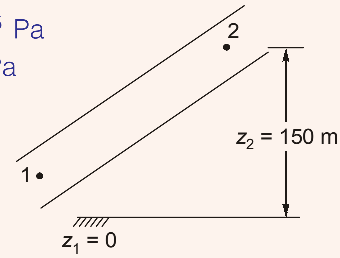
Q.67 Gasoline at 20°C (density = 680 kg/m^3) is pumped through a smooth 12 cm diameter pipe, 10 km long, at a flow rate of 75 m^3/hr. The inlet is fed by a pump at an absolute pressure of 24 atm. The exit is at standard atmospheric pressure and is 150 m higher. Estimate frictional head loss h_f.

(a) 199 m
(b) 299 m
(c) 99 m
(d) 399 m

Ans. (a)

Gasoline

$$T = 20°C$$
$$\rho = 680 \text{ kg/m}^3$$
$$D = 12 \text{ cm} = 0.12 \text{ m}$$
$$L = 10 \text{ km} = 10 \times 10^3 \text{ m}$$
$$Q = 75 \text{ m}^3\text{/hr} = 0.020833 \text{ m}^3\text{/s}$$
$$Q = A \times V$$
$$0.020833 = \frac{\pi}{4} \times (0.12)^2 \times V$$
$$V = 1.84 \text{ m/s}$$
$$P_1 = 24 \text{ atm} = 24 \times 1.01325 \times 10^5 \text{ Pa}$$
$$P_2 = 1 \text{ atm} = 1 \times 1.01325 \times 10^5 \text{ Pa}$$



As the pipe is of uniform x-section

So, $V_1 = V_2$

$$\text{Piezometric head at 1} = \frac{P_1}{\gamma} + z_1 = 364.54 \text{ m}$$

$$\text{Piezometric head at 2} = \frac{P_2}{\gamma} + z_2 = 165.189 \text{ m}$$

Bernoulli's equation between (1) and (2)

$$(PH)_1 + (kE)_1 = (PH)_2 + (kE)_2 + h_L$$
$$h_L = 199351 \text{ m}$$

Alternate Solution:

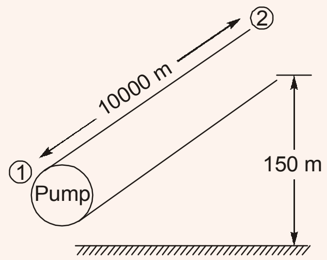
$$\frac{P_1}{\gamma}+\frac{V_1^2}{2g}+z_1 = \frac{P_1}{\gamma}+\frac{V_2^2}{2g}+z_2+h_f$$

$$A_1V_1 = A_2V_2$$

$$h_f = \frac{P_1+P_2}{\gamma}+(z_1-z_2)$$

$$= \frac{(24-1)\times 1.01\times 10^5}{680\times 9.81}+(-150)$$

$$= 198.23 \approx 199 \text{ m}$$



End of Solution

Q.68 Oil at 20°C (density = 870 kg/m^3 and velocity = 0.104 kg/m-s) flow at 1.1 m^3/hr through a horizontal pipe with diameter d = 2 cm and length L = 12 m. Find the Reynolds number for the flow.

(a) 104
(b) 163
(c) 208
(d) 78

Ans. (b)

$$\rho = 870 \text{ kg/m}^3$$

$$\mu = 0.104 \text{ kg/m-s}$$

$$Q = 1.1 \text{ m}^3\text{/hr} = 3.055 \times 10^{-4} \text{ m}^3\text{/s}$$

$$D = 2 \text{ cm} = 0.02 \text{ m}$$

$$L = 12 \text{ m}$$

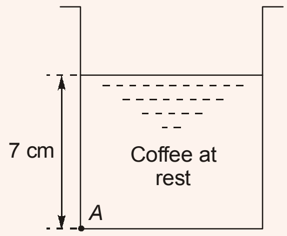
$$Q = A \times V$$

$$V = \frac{Q\times 4}{\pi\times D^2} = \frac{3.055\times 10^{-4}\times 4}{\pi\times (0.02)^2} = 0.9727 \text{ m/s}$$

$$\text{Re} = \frac{\rho VD}{\mu} = 162.72$$

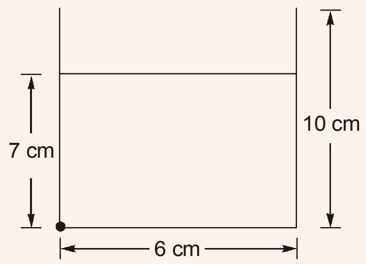
End of Solution

Q.69 A person rests her coffee mug on a horizontal tray while she accelerates at $\frac{10}{\sqrt{3}}$ m/s^2. The mug is 10 cm deep and 6 cm in diameter and contains coffee 7 cm deep at rest. Assuming rigid body acceleration, calculate gauge pressure in the bottom corner point *A* as shown in figure if density of coffee is 1010 kg/m^3. Assume acceleration due to gravity g = 10 m/s^2.



