BYJU'S EXAM PREP

ESE 2019

Paper-2

Mechanical Engineering

Questions & Solutions

MECHANICAL-ENGINEERING-ESEP-2019

1. Water is discharged from a tank maintained at a constant head of 5 m above the exit of a straight pipe 100 m long and 15 cm in diameter. If the friction coefficient for the pipe is 0.01, the rate of flow will be nearly ________.

A. 0.04 m^3/s B. 0.05 m^3/s

C. 0.06 m^3/s D. 0.07 m^3/s

Ans. D

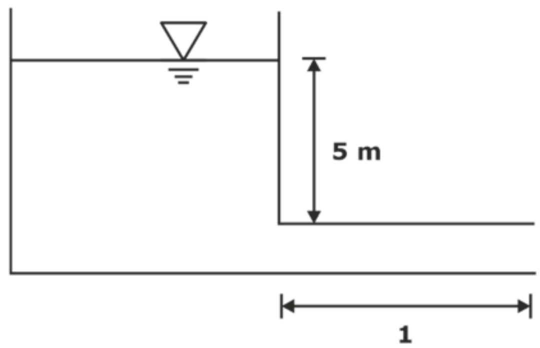
Sol. Given:

Head of water (H) = 5 m

Length of pipe (L) = 100 m

Diameter of pipe (d) = 15 cm

Coefficient of friction (f) = 0.01



Two losses are present in this case:

(a). Friction loss: $h_f = \frac{fLV^2}{2dg}$

(b). Sudden contraction losses: $h_{L,C} = \frac{0.5V^2}{2g}$

Total losses will be given by:

$$H = \frac{0.5V^2}{2g} + \frac{fLV^2}{2dg}$$

where $V = \frac{Q}{A} = \frac{4Q}{\pi d^2}$

Where Q is the discharge and A is the area of cross section.

$$\Rightarrow 5 = \frac{0.5 \times 16Q^2}{\pi^2 \times d^4 \times 2g} + \frac{fL \times 16Q^2}{2\pi^2 \times d^5 \times g}$$

$$5 = Q^2\left[\frac{0.5 \times 16}{\pi^2 \times (0.15)^4 \times 2 \times 9.81} + \frac{0.01 \times 100 \times 16}{2\pi^2 (0.15)^s \times 9.81}\right]$$

$$5 = Q^2 \times 1169.697$$

$$Q^2 = 0.0042746 \Rightarrow Q = 0.06538 \ m^3/s$$

2. A plate weighing 150 N and measuring 0.8 m × 0.8 m just slides down an inclined plane over an oil film of 1.2 mm thickness for an inclination of 30° and velocity of 0.2 m/s. Then the viscosity of the oil used is __________.

A. 0.3 N-s/m^2 B. 0.4 N-s/m^2

C. 0.5 N-s/m^2 D. 0.7 N-s/m^2

Ans. D

Sol. Given:

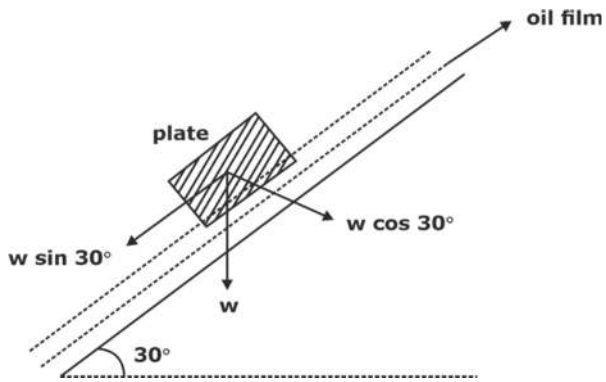
Weight of plate: w = 150 N

Area of plate: A = 0.8 m × 0.8 m

Angle of inclination: θ = 30°

Velocity of plate: V = 0.2 m/s

Thickness of the film: dy =1.2 mm



For Newtonian fluid:

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

Where:

τ = shear stress

$$\tau = \frac{F}{A} = \frac{w \sin 30°}{A}$$

$$\tau = \frac{150 \times 1}{2 \times 0.8 \times 0.8} = 117.1875 \ N/m^2$$

μ = Dynamic viscosity

$\frac{du}{dy}$ = Rate of shear strain

$$\frac{du}{dy} = \frac{0.2}{1.2\times10^{-3}} = \frac{1000}{6}\,\text{sec}^{-1}$$

Thus, $117.1875 = \mu \times \frac{1000}{6}$

$\mu = 0.703$ N-s/m^2

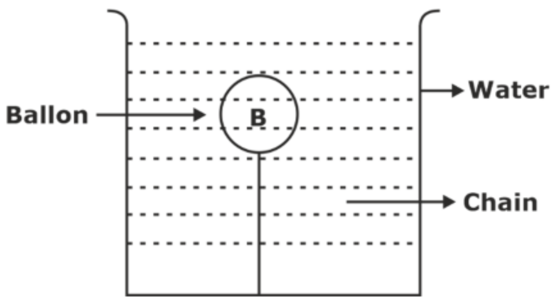
3. A spherical balloon of 1.5 m diameter is completely immersed in water and chained to the bottom. If the chain has a tension of 10 kN, the weight of the balloon will be nearly __________.

A. 9.11 kN B. 8.22 kN

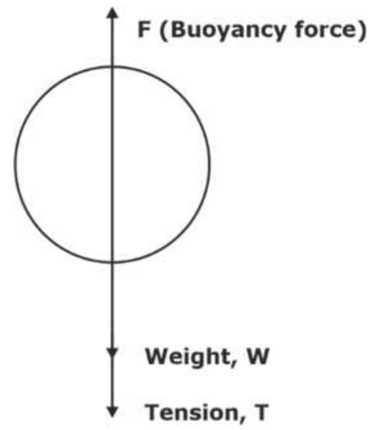
C. 6.44 kN D. 7.33 kN

Ans. D

Sol.



Free body diagram for balloon:



Therefore:

$F = W + T \Rightarrow W = F - T$

Weight: $W = \rho_l . g . V_{disp} - T$

[$\because \rho_l =$ Density of water]

$$W = 1000 \times 9.81 \times \frac{\pi(1.5)^3}{6} - 10\times10^3$$

$$= (17.33 - 10)\times10^3$$

W = 7.33kN

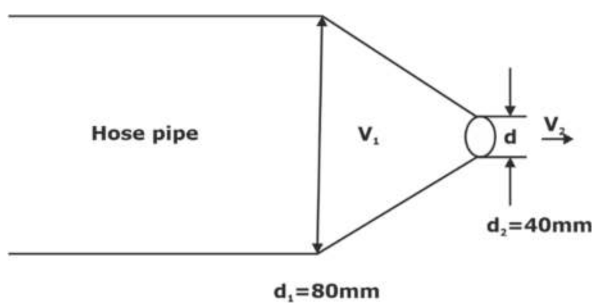
4. A nozzle at the end of an 80 mm hosepipe produces a jet 40 mm in diameter. When it is discharging the water 1200 Lpm, the force on the joint at the base of the nozzle will be __________.

A. 180 N B. 200 N

C. 220 N D. 240 N

Ans. D

Sol.



Flow rate: Q = 1200 Lpm = 1.2 m^3/min

Force at joint will be given by:

$F = \rho Q(V_2 - V_1)$ ....(i)

$$\therefore V_1 = \frac{Q_1}{A_1} = \frac{1.2\times4}{60\times\pi\times(0.08)} = 3.98\text{ m/sec}$$

$V_2 = 4V_1 = 15.9155$ m/s

Force (F) is given by:

$\therefore F = \rho Q(V_2 - V_1)$

$$F = \frac{100\times1.2}{60}\times(15.9155 - 3.98) = 23.871\text{N}$$

5. A vertical water pipe, 1.5 m long, tapers from 75 mm diameter at the bottom to 150 mm diameter at the top and the rate of flow is 50 L/s upwards. If the pressure at the bottom end is 150 kN/m^2, the pressure at the top will be nearly __________.

A. 195.2 kN/m^2 B. 191.4 kN/m^2

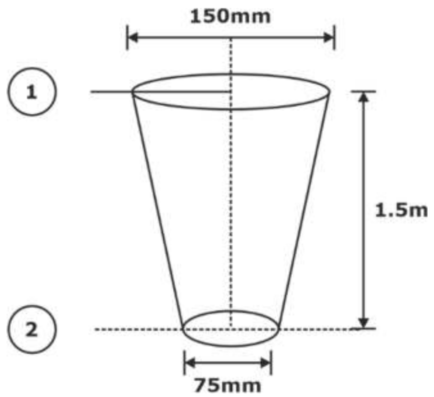
C. 187.6 kN/m^2 D. 183.8 kN/m^2

Ans. A

Sol. Given:

Flow rate: $Q = 50$ L/s $= 0.05$ m^3/s

Pressure: $P_2 = 150$ kN/m^2



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

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$\because Q = V_1A_1 = V_2A_2$$

$$\Rightarrow \frac{P_1}{\rho g} + \frac{Q^2 \times 16}{2 \times g \times \pi^2 \times d_1^4} + z_1 = \frac{P_2}{\rho g} + \frac{Q^2 \times 16}{2 \times g \times \pi^2 \times d_2^4}$$

$$\Rightarrow \frac{P_1}{\rho g} = \frac{150 \times 10^3}{10^3 \times 9.81} + \frac{(0.05)^2 \times 16}{2 \times \pi^2 \times 9.81 \times (0.075)^4} - \frac{(0.05)^2 \times 16}{2 \times \pi^2 \times 9.81 \times (0.15)^4} - 1.5$$

$$\frac{P_1}{\rho g} = 19.911 \Rightarrow P_1 = 1000 \times 9.81 \times 19.911$$

Pressure at the top of the pipe,

$P_1 = 195.327 N/m^2$

6. The stream function for a flow field is $\psi = 3x^2y + (2+t)y^2$. The velocity at a point P for position vector $r = \hat{i} + 2\hat{j} - 3\hat{k}$ at time $t = 2$ will be __________.

A. $19\hat{i} - 12\hat{j}$ B. $21\hat{i} - 12\hat{j}$

C. $19\hat{i} + 22\hat{j}$ D. $21\hat{i} + 22\hat{j}$

Ans. A

Sol. Stream function is given by:

$$\Psi = 3x^2y + (2+t)y^2$$

$$u = \frac{\partial \Psi}{\partial y} = 3x^2 + 2(2+t)y$$

$$= 3 \times 1^2 + 2 \times (2+2) \times 2 = 19$$

$$v = -\frac{\partial \Psi}{\partial x} = -6xy + 0 = -6 \times 1 \times 2 = -12$$

Thus, velocity vector is given by:

$$\bar{v} = u\hat{i} + v\hat{j} = 19\hat{i} - 12\hat{j}$$

7. In a laminar flow through pipe, the point of maximum instability exists at a distance of y from the wall which is _________.

A. $\frac{3}{2}$ of pipe radius R

B. $\frac{2}{3}$ of pipe radius R

C. $\frac{1}{2}$ of pipe radius R

D. $\frac{1}{3}$ of pipe radius R

Ans. B

Sol.

- In a laminar flow through pipe, the point of maximum instability exists at a distance of $y = \frac{2}{3}$ of pipe radius R.

Where y from the wall.

8. $Q = \frac{\partial u'}{\partial x} = -\frac{\partial v'}{\partial y}$ for a turbulent flow signifies _________.

A. conservation of bulk momentum transport

B. increase in 'u' in x-direction followed by increase in v' in negative y-direction.

C. turbulence is anisotropic.

D. turbulence is isotropic.

Ans. B

Sol. Given:

$$Q = \frac{\partial u'}{\partial x} = -\frac{\partial v'}{\partial y}$$

The above equation shows the increase in 'u' in x-direction followed by increase in v' in negative y-direction.