(a) 965 Pa
(b) 1005 Pa
(c) 865 Pa
(d) 765 Pa

Ans. (c)



$$\rho_{coffee} = 1010 \text{ kg/m}^3 \qquad a_x = \frac{10}{\sqrt{3}} \text{ m/s}^2$$

Condition for No spillage [Rise = Fall]

$$\tan\theta_{max} = \frac{a_n}{g} = \frac{6}{6} = 1$$

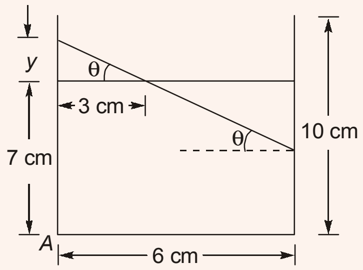
$$\theta_{max} = 45^\circ$$ For no spillage

For $$a_x = \frac{10}{\sqrt{3}} \text{ m/s}^2$$

$$\tan\theta = \frac{a_x}{g} = \frac{10}{\sqrt{3}\times 10}$$

$$\theta = 30^\circ$$

Which is less than 45° hence in this case no water is spilling out.



$$y = 3\tan 30° = 1.732 \text{ cm}$$
$$h \text{ at } A = 7 + 1.732 \text{ cm} = 8.732 \text{ cm}$$
$$p_{gauge} \text{ at } A = \rho g h = 1010 \times 10 \times 0.08732 = 881.932 \text{ Pa}$$

End of Solution

Q.70 A process in which the working substance neither receives nor gives out heat to its surroundings durings its expansion or contraction is called

(a) Isothermal process
(b) Isentropic process
(c) Polytropic process
(d) Adiabatic process

Ans. (d)

End of Solution

Q.71 A two stage centrifugal compressor operating at 3000 rpm is to compress refrigerant R134a from an evaporator temperature of 0°C (h_i = 398.6 kJ/kg) to a condensing temperature of 32°C (h_e = 419.8 kJ/kg). If the impeller diameter of both the stages have to be same, what is the diameter of the impeller?

Assume suction condition to be dry saturated, compression process isentropic, impeller blades radial and refrigerant enters impeller radially

(a) 0.65 m
(b) 0.8 m
(c) 1.0 m
(d) 1.5 m

Ans. (a)

$$W_{total} = (419.8 - 398.6) \times 10^3 \text{ J/kg} = 21200 \text{ J/kg}$$

$$\text{Work per stage} = \frac{W_{total}}{2} = u_2^2 = 10600 \text{ J/kg}$$

$$u_2 = 102.95 \text{ m/s} = \frac{\pi D_2 N}{60}$$

$$D_2 = 0.655 \text{ m}$$

End of Solution

Q.72 Water with specific heat (c_p = 4 kJ/kgK) is fed to a boiler at 30°C, the enthalpy of vaporization at atmospheric pressure in the boiler is 2400 kJ/kg, the steam coming from the boiler is 0.9 dry. The net heat supplied (in kJ/kg) in the boiler is

(a) 2160 (b) 2400
(c) 2440 (d) 2280

Ans. (c)

$$h = C_p(T_{sat} - T_{in}) + x \,.\, h_{fg}$$
$$h = 4(100 - 30) + 0.9 \times 2400$$
$$h = 280 + 2160 = 2440 \text{ kJ/kg}$$

End of Solution

Q.73 Subsonic and supersonic diffusers have the following geometry

(a) Divergent and convergent respectively
(b) Both divergent
(c) Both convergent
(d) Convergent and divergent respectively

Ans. (a)

For subsonic flow diverging passage act as diffuser and for supersonic flow converging passage act as diffuser.