9. A flow field satisfying $\nabla.\vec{V} = 0$ as the continuity equation represents always ___________.

A. a steady compressible flow

B. an incompressible flow

C. an unsteady and incompressible flow

D. an unsteady and compressible flow

Ans. B

Sol. Equation of continuity is given by:

$$\rho\left(\nabla.\vec{v}\right) + \frac{d\rho}{dt} = 0$$

For incompressible flow: $\frac{d\rho}{dt} = 0$

$$\nabla.\vec{v} = 0$$

10. An oil of viscosity 8 poise flows between two parallel fixed plates, which are kept at a distance of 30 mm apart. If the drop of pressure for a length of 1 m is 0.3×10^4 N/m^2 and width of the plates is 500 mm, the rate of oil flow between the plates will be ___________.

A. 4.2×10^{-3} m^3/s B. 5.4×10^{-3} m^3/s

C. 6.6×10^{-3} m^3/s D. 7.8×10^{-3} m^3/s

Ans. A

Sol. Given:

Viscosity: μ = 8 poise = 0.8 N-S/m^2

t = 30 mm = 0.03 m

Pressure drop per meter length:

ΔP = 0.3×10^4 N/m^2

Pressure head loss:

$$h_f = \frac{p_1 - p_2}{\rho g} = \frac{12\mu\bar{V}L}{\rho g B^2} \Rightarrow \frac{p_1 - p_2}{L} = \frac{12\mu\bar{V}}{B^2}$$

$$\frac{0.3\times 10^4}{1} = \frac{12\times 8\times 10^{-1}\times \bar{V}}{\left(30\times 10^{-3}\right)^2}$$

$$\bar{V} = 0.281\,m/s$$

$\therefore$ Discharge: $Q = \bar{V}Bt$

$$Q = 0.281\times 30\times 10^{-3}\times 500\times 10^{-3}\ m^3/s$$

Q= 4.2×10^{-3} m^3/s

11. In case of transmission of hydraulic power by a pipeline to a turbine in a hydroelectric power station, the maximum power transmission efficiency through the pipeline is __________.

A. 76 %

B. 67 %

C. 54 %

D. 42 %

Ans. B

Sol. Transmission of power through pipes:

Power (energy/sec) available at the outlet of pipe is:

P = weight of water per sec × head available at exit of pipe

$$P = \rho Qg\left(H - h_f\right) = \rho g\left(\frac{\pi D^2}{4}\times V\right)\left(H - \frac{flV^2}{2gD}\right)$$

$$P = \rho g\times \frac{\pi}{4}D^2\times\left(HV - \frac{flV^3}{2gD}\right)$$

For maximum power:

$$\frac{dP}{dV} = \rho g\left(\frac{\pi}{4}D^2\right)\times\left(H - \frac{3flV^2}{2gD}\right) = 0$$

$$\Rightarrow H = 3h_f$$

i.e., power transmitted through a pipe is maximum if head loss due to friction is $\frac{1}{3}$ of total head loss.

$\therefore$ Efficiency (η) is given by:

$$\eta_{max} = \frac{H - h_f}{H} = \frac{3h_f - h_f}{3h_f} = \frac{2}{3} = 66.7\%$$

12. A pipe, having a length 200 m and 200 mm diameter with friction factor 0.015, is to be replaced by a 400 mm diameter pipe of friction factor 0.012 to convey the same quantity of flow. The equivalent length of the new pipe for the same head loss will be __________.

A. 8300 m B. 8240 m

C. 8110 D. 8000 m

Ans. D

Sol. Given:

Pipe length: L = 200 m

Pipe diameter: d_1 = 200 mm = 0.20 m

Friction factor: f = 0.012

New pipe diameter: d_2 = 400 mm = 0.40 m

Head loss is given by:

$$h_f = \frac{fLQ^2}{12.1d^5}$$

For same discharge and head loss:

$$\frac{f_1L_1}{d_1^5} = \frac{f_2L_2}{d_2^5}$$

$$\frac{0.015 \times 200}{200^5} = \frac{0.012 \times \ell_2}{400^5} \Rightarrow \ell_2 = 8000\,\text{m}$$

13. Certain quantities cannot be located on the graph by a point but are given by the area under the curve corresponding to the process. These quantities in concepts of thermodynamics are called as __________.

A. cyclic functions

B. point functions

C. path functions

D. real functions

Ans. C

Sol. Path functions are quantities whose values depend on the transition of a system from the initial state to the final state. Path functions like heat transfer and work transfer which are dependent on how the thermodynamic system changes from the initial state to final state.

Ex: heat transfer will be area under curve in T-s diagram work transfer will be area under curve in P-V diagram.

14. When 25 kg of water at 95 °C is mixed with 35 kg of water at 35 °C, the pressure being taken as constant at surrounding temperature of 15 °C, and C_p of water is 4.2 kJ/kg K, the decrease in available energy due to mixing will be nearly __________.

A. 270.5 kJ B. 277.6 kJ

C. 281.8 kJ D. 288.7 kJ

Ans. C

Sol. Given:

m_1 = 25 kg @ 95°C

m_2 = 25 kg @ 35°C

Surrounding temperature: T_o = 15°C

C_p = 4.2 kJ/kg K

After mixing, if t °C be the final temperature, then:

$$25 \times 4.2 \times (95 - t) = 35 \times 4.2 \times (t - 35)$$

$$\Rightarrow t = \frac{25 \times 95 + 35 \times 35}{25 + 35} = 60^\circ C$$

Available energy:

$$AE = mC_p\left[(T - T_\circ) - T_\circ \ell n\left(\frac{T}{T_\circ}\right)\right]$$

$\therefore$ Available energy of 25 kg water at 95°C:

$$(AE)_1 = 25 \times 4.2 \times \left[(368 - 288)288\ell n\frac{368}{288}\right]$$

$$(AE)_1 = 987.49 \text{ kJ}$$

Available energy of 35 kg water at 35°C

$$(AE)_2 = 35 \times 4.2 \times \left[(308 - 288) - 288\ell n\left(\frac{308}{288}\right)\right]$$

$$(AE)_2 = 97.59 \text{ kJ}$$

Final available of 60 kg water at 60°C:

$$(AE)_{final} = 60 \times 4.2 \times \left[(333 - 288) - 288 \ell n\left(\frac{333}{288}\right)\right]$$

$$(AE)_{final} = 803.27 \text{ kJ}$$

$\therefore$ Decrease in available energy due to mixing:

$$\Delta AE = (AE)_1 + (AE)_2 - (AE)_{final} = (987.49 + 97.59 - 803.27)$$

$$\Delta AE = 281.8 \text{ kJ}$$

15. A frictionless piston cylinder device contains 5 kg of steam at 400 kPa and 200 °C. The heat is now transferred to the steam until the temperature reaches 250 °C. If the piston is not attached to a shaft, its mass is constant, and by taking the values of specific volume v_1 as 0.53434 m^3/kg and v_2 as 0.59520 m^3/kg, the work done by the steam during this process is ___________.

A. 121. 7 kJ B. 137.5 kJ

C. 153.3 kJ D. 189.1 kJ

Ans. A

Sol. Given:

m = 5 kg of steam @ P = 400 kPa and

T = 200 °C

Now, after expansion: T_2 = 250°C

Specific volume: v_1 = 0.53434 m^3/kg and

v_2 = 0.59520 m^3/kg

Since the weight of the piston and the atmosphere pressure are constant, so assuming it as a constant pressure process:

Work done (W) is given by:

$$W = P(V_2 - V_1)$$

$$W = P \times m(v_2 - v_1)$$

$$W = 400 \times 10^3 \times 5 \times (0.59520 - 0.53434)$$

$$W = 121.72 \text{ kJ}$$

16. A diesel engine has a compression ratio of 14 and cut off takes place at 6% of the stroke. The air standard efficiency will be ___________.

A. 74.5% B. 60.5%

C. 52.5% D. 44.5%

Ans. B

Sol. Given:

Compression ratio: r_k = 14

Cut off takes place at = 6% of stroke

$$V_3 - V_2 = 0.06 \times (V_1 - V_2)$$

$$\left(\frac{V_3}{V_2} - 1\right) = 0.06\left(\frac{V_1}{V_2} - 1\right)$$

$$\Rightarrow (r_c - 1) = 0.06 \times (r_k - 1)$$

$$\Rightarrow (r_c - 1) = 0.06(14 - 1)$$

$$\Rightarrow r_c = 1.78$$

Diesel cycle efficiency is given by:

$$\eta = 1 - \frac{1}{(r_k)^{\gamma-1}} \times \left[\frac{r_c^{\gamma} - 1}{\gamma(r_c - 1)}\right]$$

$$\eta = 1 - \frac{1}{(14)^{1.4-1}} \times \left[\frac{(1.78)^{1.4} - 1}{1.4 \times (1.78 - 1)}\right] = 0.6043$$

η = 60.43 %

17. A gas mixture consists of 3 kg of O_2, 5 kg of N_2 and 12 kg of CH_4. The mass fraction and mole fraction of O_2 are ___________.

A. 0.25 and 0.125 B. 0.15 and 0.092

C. 0.25 and 0.092 D. 0.15 and 0.125

Ans. B

Sol. Given:

m_{O2} = 3 kg

$m_{N_2} = 5$ kg and $m_{CH_4} = 12$ kg

Mass fraction of oxygen is given by:

$$f_{O_2} = \frac{m_{O_2}}{m_{O_2} + m_{N_2} + m_{CH_4}} = \frac{3}{3 + 5 + 12} = \frac{3}{20} = 0.15$$

Mole fraction of oxygen is given by:

$$\text{Mole fraction of } O_2 = \frac{n_{O_2}}{n_{O_2} + n_{N_2} + n_{CH_4}}$$

$$= \frac{\frac{3}{32}}{\frac{3}{32} + \frac{5}{28} + \frac{12}{6}} = 0.092$$

18. An insulated pipe of 50 mm outside diameter with $\varepsilon = 0.8$ is laid in a room at 30°C. If the surface temperature is 250°C and the convective heat transfer coefficient is 10 W/m²K, the total heat loss per unit length of the pipe will be ___________.

A. 896.6 W/m B. 818.8 W/m

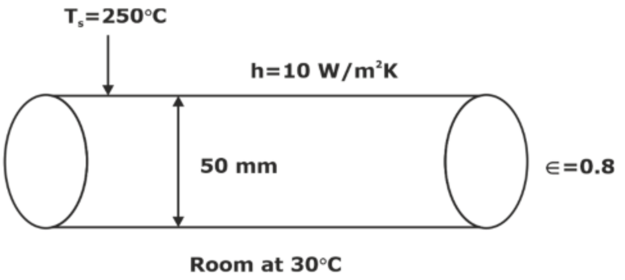
C. 786.4 W/m D. 742.2 W/m

Ans. B

Sol. Outside diameter: D = 50 mm

Emissivity: ϵ = 0.80 @ T_{room} = 30°C

Surface temperature: T_s = 250°C



Total heal loss per unit length of the pipe:

$$Q_{Total} = Q_{conv} + Q_{rad}$$

$$Q_{Total} = h_{conv} \cdot A_s (T_s - T_{room}) + \in \sigma A_s (T_s^4 - T_{room}^4)$$

$$Q_{Total} = A_s \left[h_{conv} + \in \sigma (T_s + T_{room})(T_s^2 + T_{room}^2) \right] (T_s - T_{room})$$

$$Q_{total} = 2\pi \times 0.025 \left[10 + 0.8 \times 5.67 \times 10^{-8} \times (523 + 303) + (523^2 + 303^2) \right] \times (523 - 303)$$

$$Q_{Total} = 818.6 \text{ W / m}$$

19. A wire of 8 mm diameter at a temperature of 60 °C is to be insulated by a material having k = 0.174 W/m-K. The heat transfer coefficient on the outside h_a = 8 W /m²K and ambient temperature T_a = 25 °C. The maximum thickness of insulation for maximum heat loss will be __________.