End of Solution

Q.74 The isentropic heat drop in the nozzle of an impulse steam turbine with nozzle efficiency 0.9, blade velocity ratio 0.5 and mean blade velocity 150 m/s in kJ/kg is

(a) 50 (b) 40
(c) 60 (d) 70

Ans. (a)

$$\eta_{nozzle} = \frac{\frac{V_1^2}{2000}}{\Delta h_s}; \quad u = 150 \text{ m/s} \quad (\Delta h_s \text{ is in kJ/kg})$$

$$\frac{u}{V_1} = \frac{150}{V_1} = 0.5$$

$$V_1 = 300 \text{ m/s}$$

$$\Delta h_s = \frac{\frac{V_1^2}{2000}}{\eta_n} = \frac{300^2}{2000 \times 0.9} = 50 \text{ kJ/kg}$$

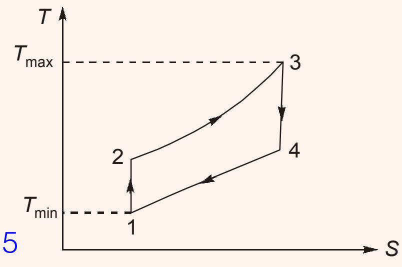
End of Solution

Q.75 Consider a simple gas turbine (Brayton cycle) and a gas turbine with perfect regeneration. In both the cycles, the pressure ratio is 8 and the ratio of specific heats of working medium is 1.5. The ratio of minimum to maximum temperature is 0.2 (with temperature in K) in the regenerative cycle. The ratio of the thermal efficiency of the simple cycle to that of regenerative cycle is

(a) 0.63 (b) 0.73
(c) 0.83 (d) 0.93

Ans. (c)

Given data: $r_p = 8;\ \gamma = 1.5$



$$\frac{T_1}{T_3} = 0.2$$

$$\eta_{cycle} = 1 - \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}} = 1 - \frac{1}{8^{1/3}} = 0.5$$

$$\eta_{reg} = 1 - \frac{T_1}{T_3}(r_p)^{\frac{\gamma-1}{\gamma}} = 0.6$$

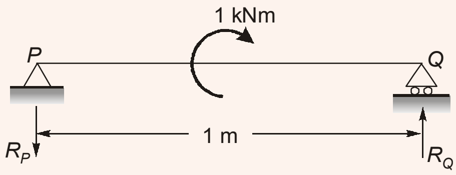
$$\frac{\eta_{cycle}}{\eta_{req}} = \frac{1-\frac{1}{2}}{1-0.2\times 2} = \frac{0.5}{0.6} = 0.833$$

End of Solution

Q.76 A simply supported beam PQ is loaded by a moment of 1 kN-m at the mid span of the beam of length 1 m. The reaction forces R_p and R_q at supports P and Q respectively are

(a) 1 kN downward, 1 kN upward (b) 0.5 kN upward, 0.5 kN downward
(c) 0.5 kN downward, 1 kN upward (d) 0.5 kN upward, 0.5 kN upward

Ans. (a)



$$R_P - R_Q = 0$$
$$\Sigma M_P = 0$$
$$R_Q \cdot 1 - 1 = 0$$
$$R_Q = 1\ (\downarrow)$$
$$R_P = 1\ (\uparrow)$$

End of Solution

Q.77 Two solid shafts 'A' and 'B' are made of the same material. The shaft 'A' is 50 mm diameter and shaft 'B' is 100 mm diameter. The ratio of strength of shaft 'B' compared to shaft 'A' is

(a) $\frac{1}{2}$ (b) 2

(c) 4 (d) 8

Ans. **(d)**

$$d_A = 50 \text{ mm}$$
$$d_B = 100 \text{ mm}$$

$$\therefore \quad \frac{Z_{p_B}}{Z_{p_A}} = \left(\frac{d_B}{d_A}\right)^3 = 8$$

End of Solution

Q.78 Two simply supported beams 'A' and 'B' of same breadth and depth and same material carries constant central load W at the centre. The span of beam B is double that of beam A. The deflection of beam B compared to beam A will be

(a) one-half (b) one-eighth

(c) four times (d) eight times

Ans. **(d)**

For concentrated load $\delta \propto L^3$

$$\therefore \quad \frac{\delta_B}{\delta_A} = \left(\frac{L_B}{L_A}\right)^3 = 8$$

End of Solution

Q.79 In a beam where shear force changes its sign, the bending moment will be

(a) minimum (b) zero

(c) maximum (d) same as shear force

Ans. **(c)**

End of Solution

Q.80 The rectangular beam '*A*' has length *l*, width *b* and depth *d*. Another beam '*B*' of same material has the same length and width but depth is double that of '*A*'. The elastic strength of beam *B* compared to that of *A* will be

(a) same
(b) double
(c) four times
(d) six times

Ans. (c)

For beam moment carrying capacity depends on section modulus.

For rectangular cross-section,

$$Z = \frac{bd^2}{6}$$

$$\therefore \quad \frac{Z_B}{Z_A} = 4$$

End of Solution

■■■■