A. 15.25 mm B. 16.50 mm

C. 17.75 mm D. 18.25 mm

Ans. C

Sol. Given:

Wire diameter: d = 8mm @ 60°C

Thermal conductivity: k = 0.174 W/m-K

heat transfer coefficient: h_a = 8 W /m²K

Ambient temperature: T_a = 25 °C

The Maximum heat loss is corresponding to critical radius of insulation:

$$r_c = \frac{k}{h} = \frac{0.174}{8} = 0.02175\,m = 21.75\,mm$$

∴ Maximum thickness of insulation (t) for maximum heat loss:

$$t = r_c - r = 21.75 - 4 = 17.75\,mm$$

20. In liquid metals, thermal boundary layer develops much faster than velocity boundary layer due to __________.

A. lower value of Nusselt number

B. higher value of Prandtl number

C. lower value of Prandtl number

D. higher value of Nusselt number

Ans. C

Sol. Prandtl number $(Pr) = \frac{\delta}{\delta_{th}}$

Where: δ = hydrodynamic boundary layer thickness

δ_{th} = thermal boundary layer thickness

For liquid metals: Prandtl number (Pr) = 0.01 to 0.001

Thus, $\delta_{th} = (100 \text{ to} 1000)\delta$

21. The temperature of a body of area 0.1 m^2 is 900 K. The wavelength for maximum monochromatic emissive power will be nearly __________.

A. 2.3 μm B. 3.2 μm

C. 4.1 μm D. 5.0 μm

Ans. B

Sol. Given:

Area: A = 0.1 m^2

Temperature: T = 900 K

From Wien's displacement law:

$\lambda_{max} T = 2898$

$\lambda_{max} \times 900 = 2898$

$\lambda_{max} = 3.2 \mu m$

22. Consider the following statements:

For the laminar condensation on a vertical plate, the Nusselt theory says that:

1. inertia force in the film is negligible compared to viscosity and weight

2. heat flow is mainly by conduction through the liquid film, convection in liquid film as well as in vapour is neglected

3. velocity of vapour is very high

Which of the above statements are correct __________?

A. 1, 2 and 3 B. 1 and 2 only

C. 1 and 3 only D. 2 and 3 only

Ans. B

Sol. Assumptions for Laminar condensation on vertical plate:

1. The fluid properties are constant.

2. The liquid vapour interface is at the saturation temperature T_{sat}, i.e., there is no thermal resistance at the liquid vapour interface.

3. Momentum effects in the film are negligible, i.e., there is a static balance of forces.

4.The vapour exerts no shear stress at the liquid vapour interface. Vapour is quiescent i.e., $u_\infty = 0$.

5. The temperature distribution in the film is linear.

6. Enthalpy changes associated with sub-cooling of the liquid are negligible.

23. In transition boiling, heat flux decreases due to which of the following?

1. Low value of film heat transfer coefficient at the surface during 100°C to 120°C surface temperature

2. Major portion of heater surface is covered by vapour film which has smaller thermal conductivity as compared to liquid

3. Nucleate boiling occurs very fast

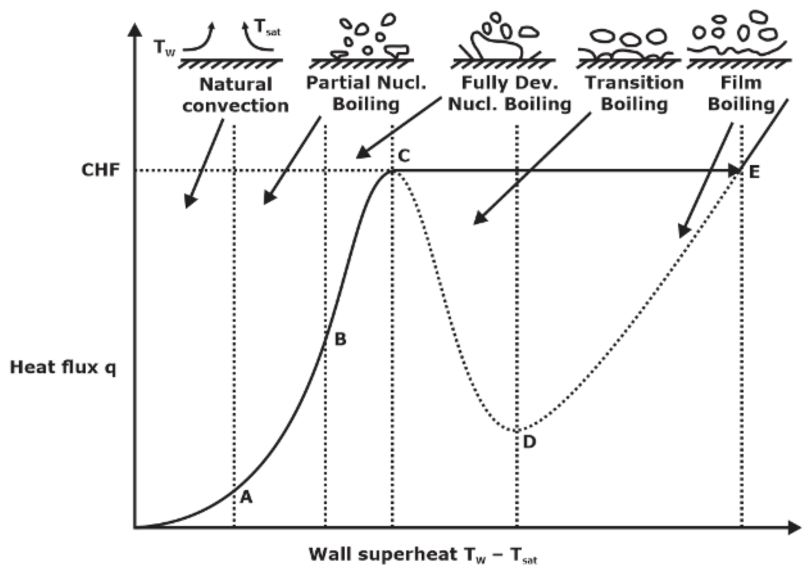
Select the correct answer using the code given below _________.

A. 1 only B. 2 only

C. 3 only D. 1, 2 and 3

Ans. (b)

Sol. **Pool Boiling curve:**



In transition boiling heat flux decreases because a large fraction of the heater surface is covered by a vapor film, which acts as an insulation due to the low thermal conductivity of the vapor relative to that of the liquid.

24. A hemispherical furnace of radius 1.0 m has a roof temperature of T_1 = 800 K and emissivity ϵ_1 = 0.80. The flat floor of the furnace has a temperature T_2 = 600 K and emissivity ϵ_2 = 0.50. The view factor F_{12} from surface 1 to 2 will be _________.

A. 0.3

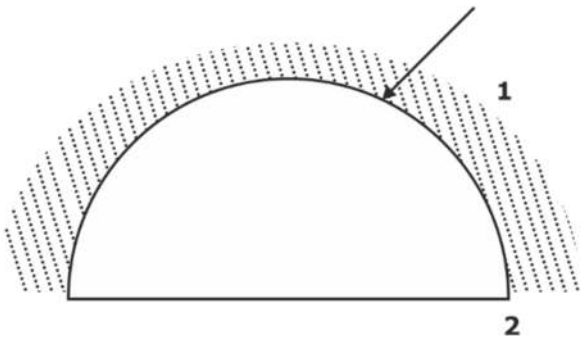
B. 0.4

C. 0.5

D. 0.6

Ans. C

Sol. Given:



T_1 = 800 K and emissivity: ϵ_1 = 0.80.

T_2 = 600 K and emissivity: ϵ_2 = 0.50

Since $F_{11} + F_{12} = 1$

Hemispherical furnace

$F_{21} + F_{22} = 1$ $\quad (r_1 = r_2 = 1m)$

For flat surface: F_{22} = 0

Thus, F_{21} = 1

From reciprocity theorem:

$A_1F_{12} = A_2F_{21}$

$2\pi r^2 \times F_{12} = \pi r^2 \times 1$

$F_{12} = \frac{1}{2} = 0.5$

25. Consider the following statements:

Combustion chamber is:

1. the volume between TDC and BDC during the combustion process

2. the space enclosed between the upper part of the cylinder and the top of the piston during the combustion process

3. the space enclosed between TDC and the top of the piston during the combustion process

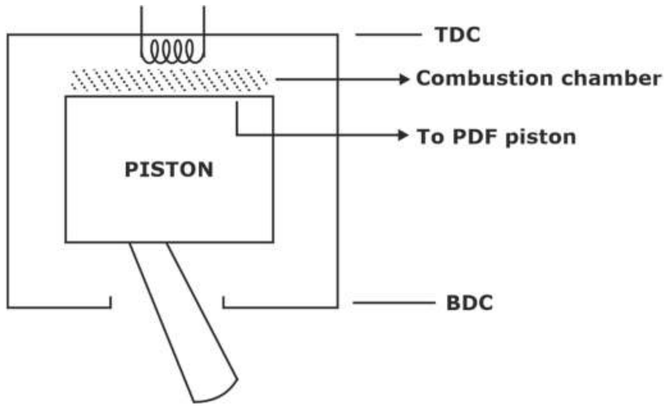
Which of the above statements is/are correct _________?

A. 1 only B. 2 only

C. 3 only D. 1, 2 and 3

Ans. B

Sol. The combustion chamber is the area inside the engine where the fuel/air mixture is compressed and then ignited. It is the space enclosed between the upper part of the cylinder and the top of the piston during the combustion process.



26. A 4-stroke diesel engine has length of 20 cm and diameter of 16 cm. The engine is producing power of 25 kW when it is running at 2500 rpm. The mean effective pressure of the engine will be nearly __________.

A. 5.32 bar

B. 4.54 bar

C. 3.76 bar

D. 2.98 bar

Ans. D

Sol. Given:

Length: L = 20 cm

Diameter: d = 16 cm

Power: P = 25 kW @ running: N = 2500 rpm

Indicated power (IP) is given by:

$$I.P. = P_m \times LA \times \left(\frac{N}{2\times 60}\right) \times K$$

$$P_m = \frac{25\times 10^3 \times (2\times 60)}{0.20\times 0.020\times 2500} \times 10^{-5} bar \approx 3 bar$$

27. A 4-stroke, 6-cylinder gas engine with a stroke volume of 1.75 litres develops 26.25 kW at 506 rpm and the MEP is 600 kN/m^2. The number of misfires per minute per cylinder will be ___________.

A. 3 B. 4

C. 5 D. 6

Ans. A

Sol. Number of cylinders: n = 6

Stroke volume: $V_s = 1.75\,litres$

$$V_S = 1.75\times 10^{-3} m^3$$

Indicated power: IP = 26.25 kW

Engine speed: N = 506 rpm

Mean effective pressure: P_m = 600×10^{3}N/m^2

For four stroke engines: $N' = N/2$

$$IP = p_m \frac{AL\times N'}{60} \times n = p_m \frac{AL}{60} \times \left(\frac{N}{2}\right) \times n$$

$$\Rightarrow 26.25\times 10^3 = 600\times 10^3 \times \frac{1.75\times 10^{-3}\times N}{2\times 60} \times 6$$

$$\Rightarrow N = \frac{26.25\times 10^3 \times 2}{10\times 1.75\times 6} = 500 rpm$$

$\therefore$ Actual number of fires in one minute:

$$n_{actual} = \frac{500}{2} \times 6 = 1500$$

Expected number of fires in one minute:

$$n_{expected} = \frac{506}{2} \times 6 = 1518$$

$\therefore$ Number of misfires/min = $n_{expected} - n_{actual}$

= 1518 – 1500 = 18

$\therefore$ Average number of misfires per min per cylinder $= \frac{18}{6} = 3$

28. Which one of the following compressors will be used in vapour compression refrigerator for plants up to 100 tonnes capacity __________?

A. Reciprocating compressor

B. Rotary compressor

C. Centrifugal compressor

D. Double-acting compressor

Ans. A

Sol. Reciprocating compressors are used in plants up to 100 tonnes capacity. For plants of higher capacities, centrifugal compressors are employed.

29. A cold storage is to be maintained at -5 °C while the surroundings are at 35 °C. The heat leakage from the surroundings into the cold storage is estimated to be 29 kW. The actual COP of the refrigeration plant used is 1/3 rd that of an ideal plant working between the same temperatures. The power required to drive the plant will be ___________.

A. 13 kW

B. 14 kW

C. 15 kW

D. 16 kW

Ans. A

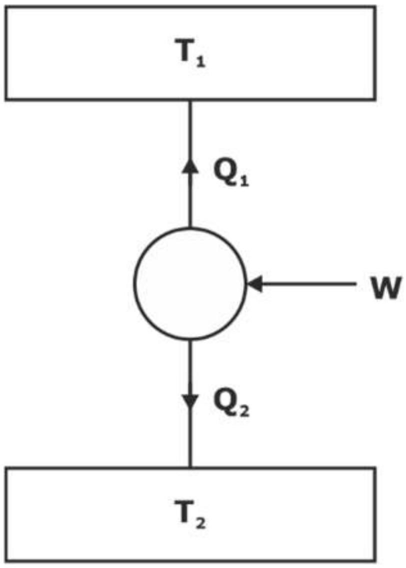
Sol. Given:

Cold storage temperature: T_2 = – 5°C = 268 K

Surrounding temperature: T_1 = 35°C = 308 K

Heat leaked into cold storage: Q_2 = 29 kW

$(COP)_{actual}$ = (1/3)$(COP)_{Ideal}$



$$(COP)_{Ideal} = \frac{T_2}{T_1 - T_2}$$

$$(COP)_{Ideal} = \frac{268}{308-268} = \frac{268}{40} = 6.7$$

$$(COP)_{Actual} = \frac{1}{3} \times (COP)_{Ideal} = \frac{6.7}{3}$$

$$\therefore (COP)_{Actual} = \frac{Q_2}{W} = \frac{6.7}{3}$$

$$\Rightarrow W = \frac{Q_2}{(COP)_{Actual}} = \frac{29 \times 3}{6.7}$$

$$= 12.985 kW \simeq 13 kW$$

30. Consider the following statements:

An expansion device in a refrigeration system:

1. reduces the pressure from the condenser to the evaporator

2. regulates the flow of the refrigerant to the evaporator depending on the load

3. is essentially a restriction offering resistance to flow.

Which of the above statements are correct __________?

A. 1 and 2 only

B. 1 and 3 only

C. 2 and 3 only

D. 1, 2 and 3

Ans. D

Sol.

- An expansion device in a refrigeration system expands the liquid refrigerant from the condenser pressure to the evaporator pressure.
- The expansion device also controls the supply of the liquid to the evaporator at the rate at which it is evaporated. The expansion device is essentially a restriction.

31. A reversed Carnot engine is used for heating a building. It supplies 210×10^3 kJ/hr of heat to the building at 20 °C. The outside air is at –5 °C. The heat taken from the outside will be nearly __________.

A. 192×10^3 kJ/hr

B. 188×10^3 kJ/hr

C. 184×10^3 kJ/hr

D. 180×10^3 kJ/hr

Ans. A

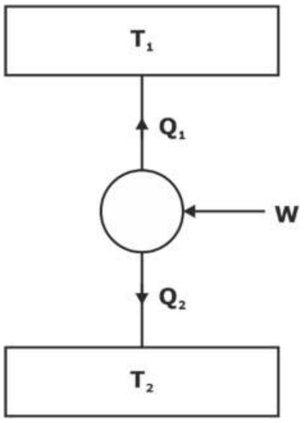
Sol. Given:

$$T_1 = 273 + 20 = 293 K$$

$$T_2 = 273 - 5 = 268 K$$

$Q_1 = 210\times10^3$ kJ/hr

For a reversed Carnot engine, the relations are:



$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$$

$$Q_2 = \frac{Q_1}{T_1} \times T_2$$

$$Q_2 = 210 \times 10^3 \times \frac{268}{293}$$

$Q_2 = 192\times10^3$ kJ/hr

32. In an Electrolux refrigerator, a thermosiphon bubble pump is used to lift the __________.

A. weak aqua solution from the generator to the separator

B. weak aqua solution from the separator to the absorber

C. strong aqua solution from the generator to the separator

D. strong aqua solution from the generator to the evaporator

Ans. A

Sol.

- In Electrolux refrigerator, a thermosyphon bubble pump is used to lift the weak aqua solution from the generator to the separator.
- The discharge tube from the generator is extended down below the liquid level in the generator. The bubbles rise and carry slugs of weak $NH_3 - H_2O$ solution into the separator.

33. The enthalpy of moist air with normal notations is given by __________.

A. h = (1.005 + 1.88ω) t + 2500ω

B. h = 1. 88 ωt +2500ω

C. h = 1.005ωt

D. h = (1.88 + 1.005ω) t + 2500ω

Ans. A

Sol. Enthalpy of moist air:

$$h = h_a + \omega\, h_v$$

$$\Rightarrow h = 1.005t + \omega\left[2500 + 1.88t\right] \text{ kJ/kgda}$$

$$\Rightarrow h = \left[1.005 + 1.88\omega\right]t + 2500\omega$$

34. If the relative humidity of atmospheric air is 100%, then the wet-bulb temperature will be __________.

A. more than dry-bulb temperature

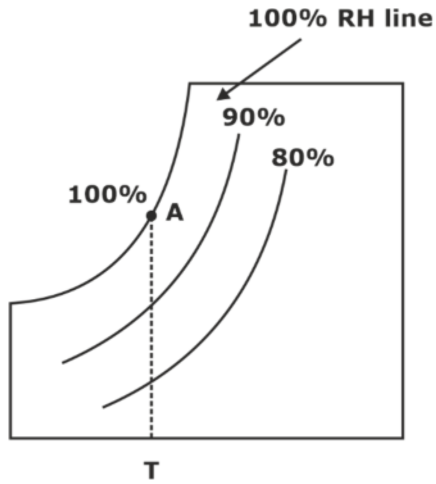
B. equal to dew-point temperature

C. equal to dry-bulb temperature

D. less than dry-bulb temperature

Ans. B

Sol.



For point A on 100% RH line:

$\therefore$ DBT = WBT = DPT

35. During an air-conditioning of a plant, the room sensible heat load is 40 kW and room latent heat load is 10 kW, ventilation air is 25% of supply air. At full load, the room sensible heat factor will be __________.

A. 0.9 B. 0.8

C. 0.7 D. 0.6

Ans. B

Sol. Given:

Room sensible heat: RSH = 40 kW

Room Latent heat: RLH = 10 kW

ventilation air = 25% of supply air

Room sensible heat factor (RSHF) is given by:

$$RSHF = \frac{RSH}{RSH + RLH} = \frac{40}{40 + 10} = 0.8$$

36. A 2-stroke oil engine has bore of 20 cm, stroke 30 cm, speed 350 rpm, i.m.e.p. 275 kN/m^2, net brake load 610 N, diameter of brake drum 1 m, oil consumption 4.25 kg/hr, calorific value of fuel 44 $\times 10^3$ kJ/kg. The indicated thermal efficiency will be ___________.

A. 29.1 % B. 31.3 %

C. 33.5 % D. 35.7 %

Ans. A

Sol. Diameter: D = 20 cm

Stroke: L = 30 cm

Speed: N = 350 rpm

imep = 275 kN/m^2

Net brake load = 610 N

Calorific value: CV = 44×10^6 J/kg

$$\dot{m}=\frac{4.25}{60\times 60}\text{ kg/s}$$

$$\text{i.p}=275\times\frac{\pi}{4}\left(20\times 10^{-2}\right)^2\times 3\times 10^{-2}\times\frac{350}{60}\times 10^3$$

$$\text{i.p.}=15118.9\times 10^{-3}\,\text{Watt}$$

Indicated thermal efficiency is given by:

$$\eta_{ip}=\frac{115118.9\times 10^{-3}}{4.25\times 44\times 10^6}\times 60\times 60$$
$$=0.291=29.1\%$$

37. The hydraulic efficiency of a turbine is the ratio of __________.

A. mechanical energy in the output shaft at coupling and hydrodynamic energy available from the fluid.

B. mechanical energy supplied by the rotor and hydrodynamic energy available from the fluid.

C. useful hydrodynamic energy in the fluid at final discharge and mechanical energy supplied to the rotor.

D. useful hydrodynamic energy in the fluid at final discharge and mechanical energy supplied to the shaft and coupling.

Ans. B

Sol. Hydraulic efficiency is given by:

$$\text{Hydraulic efficiency}(\eta_h)=\frac{\text{Head extracted by the rotor}}{\text{Net load available to the rotor}}$$

$$\eta_h=\frac{\text{work done by the runner}}{\text{K.E. of the jet inlet to bucket Mechanical energy}}$$

$$\eta_h=\frac{\text{supplied by the rotor}}{\text{Hydrodynamic energy available from fluid}}$$

38. Consider the following statements regarding compounding in steam turbines:

1. In impulse turbine, steam pressure remains constant between ends of the moving blades.

2. In reaction turbine, steam pressure drops from inlet to outlet of the blade.

3. In velocity compounding, partial expansion of steam takes place in the nozzle and further expansion takes place in the rotor blades.

Which of the above statements are correct __________?

A. 1 and 2 only B. 1 and 3 only

C. 2 and 3 only D. 1, 2 and 3

Ans. D

Sol.

- In impulse turbine inlet pressure = outlet pressure and blade is equiangular. So, change in relative component is zero and hence relative component is same, so no reaction takes place.
- In reaction turbine steam pressure drops from inlet to outlet of the blade.
- In velocity compounding whole expansion takes place in nozzle and velocity is reduced subsequent stages.

39. In a lawn sprinkler, water leaves the jet with an absolute velocity of 2 m/s and the sprinkler arms are 0.1 m in length. The sprinkler rotates at a speed of 120 rpm. The utilization factor of this sprinkler will be nearly __________.

A. 0.72 B. 0.64

C. 0.56 D. 0.49

Ans. A

Sol. Consider sprinkles as radial blade:

$$\eta=\frac{\left(\frac{2\pi N}{60}\times 0.1\right)^2}{\frac{(2)^2}{2}}=\frac{1.578}{2}=0.7895$$

η = 78.95%

40. Which one of the following statements is correct with respect to axial flow 50% reaction turbine __________?

A. The combined velocity diagram is symmetrical.

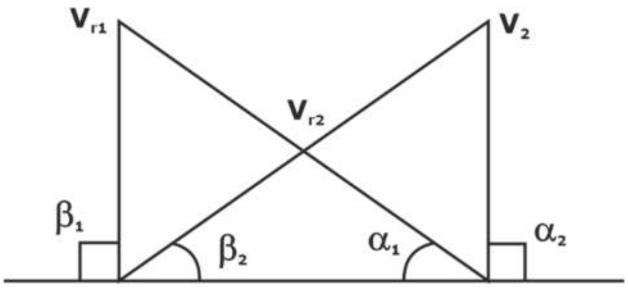
B. The outlet absolute velocity should not be axial for maximum utilization.

C. Angles of both stator and rotor are not identical.

D. For maximum utilization, the speed ratio $\frac{U}{V_1} = \sin^2 \alpha$.

Ans. A

Sol.



For maximum ' η ':

In 50% reaction turbine for maximum ' η '

$\alpha_2 = 90°, \alpha_3 = \alpha_2$

$\frac{U}{V_1} = \cos\alpha$

41. In axial flow pumps and compressors, the combined velocity diagram with common base is used to determine change in ___________.

A. absolute velocity $(V_2 - V_1)$

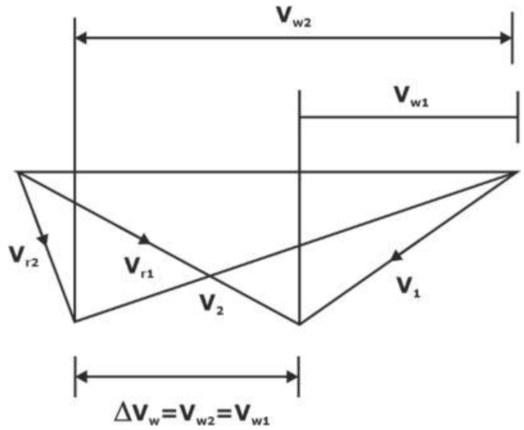
B. relative velocity $(V_{r_2} - V_{r_1})$

C. tangential velocity $(U_2 - U_1)$

D. whirl velocity $(V_{u_2} - V_{u_1})$

Ans. D

Sol.



42. In a steam turbine with steam flow rate of 1 kg/s, inlet velocity of steam of 100 m/s, exit velocity of steam of 150 m/s, enthalpy at inlet of 2900 kJ/kg, enthalpy at outlet of 1600 kJ/kg, the power available from the turbine will be nearly __________.

A. 1575.5 Kw B. 1481.6 kW

C. 1387.7 kW D. 1293.8 kW

Ans. D

Sol. Given:

steam flow rate: $\dot{m} = 1\ kg/s$

Inlet velocity of steam: v_1 = 100 m/s

Exit velocity of steam: v_2 = 150 m/s

Enthalpy at inlet: h_1 = 2900 kJ/kg

Enthalpy at outlet: h_2 = 1600 kJ/kg

Stagnation enthalpy:

$$\Delta h_0 = \left(h_1 + \frac{v_1^2}{2}\right) - \left(h_2 + \frac{v_2^2}{2}\right)$$

$$\Delta h_o = \left(2900 + \frac{(100)^2}{2}\right) - \left(1600 - \frac{(150)^2}{2}\right)$$

$$\Delta h_o = 1293.8\,kW.$$

43. In an isentropic flow through a nozzle, air flows at the rate of 600 kg/hr. At inlet to nozzle, the pressure is 2 MPa and the temperature is 127 °C. The exit pressure is of 0.5 MPa. If the initial velocity of air is 300 m/s, the exit velocity will be __________.

A. 867 m/s B. 776 m/s

C. 685 m/s D. 594 m/s

Ans. D

Sol. Given:

$\dot{m} = 600 \text{ kg/hr}$

$T_1 = 127°C = 273 + 127 = 400 \text{ K}$

$P_1 = 2\text{MPa}, P_2 = 0.5\text{MPa}$

Inlet velocity: $V_1 = 300 \text{ m/sec}$

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{2}{0.5}\right)^{\frac{1.4-1}{1.4}} = (4)^{0.285} = 1.4845$$

$$T_2 = \frac{T_1}{1.4845} = 269.450 \text{ K}$$

Apply SFEE:

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$$

$$V_2 = \sqrt{2(h_1 - h_2) + (300)^2}$$

$$V_2 = \sqrt{2 \times 1.005 \times 1000(400 - 269.5) + (300)^2}$$

$$V_2 = 594 \text{ m/sec}$$

44. In a steam turbine, the nozzle angle at the inlet is 18°. The relative velocity is reduced to the extent of 6% when steam flows over the moving blades. The output of the turbine is 120 kJ/kg flow of steam. If the blades are equiangular, the speed ratio and the absolute velocity of steam at inlet for maximum utilization are nearly __________.

A. 0.42 and 230.2 m/s

B. 0.48 and 230.2 m/s

C. 0.42 and 515.1 m/s

D. 0.48 and 515.1 m/s

Ans. D

Sol. Given:

Inlet angle: $\alpha = 18°$

$V_{r2} = 0.94 V_{r1}$

$$K = \frac{V_{r2}}{V_{r1}} = 0.94$$

$$\frac{V_b}{V_1} = \frac{\cos\alpha}{2} = 0.4755 = 0.48$$

$$(V_1 \cos\alpha_1 - V_b)(1 + K) \times V_b = 120 \times 10^3$$

$$\left(V_1 \cos 18° - 0.48 V_1\right)\left(1 + \frac{94}{100}\right)$$

$$\times 0.48 V_1 = 120 \times 10^3$$

$$V_1^2 \left(\cos 18° - 0.48\right) \times (1.94) \times 0.48 = 120 \times 10^3$$

$$V_1 \cong 515.1 \text{ m/s}$$

45. An air compressor compresses atmospheric air at 0.1 MPa and 27 °C by 10 times of air inlet pressure. During compression, the heat lost to the surrounding is estimated to be 5% of compression work. Air enters the compressor with a velocity of 40 m/s and leaves with 100 m/s. The inlet and exit cross-sectional areas are 100 cm^2 and 20 cm^2 respectively. The temperature of air at the exit from the compressor will be __________.

A. 1498 K B. 1574 K

C. 1654 K D. 1726 K

Ans. A

Sol. Given:

$P_1 = 0.1$ MPa and $T_1 = 27°C = 300$ K

$\eta_c = 0.95$

Inlet velocity: $V_1 = 40$ m/s

Outlet velocity: $V_2 = 100$ m/s

Inlet cross-sectional area: $A_1 = 100 \text{ cm}^2$

Exit cross-sectional area: $A_2 = 20 \text{ cm}^2$

Density at inlet is given by:

$$\rho_1 = \frac{P_1}{RT_1} = \frac{0.1 \times 10^6}{0.287 \times 10^3 \times 300} = 1.1614 \text{ kg/m}^3$$

$$\dot{m} = \rho_1 A_1 V_1 = 1.1614 \times 100 \times 10^{-4} \times 40$$

$$\dot{m} = 0.4646 \text{ kg/s}$$

$$\dot{m} = \rho_2 A_2 V_2 = \left(\frac{P_2}{RT_2}\right) \times A_2 V_2$$

Temperature at exit is given by:

$$T_2 = \frac{P_2 A_2 V_2}{\dot{m} R}$$

$$T_2 = \frac{1 \times 10^6 \times 20 \times 10^{-4} \times 100}{0.4646 \times 0.287 \times 10^3} = 1499.9227 K$$

46. A compressor delivers 4 m^3 of air having a mass of 5 kg. The specific weight and specific volume of air being delivered will be nearly ________.

A. 12.3 N/m^3 and 0.8 m^3 /kg

B. 14.6 N/m^3 and 0.4 m^3 /kg

C. 12.3 N/m^3 and 0.4 m^3 /kg

D. 14.6 N/m^3 and 0.8 m^3 /kg

Ans. A

Sol. Volume: V = 4 m^3

Mass: m = 5 kg

Specific weight: $w = \frac{weight}{volume} = \frac{mg}{V}$

$$w = \frac{5 \times 9.81}{4} = 12.26 \text{ N/m}^3$$

Specific volume(v) = $\frac{volume(V)}{mass}$

$$v = \frac{4}{5} = 0.8 \text{ m}^3/\text{kg}$$

47. In centrifugal compressors, there exists a loss of energy due to the mismatch of direction of relative velocity of fluid at inlet with inlet blade angle. This loss is known as __________.

A. frictional loss B. incidence loss

C. clearance loss D. leakage loss

Ans. B

Sol. Additional losses that occur in a row of blades in a centrifugal compressor stage on account of incidence (mismatch of direction of relative velocity of fluid of inlet with inlet blade angle) termed as incidence losses. It is conventionally known as shock losses.

48. A centrifugal compressor develops a pressure ratio of 5 and air consumption of 30 kg/ s. The inlet temperature and pressure are 15 °C and 1 bar respectively. For an isentropic efficiency of 0.85, the power required by the compressor will be nearly __________.

A. 5964 kW B. 5778 kW

C. 5586 kW D. 5397 kW

Ans. A

Sol. Given:

Pressure ratio: r_p = 5

Air consumption: $\dot{m} = 30$ kg / s

Isentropic efficiency: η_{isen} = 0.85

$$W = C_p T_0 \left(r_p^{\frac{\gamma-1}{\gamma}} - 1 \right)$$

$$W = 1.005 \times 288 \left((5)^{\frac{0.4}{1.4}} - 1 \right)$$

$$W = 1.005 \times 288 \times 0.5819 = 168.45 \text{ kW/kg}$$

$$W_{ideal} = 167.615 \times 30 = 5053.62$$

$$\eta_{isen} = \frac{W_{ideal}}{W_{actual}}$$

$$W_{actual} = \frac{W_{ideal}}{\eta_{isen}} = \frac{5053.62}{0.85} = 5964 \text{ kW}$$

49. The efficiency of superheat Rankine cycle is higher than that of simple Rankine cycle because _________.

A. the enthalpy of main steam is higher for superheat cycle.

B. the mean temperature of heat addition is higher for superheat cycle.

C. the temperature of steam in the condenser is high.

D. the quality of steam in the condenser is low.

Ans. B

Sol. The efficiency of superheat Rankine cycle is higher than that of simple Rankine cycle because the mean temperature of heat addition is higher for superheat cycle.

50. In steam power cycle, the process of removing non-condensable gases is called __________.

A. scavenging process

B. deaeration process

C. exhaust process

D. condensation process

Ans. B

Sol.

- In steam power cycle, the process of removing non-condensable gases is called the deaeration process and deaerator is a device that is widely used for the removal of air and other dissolved gases from the feedwater to steam generating boilers.
- The removal of dissolved oxygen in boiler feed water is necessary because it causes serious corrosion damage in steam systems by attaching to the walls of metal piping and other metallic equipment and forming oxides (rust).

51. The internal irreversibility of Rankine cycle is caused by:

1. fluid friction
2. throttling
3. mixing

Select the correct answer using the code given below __________.

A. 1 and 2 only

B. 1 and 3 only

C. 2 and 3 only

D. 1, 2 and 3

Ans. D

Sol. Internal irreversibility of Rankine cycle is caused by fluid friction, throttling, and mixing.

52. A 1 g sample of fuel is burned in a bomb calorimeter containing 1.2 kg of water at an initial temperature of 25 °C. After the reaction, the final temperature of the water is 33.2 °C. The heat capacity of the calorimeter is 837 J/°C. The specific heat of water is 4.18 J/ °C. The heat released by the fuel will be nearly ___________.

A. 36 kJ/g B. 42 kJ/g

C. 48 kJ/g D. 54 kJ/g

Ans. (c)

Sol. Given:

$m_f = 1$ gm and $m_w = 1.2$ kg

Initial temperature: T_1 = 25°C

Final temperature: T_f = 33.2°C

C_p = 4.18 J/°C

L = 837 J/°C

$$Q_{water} = m_w \times 4.18 \times (33.2 - 25)$$

$$Q_{water} = 1.2 \times 4.18 \times 8.2 = 41.3 \text{ kJ}$$

$$Q_{calorimeter} = 837 \times \Delta T = 837 \times (33.2 - 25)$$

$$Q_{calorimeter} = 6.8634 \text{ kJ}$$

$$Q_{fuel} = Q_{water} + Q_{calorimeter}$$

$$Q_{fuel} = 41.3 + 6.8634 = 48 \text{ kJ}$$

53. A boiler is having a chimney of 35 m height. The draught produced in terms of water column is 20 mm. The temperature of flue gas inside the chimney is 365 °C and that of air outside the chimney is 32 °C. The mass of air used will be nearly ___________.

A. 10.3 kg/kg of fuel

B. 12.5 kg/kg of fuel

C. 14.7 kg/kg of fuel

D. 16.9 kg/kg of fuel

Ans. D

Sol. Given:

Chimney height: H = 35 m

Draught produced in terms of water column:

h_w = 20 mm

Flue gas temperature: T_g = 365°C = 638 K

Outside air temperature: T_a = 32°C = 305 K

Chimney draught in terms of water column is given by:

$$h_w = 353H\left[\frac{1}{T_a} - \frac{1}{T_g}\left(\frac{m_a+1}{m_a}\right)\right]$$

$$20 = 353 \times 35\left[\frac{1}{305} - \frac{1}{638}\left(\frac{m_a+1}{m_a}\right)\right]$$

$$1.618 \times 10^{-3} = \left[\frac{1}{305} - \frac{1}{638}\left(\frac{m_a+1}{m_a}\right)\right]$$

$$m_a = 16.9\,\text{kg/kg of fuel}$$

54. A 2 kg of steam occupying 0.3 m^3 at 15 bar is expanded according to the law $pv^{1.3}$ = constant to a pressure of 1.5 bar. The work done during the expansion will be __________.

A. 602.9 kJ B. 606.7 kJ

C. 612.5 kJ D. 618.3 kJ

Ans. D

Sol. Given:

m = 2 kg

V_1 = 0.3 m^3 at p_1 = 15 bar

Expansion follows: $pv^{1.3}$ = constant

P_2 = 1.5 bar

$$\text{Now: } P_1V_1^{1.3} = P_2V_2^{1.3} \Rightarrow \frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{1.3}$$

$$\Rightarrow V_2 = \left(\frac{P_1}{P_2}\right)^{\frac{1}{1.3}} \times V_1$$

$$\Rightarrow V_2 = \left(\frac{15}{1.5}\right)^{\frac{1}{1.3}} \times 0.3m^3 = 1.7634\,m^3$$

$$Pv^{1.3} = \text{constant} = C(\text{say})$$

$$P = \frac{C}{V^{1.3}}$$

$$\text{Work done: } W = \int_{v_1}^{v_2} Pdv = \int_{v_1}^{v_2} \frac{C}{V^{1.3}}dV$$

$$W = \int_{v_1}^{v_2} CV^{-1.3}dV = C\left|\frac{V^{-0.3}}{-0.3}\right|_{v_1}^{v_2}$$

$$W = \frac{C}{-0.3}\left|V_2^{-0.3} - V_1^{-0.3}\right|$$

$$W = \frac{-1}{0.3}\left[P_2V_2^{1.3}.V_2^{-0.3} - P_1V_1^{1.3}.V_1^{-0.3}\right]$$

$$W = \frac{-1}{0.3}\left[P_2V_2 - P_1V_1\right] = \left[\frac{P_1V_1 - P_2V_2}{0.3}\right]$$

$$W = \frac{\left[15 \times 10^5 \times 0.3 - 1.5 \times 10^5 \times 1.7634\right]}{0.3}$$

$$W = 618.3\text{ kJ}$$

55. Which of the following statements is/are correct regarding superheater in boilers?

1. It is a heat exchanger in which heat is transformed to the saturated steam to increase its temperature.

2. It raises the overall efficiency.

3. It reduces turbine internal efficiency.

Select the correct answer using the code given below __________.

A. 1 and 2 B. 1 and 3

C. 2 and 3 D. 1 only

Ans. A

Sol.

- The superheater is a heat exchanger in which heat is transferred to the saturated steam to increase its temperature.

Effect of superheating:

(i). Raises the overall efficiency.

(ii). Reduces the moisture content in last stages of the turbine and thus increases the turbine internal efficiency.

56. Water vapour at 90 kPa and 150 °C enters a subsonic diffuser with a velocity of 150 m/s and leaves the diffuser at 190 kPa with a velocity of 55 m/s, and during the process, 1.5 kJ/kg of heat is lost to the surrounding. For water vapour, C_p is 2.1 kJ/kg K. The final temperature of water vapour will be __________.

A. 154 °C B. 158 °C

C. 162 °C D. 166 °C

Ans. A

Sol. Given:

p_1 = 90 kPa and T_1 = 150 °C

Velocity: v_1 = 150 m/s

P_2 = 190 kPa and T_2 = ________?

Velocity: v_2 = 55 m/s

Q_{lost} = 1.5 kJ/kg

Applying S.F.E.E. at inlet and exit of diffuser:

$$h_1 + \frac{V_1^2}{2000} + Q_{lost} = h_2 + \frac{V_2^2}{2000}$$

$$C_p\left(T_2 - T_1\right) = \left(\frac{V_1^2 - V_2^2}{2000}\right) + (-1.5)$$

$$2.1 \times \left(T_2 - 150\right) = \left(\frac{150^2 - 55^2}{2000}\right) + (-1.5)$$

$$\Rightarrow T_2 = 153.9226°C$$

57. A steam turbine is supplied with steam at a pressure of 20 bar gauge. After expansion in the steam turbine, the steam passes to condenser which is maintained at a vacuum of 250 mm of mercury by means of pumps. The inlet and exhaust steam pressures will be nearly __________.

A. 2101 kPa and 68 kPa

B. 2430 kPa and 78 kPa

C. 2101 kPa and 78 kPa

D. 2430 kPa and 68 kPa

Ans. A

Sol. Given:

Inlet pressure: P_{gauge} = 20 bar gauge

Absolute inlet pressure: $P_{abs,\ in} = P_{gauge} + P_{atm}$

$$P_{abs,in} = \left(20 \times 10^2 + 101\right)\text{kPa} = 2101 \text{ kPa}$$

Exit pressure: P_{vacuum} = 250 mm of mercury

Absolute exit pressure: $P_{abs,\ in} = P_{atm} + P_{vacuum}$

$$P_{abs,exit} = \left[101 + \left(-13.6 \times 9.81 \times 0.25\right)\right]\text{kPa}$$

$$P_{abs,exit} = 67.64 \text{ kPa}$$

58. In a power plant, the efficiencies of the electric generator, turbine, boiler, thermodynamic cycle and the overall plant are 0.97, 0.95, 0.92, 0.42 and 0.33 respectively. The total electricity generated for running the auxiliaries will be nearly __________.

A. 4.9 % B. 5.7 %

C. 6.5 % D. 7.3 %

Ans. D

Sol. Given:

Electric generator efficiency: $\eta_g = 0.97$

Turbine efficiency: $\eta_{turbine} = 0.95$

Boiler efficiency: $\eta_{Boiler} = 0.92$

Thermodynamic cycle Efficiency: $\eta_{cycle} = 0.42$

overall plant efficiency: $\eta_{overall} = 0.33$

Overall efficiency is given by:

$$\eta_{overall} = \eta_g \times \eta_{turbine} \times \eta_{Boiler} \times \eta_{cycle} \times \eta_{auxiliaries}$$

$$0.33 = 0.97 \times 0.95 \times 0.92 \times 0.42 \times \eta_{Auxiliaries}$$

$$\eta_{Auxiliaries} = 0.926$$

Total electricity generated for running auxiliaries:

$= 1 - 0.926 = 0.073$ or 7.3%

59. A turbine in which steam expands both in nozzle as well as in blades is called as __________.

A. impulse reaction turbine

B. reciprocating steam turbine

C. gas turbine

D. Curtis turbine

Ans. A

Sol.

- An impulse turbine is consisting of a stage of stationary nozzles followed by a stage of moving blades.
- In this type of turbine, the potential energy of steam is converted into kinetic energy in nozzles. A complete process of expansion of steam with consequent pressure drop occurs only across these nozzles, with a net increase in steam velocity across the stage. Moving rotor blades absorb the kinetic energy of high-velocity steam jets and convert it to mechanical work, resulting in rotation of the turbine shaft.

60. Consider the following statements regarding reaction turbine:

1. Blade shape is aerofoil type, and its manufacturing is difficult.

2. It is suitable for small power.

3. Leakage losses are less compared to friction losses.

Which of the above statements is/are correct __________?

A. 1 only B. 2 only

C. 3 only D. 1, 2 and 3

Ans. A

Sol.

- In Reaction Turbine, the blade shapes are of aerofoil and non-symmetrical type; hence manufacturing is difficult.
- It is used suitable for medium and high-power requirements.
- Leakage losses are more compared to frictional losses.

61. The solar heat pipe works on the principle of _________.

A. heating and condensation cycle

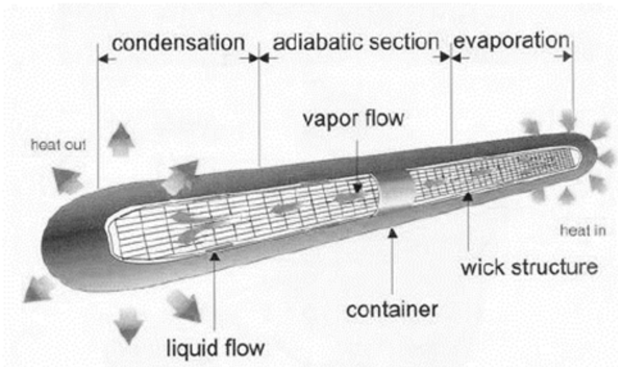
B. evaporation and condensation cycle

C. cooling and condensation cycle

D. heating and evaporation cycle

Ans. B

Sol. A Solar heat pipe is a heat-transfer device that use the principles of thermal conductivity and phase change to transfer heat between two ends at almost constant temperature i.e., process of evaporation and condensation.



62. A good approximation of the measured solar spectrum is made by _________.

A. black-body energy distribution

B. Planck's energy distribution

C. inverse square law

D. solar constant

Ans. A

Sol.

- The Sun's radiation is a good approximation of black body radiation (a continuous distribution of wavelengths with no wavelengths missing) with wavelengths in the range of about 0.2 μm to 2.6 μm.
- The solar spectrum consists of ultra-violate rays in the range of 200 to 400 nm, visible light in the range 390 nm (violet) to 740 nm (red) and the infra-red in the range 700 nm to 1mm.

63. Which one of the following types of tracker uses liquid contained in canisters that can turn easily into vapour _________?

A. Active tracker

B. Passive tracker

C. Single-axis tracker

D. Altitude-azimuth tracker

Ans. B

Sol.

- **Passive trackers** use a low boiling point compressed gas fluid that is driven to one side or the other (by solar heat creating gas pressure) to cause the tracker to move in response to an imbalance.
  As this is a non-precision orientation it is unsuitable for certain types of concentrating photovoltaic collectors but works fine for common PV panel types.
- **Active trackers** must be provided with energy for their actuators to move. The actuator systems may consist of motors and other elaborate mechanical devices.

64. Which type of fiat-plate collector is used to heat the swimming pools with plastic panel, utilizing solar energy _________?

A. Pipe and fin type

B. Full water sandwich type

C. Thermal traps type

D. Corrugated plate with selective surface type

Ans. B

Sol.

- For low temperature requirements, such as in warming swimming pools, the plastic, full water sandwich panel may be the most appropriate choice.
- pipe and fin type panel may be more suitable for domestic and industrial applications, higher temperatures are required and therefore, higher efficiency, reliability and long life are the main characteristics required.

65. The edge loss U_e in a solar collector with respect to edge area A_e, collector area A_c and back loss coefficient U_b is ___________.

A. $U_b\left(\frac{A_e}{A_c}\right)$

B. $U_b\left(\frac{A_c}{A_e}\right)$

C. $A_c\left(\frac{A_e}{U_b}\right)$

D. $U_b\left(\frac{A_e}{2A_c}\right)$

Ans. A

Sol. Edge loss coefficient (U_e) is given by:

$$U_e = U_b\left(\frac{A_e}{A_c}\right)$$

66. In solar porous type air heater, the pressure drop is usually _________.

A. higher than non-porous type

B. same as in non-porous type

C. lower than non-porous type

D. zero

Ans. C

Sol.

- Solar radiation penetrates to a great depth and is absorbed along its path. Thus, the radiation loss decreases. Air stream heats up as it passes through the matrix.
- The pressure drop for the porous matrix is usually much lower than the nonporous absorber.

67. In a drain back solar water heating system _________.

A. the water in the heat exchanger is recycled.

B. the water is heated in collectors only during times when there is available heat.

C. at the collector, the mixture of water and propylene-glycol is heated and returned to a solar storage tank.

D. there is an expansion tank with enclosed air chamber to assist water draining.

Ans. C

Sol. Two types of solar hot water systems:

(a). **A "closed loop"** (often referred to as a glycol or anti-freeze system).

(b). **A "drain back system"**: The primary difference between the two system types is that water is used for heat transfer in a drain back system and a glycol solution is used for heat transfer in a closed loop system.

68. A PV cell is illuminated with irradiance (E) of 1000 W/m^2. If the cell is 100 mm $\times$ 100 mm in size and produces 3 A at 0.5 V at the maximum power point, the conversion efficiency will be _________.

A. 15% B. 19%

C. 23% D. 27%

Ans. A

Sol. Given:

Irradiance (E) = 1000 W/m^2

Cell size = 100 mm $\times$ 100 mm

I_{max} = 3 A @ V_{max} = 0.5 V

$$\text{Conversion efficiency} = \frac{V_m.I_m}{\text{Irradiation} \times \text{area}}$$

$$\eta_{conversion} = \frac{3 \times 0.5}{1000 \times 100 \times 100 \times 10^{-6}}$$

$$= \frac{1.5}{10} \times 100 = 15\%$$

69. In a barrage of 300000 m^2 area with a tide height of 3 m, barrage drain time of 10 hr, density of seawater as 1025 kg/m^3 and gravitational acceleration as 9.8 m/s^2, the average power will be __________.

A. 377 kW B. 381 kW

C. 388 kW D. 396 kW

Ans. A

Sol. Given:

Barrage area: A = 300000 m^2

Tide height: R = 3 m

Barrage drain time: t = 10 hr

Density of seawater: ρ = 1025 kg/m^3

Average power is given by:

$$P_{avg} = \frac{W}{t} = \frac{1}{2}\frac{\rho g A R^2}{t}$$

$$P_{avg} = \frac{1}{2} \times \frac{1025 \times 9.8 \times 300000 \times 3^2}{10 \times 3600} = 377\,kW$$

70. The platinum nano-coating is made on the anode of the fuel cell to _________.

A. create lighter and more efficient fuel cell membranes.

B. make the fuel effective.

C. create high thermal conductivity in the cell.

D. make the fuel cell non-corrosive.

Ans. B

Sol.

- Platinum to catalyse the oxygen reduction reaction in the cathode side.
- While platinum is the most efficient catalyst available today for the oxygen reduction reaction, its activity is limited, and it is rare and expensive. Platinum nano-coating make the fuel effective.

71. In a fuel cell, electric current is produced when _________.

A. hydrogen and oxygen react with each other and electrons are freed.

B. hydrogen reacts with water and electrons are freed.

C. oxygen reacts with water and electrons are freed.

D. electrons react with molecules of hydrogen and oxygen is freed.

Ans. A

Sol.

- A fuel cell converts the chemical energy in hydrogen and oxygen into direct current electrical energy by electrochemical reactions.
- Hydrogen gas is converted into electrons and protons (positive hydrogen ions) at the anode.

72. Which one of the following is suitable for fuel cell electric vehicle (FCEV) _________?

A. Direct methanol fuel cell (DMFC)

B. Alkaline fuel cell (AFC)

C. Proton exchange membrane fuel cell (PEMFC)

D. Solid oxide fuel cell (SOFC)

Ans. C

Sol. DMFC (Direct Methanol Fuel Cell) technology is used to power portable applications and in some niche transport sector such as marine, motorbikes and APU.

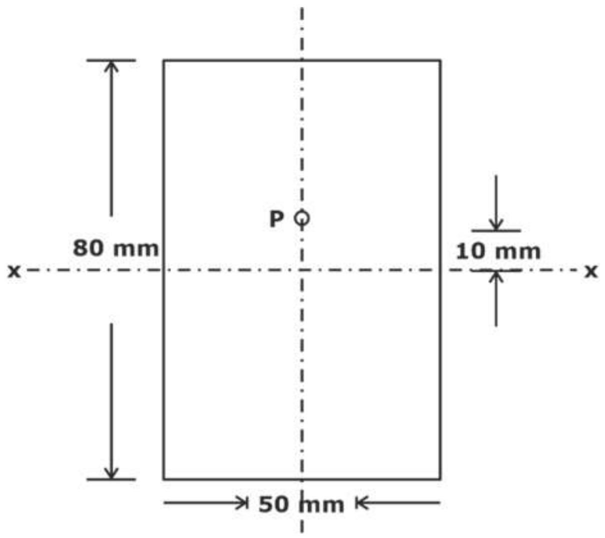
Ex:

Alkali cell → Rockets

PEMFC → Power generation

DMFC → Transport Applications

73. A pull of 100 kN acts on a bar as shown in the figure in such a way that it is parallel to the bar axis and is 10 mm away from xx:



The maximum bending stress produced in the bar at xx is nearly __________.

A. 20.5 N/mm^2

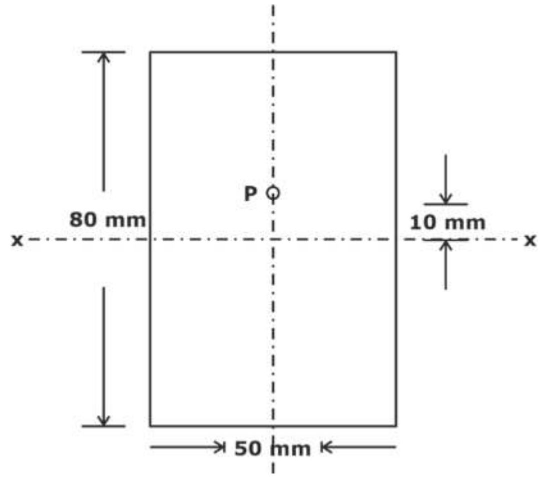
B. 18.8 N/mm^2

C. 16.3 N/mm^2

D. 14.5 N/mm^2

Ans. B

Sol. Given:



Load: P = 100 kN

Eccentricity: e = 10 mm

Width: b = 50 mm

Depth: d = 80 mm

Bending stress (σ) is given by:

$$\sigma = \frac{M}{I}y = \frac{Pe}{\frac{bd^3}{12}} \times \frac{d}{2} = \frac{6Pe}{bd^2}$$

$$\sigma = \frac{6 \times 100 \times 10^3 \times 10 \times 10^{-3}}{50 \times 80^2 \times 10^{-9}} = 18.75 \text{ MPa}$$

74. The frequency of oscillation is the number of cycles per unit time described by the particle, given by the relation __________.

A. $f = \frac{\omega}{2\pi}$

B. $\frac{1}{f} = \frac{\omega}{2\pi}$

C. $f' = \frac{2\pi r}{T}$

D. $f' = \frac{2\pi NT}{\omega}$

Ans. A

Sol. Since angular frequency is terms of frequency (f in Hz) is given as:

$\omega = 2\pi f$

Thus, $f = \frac{\omega}{2\pi}$

75. A particle of mass 1 kg moves in a straight line under the influence of a force which increases linearly with time at the rate of 60 N/s, it being 40 N initially. The position of the particle after a lapse of 5 s, if it started from rest at the origin, will be ___________.

A. 1250 m B. 1500 m

C. 1750 m D. 2000 m

Ans. A

Sol. Given:

Mass: $m = 1$ kg

$$\frac{F}{t} = 60 \text{ and } F = m\frac{dv}{dt}$$

$$\frac{m}{t}.\frac{dv}{dt} = 60$$

$$dv = 60t \ dt$$

$$v = \frac{60t^2}{2} + c_1$$

At t = 0, v = 0

$$\Rightarrow v = \frac{60t^2}{2}$$

$$s = \frac{60t^3}{6} + c_1t + c_2$$

At t = 0, s = 0, Thus: $C_2 = 0$

$$S = \frac{60 \times (5)^3}{6} = 1250 \text{ m}$$

76. Rails are laid such that there will be no stress in them at 24 °C. If the rails are 32 m long with an expansion allowance of 8 mm per rail, coefficient of linear expansion $\alpha = 11 \times 10^{-6} / {}^\circ C$ and E = 205 GPa, the stress in the rails at 80 °C will be nearly

A. 68 MPa B. 75 MPa

C. 83 MPa D. 90 MPa

Ans. B

Sol. Given,

Length, $L = 32$ m

expansion allowance = 8 mm per rail,

coefficient of linear expansion

$\alpha = 11 \times 10^{-6} / {}^\circ C$

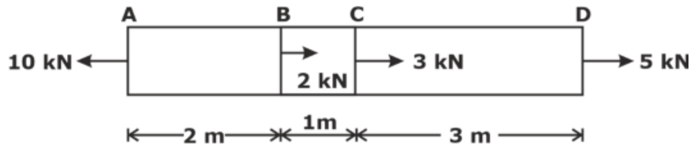
Young's Modulus of elasticity E = 205GPa,

$$\frac{\sigma_{th}}{E} = \left(\frac{\alpha \Delta TL - \delta}{L}\right)$$

$$\frac{\sigma_{th}}{205 \times 10^3} = \left(\frac{11 \times 10^{-6} \times 56 \times 32000 - 8}{32000}\right)$$

$$\sigma_{th} = 75.03 \text{ MPa}$$

77. The loads acting on a 3 mm diameter bar at different points are as shown in the figure:



If E = 205 GPa, the total elongation of the bar will be nearly

A. 29.7 mm B. 25.6 mm

C. 21.5 mm D. 17.4 mm

Ans. A

Sol. Given,

Young's modulus of elasticity E = 205 GPa,

Diameter of bar = 3 mm

$$\delta L_{total} = \frac{P_1L_1}{AE} + \frac{P_2L_2}{AE} + \frac{P_3L_3}{AE}$$

$$P_1 = 10\,kN,\ P_2 = 10 - 2 = 8\,kN, P_3 = 5\,kN$$

$$L_1 = 2000\,mm,\ L_2 = 1000\,mm, L_3 = 3000\,mm$$

$$A = \frac{\pi}{4}(3)^2, E = 205 \times 10^3 \text{ MPa}$$

$$\delta L_{total} = \frac{(10 \times 10^3 \times 2000) + (8 \times 10^3 \times 1000) + (5000 \times 3000)}{\frac{\pi}{4} \times (3)^2 \times 205 \times 10^3}$$

$= 29.68$ mm

78. A hollow circular bar used as a beam has its outer diameter thrice the inside diameter. It is subjected to a maximum bending moment of 60 MN-m. If the permissible bending stress is limited to 120 MPa, the inside diameter of the beam will be___.

A. 49.2 mm

B. 53.4 mm

C. 57.6 mm

D. 61.8 mm

Ans. C

Sol. Given,

outer diameter thrice the inside diameter

$D_o = 3D_i$

permissible bending stress is limited ,

$\sigma = 120 MPa$

maximum bending moment $M = 60 MNm$

$$\Rightarrow \sigma = \frac{32M}{\pi D_o^3 (1 - k^4)}$$

$$D_0^3 = \frac{32 \times 60 \times 10^6}{\pi \times 120 \times (1 - 0.33^4)} \Rightarrow D_o = 172.76mm$$

$$D_i = \frac{D_o}{3} = \frac{172.76}{3} = 57.6mm$$

79. In a beam of I-section, which of the following parts will take the maximum shear stress when subjected to traverse loading?

1. Flange
2. Web

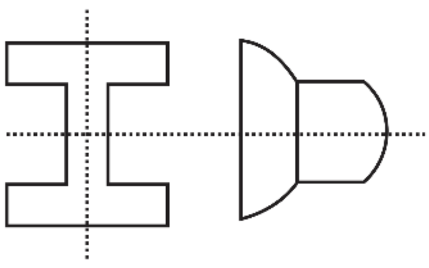
Select the correct answer using the code given below.

A. 1 only B. 2 only

C. Both 1 and 2 D. Neither 1 nor 2

Ans. B

Sol.



- In an I-section of a beam subjected to transverse shear force the maximum shear stress is developed at the centre of the web.

80. Which of the following statements is/are correct?

1. In uniformly distributed load, the nature of shear force is linear and bending moment is parabolic.
2. In uniformly varying load, the nature of shear force is linear and bending moment is parabolic.
3. Under no loading condition, the nature of shear force is linear and bending moment is constant.

Select the correct answer using the code given below.

A. 1 and 2 B. 1 and 3

C. 2 only D. 1 only

Ans. D

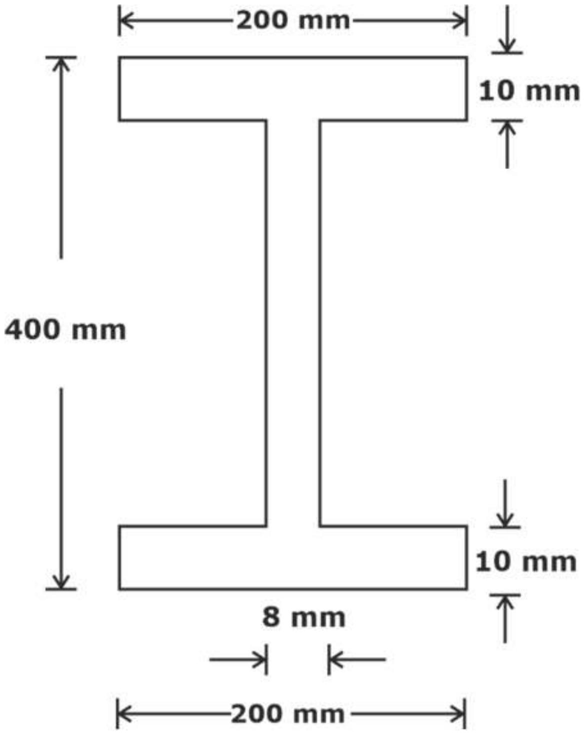
Sol.

- In uniformly distributed load, the nature of shear force is linear and bending moment is parabolic.

$$S.F. = \int \omega(x)\, dx = \omega x' (\text{linear})$$

$$B.M. = \int S.F dx = \frac{\omega x^2}{2} (\text{parabolic})$$

81. The cross-section of the beam is as shown in the figure:



If the permissible stress is 150 N/mm², the bending moment M will be nearly.

A. 1.21×10^8 N mm B. 1.42×10^8 N mm

C. 1.64×10^8 N mm D. 1.88×10^8 N mm

Ans. B

Sol. Given,

permissible stress = 150 N/mm²

moment of inertia;

$$I = \frac{200 \times 400^3}{12} - \frac{2 \times 96 \times 380^3}{12}$$

$$= 1.8871 \times 10^8 mm^4$$

$\sigma = 150$ MPa; $y = 200\,mm$

$$\text{bending moment } M = \frac{\sigma I}{y} = \frac{150 \times 1.8871 \times 10^8}{200}$$

$$= 1.42 \times 10^8 N - mm$$

82. In a propeller shaft, sometimes apart from bending and twisting, end thrust will also develop stresses which would be

A. tensile in nature and uniform over the cross-section

B. compressive in nature and uniform over the cross-section

C. tensile in nature and non-uniform over the cross-section

D. compressive in nature and non-uniform over the cross-section

Ans. B

Sol.

- In a propeller shaft, sometimes apart from bending and twisting, end thrust will also develop stresses which would be compressive in nature and uniform over the cross-section.

83. A spherical shell of 1.2 m internal diameter and 6 mm thickness is filled with water under pressure until volume is increased by 400×10^3 mm³. If E = 204 GPa, Poisson's ratio v = 0.3, neglecting radial stresses, the hoop stress developed in the shell will be nearly

A. 43 MPa B. 38 MPa

C. 33 MPa D. 28 MPa

Ans. A

Sol. Given,

internal diameter $D = 1200\,mm$;

thickness ,$t = 6\,mm$

volume is increased, $\Delta V = 400 \times 10^3$ mm³

young modulus, E = 204GPa

Poisson's ratio = 0.3,

hoop stress developed = ?

$$V = \frac{4}{3} \times \pi \times \left(600^3\right) = 904{,}778{,}684.2 \text{ mm}^3$$

$$\epsilon_V = \frac{\delta V}{V} = \frac{3\sigma_h}{E}(1-\mu)$$

$$\Rightarrow \frac{400 \times 10^3}{904{,}778{,}684.2} = \frac{3 \times \sigma_h}{204 \times 10^3}(1-0.3)$$

$$\sigma_h = 42.94 \cong 43 \text{ MPa}$$

84. The inner diameter of a cylindrical tank for liquefied gas is 250 mm. The gas pressure is limited to 15 MPa. The tank is made of plain carbon steel with ultimate tensile strength of 340 N/mm^2, Poisson's ratio of 0.27 and the factor of safety of 5. The thickness of the cylinder wall will be.

A. 60 mm

B. 50 mm

C. 40 mm

D. 30 mm

Ans. D

Sol. Given,

Inner diameter of a cylindrical tank $D = 250\,mm$,

Gas pressure $P = 15\,MPa$,

Ultimate tensile strength $\sigma_{ut} = 340$ MPa,

Poisson's ratio = 0.27,

factor of safety = 5,

thickness of the cylinder $t = ?$

$$\frac{Pr}{t} \le \frac{\sigma_{ut}}{FOS}$$

$$\frac{15 \times 125}{t} = \frac{340}{5}$$

$$t = 27.5\,mm \simeq 30 \text{ mm}$$

85. The structure of sodium chloride is considered as

A. a body-cantered crystal

B. a simple cubic crystal

C. two interpenetrating FCC sublattices of Cl^- ions and Na^+ ions

D. a cubic crystal with Na^+ and Cl^- alternatively at the cubic corners

Ans. C

Sol.

- NaCl has a cubic unit cell. It is best thought of as a face-cantered cubic array of anions with an interpenetrating FCC cation lattice (or vice-versa).
- Each ion is 6-coordinate and has a local octahedral geometry.

86. Hardenability of steel is assessed by

A. Charpy impact test

B. Rockwell hardness test

C. Jominy end-quench test

D. open-hole test

Ans. C

Sol.

- The Jominy end quench test is used to measure the hardenability of a steel.
- This is the ability of the steel to partially or to completely transform from austenite to some fraction of martensite at a given depth below the surface, when cooled under a given condition from high temperature.

87. A metal has lattice parameter of 2.9 Å, density of 7.87 g/cc, atomic weight of 55.85, and Avogadro's number is 6.0238×10^{23}. The number of atoms per unit cell will be nearly____.

A. 1 B. 2

C. 8 D. 16

Ans. B

Sol. Given,

lattice parameter = 2.9 Å,

Density = 7.87 g/cc,

Atomic weight = 55.85,

Avogadro's number is 6.0238×10^{23},

Volumetric density, $\rho_v = \dfrac{N_{avg.} \times A}{6.023 \times 10^{23} \times a^3}$

$N_{avg.}$ = number of atoms (is to be determined)

A = Atomic weight = 55.85

V_c = volume of unit cell

$$V_c = a^3 = \left(2.9 \times 10^{-10}\right)^3 \; m^3$$

$$\rho = 7.87\,gm/cc = 7.87 \times 10^6 \;\; gm/m^3$$

$$\Rightarrow 7.87\times10^{6} = \frac{N_{avg.}\times 55.85}{\left(2.9\times10^{-10}\right)^{3}\times 6.023\times10^{23}}$$

$$\Rightarrow N_{avg.} = 2.06 \approx 2$$

88. An atomic packing factor (APF) for the BCC unit cell of hard spheres atoms will be

A. 0.63 B. 0.68

C. 0.73 D. 0.78

Ans. B

Sol.

- Atomic packing factor (APF) for the BCC unit cell of hard spheres atoms will be 0.68.

Unit cell	Effective number of atoms	Atomic packing fraction	Coordination number
Simple Cubic (SC)	1	0.52	6
Body centred Cubic (BCC)	2	0.68	8
Face centred cubic (FCC)	4	0.74	12
Hexagonal Close packed (HCP)	6	0.74	12

89. The distinct characteristic of Invar is

A. it is magnetic,

B. it has low coefficient of thermal expansion,

C. it has high tensile strength

D. it is non-corrosive,

Ans. B

Sol.

- The nickel-iron alloy Invar contains 36% nickel, and possesses the lowest thermal expansion among all metals and alloys in the range from room temperature up to approximately 230°C.

90. An alloy produced by adding 1% of tin to Muntz metal is called as

A. α brass

B. Admiralty brass

C. Naval brass

D. Leaded brass

Ans. C

Sol.

- An alloy produced by adding 1% of tin to Muntz metal is called as Naval brass.

Naval Brass = 60% Cu + 39% Zn + 1% Sn

91. A sample of glass has a crack of half-length 2 μm. The Young's modulus of glass is 70 GN/m^2 and specific surface energy is 1 J/m^2. The fractures strength will be

A. 885 MPa B. 895 MPa

C. 915 MPa D. 149.27MPa

Ans. D

Sol. Given,

Crack of half-length, a= 2μm

Young's modulus of glass, E = 70 GN/m^2,

specific surface energy = 1 J/m^2,

$$\text{Fracture strength} = \left[\frac{2E\gamma}{\pi a}\right]^{\frac{1}{2}} = \left[\frac{2\times70\times10^{9}\times1}{\pi\times2\times10^{-6}}\right]^{\frac{1}{2}}$$

$$= 149.27 \text{ MPa}$$

92. In the Pb-Sn system, the fraction of total α phase is 3 times the fraction of β phase at eutectic temperature of 182 °C, Pb with 19% Sn dissolved in it, Sn with 2.5% Pb dissolved in it, and liquid is in equilibrium. The alloy compositions of tin (Sn) and lead (Pb) are nearly.

A. 28.6% and 71.4%

B. 38.6% and 61.4%

C. 48.6% and 51.4%

D. 58.6% and 41.4%

Ans. B

Sol. Given,

Pb – Sn system:

C_{α} = 19% Sn

C_{β} = (100 – 2.5) = 97.5% Sn

Let C be composition of Sn. Then:

Now;

total α phase is 3 times the fraction of β phase at eutectic temperature of 182 °C

$F_{\alpha} = f_{\beta}$

$$\frac{(C_\beta - C_0)}{C_\beta - C_\alpha} = 3 \times \left\{\frac{C_0 - C_\alpha}{C_\beta - C_\alpha}\right\}$$

$$\frac{(97.5 - C_0)}{C_\beta - C_\alpha} = 3 \times \left\{\frac{C_0 - 19}{C_\beta - C_\alpha}\right\}$$

$$97.5 - C_o = 3C_o - 57$$

C_o = 38.60% Sn

Tin (Sn)= 38.60%

Thus,

Lead (Pb) = (100 –38.60) = 61.4%

93. A cylindrical specimen of steel having an original diameter of 12.8 mm is tensile tested to fracture and found to have engineering fracture strength σ_f of 460 MPa. If its cross-sectional diameter at fracture is 10.7 mm, the true stress at fracture will be____.

A. 660 MPa
B. 645 MPa
C. 630 MPa
D. 615 MPa

Ans. A

Sol. Given,

Cylindrical specimen of steel having an original diameter = 12.8 mm,

Engineering fracture strength σ_f = 460 MPa,

Cross-sectional diameter at fracture = 10.7 mm,

True stress at fracture;

True stress = engineering stress $\times$ (1 + true strain)

$$\sigma_T = \sigma_o \times (1 + \varepsilon)$$

Since load is constant.

$$\sigma_T \times A = \sigma_f \times A_0 = 460\left(\frac{12.8}{10.7}\right)^2 = 658.3 \text{ MPa}$$

94. An iron container 10 cm $\times$ 10 cm at its base is filled to a height of 20 cm with a corrosive liquid. A current is produced as a result of an electrolytic cell, and after four weeks, the container has decreased in weight by 70 g. If n = 2, F = 96500 C and M = 55.84 g/mole, the current will be

A. 0.05 A
B. 0.10 A
C. 0.20 A
D. 0.40 A

Ans. B

Sol. Given,

iron container size = 10 cm $\times$ 10 cm,

height = 20 cm,

F= Faraday's constant = 96500,

M = molecular wt. of metal (g/mole) = 55.84 g/mole,

Total exposure time $= 4 \times 7 \times 24 \times 3600$
$= 2419200$ sec

$\approx 2.42 \times 10^6$ S

$$Q = \frac{AI}{\rho ZF}$$

$$MRR = Q \times \rho = \frac{AI}{ZF}$$

$$I = \frac{MRR \times ZF}{A}$$

$$\Rightarrow I = \frac{mass \times ZF}{t \times A} = \frac{70 \times 2 \times 96500}{(2.42 \times 10^6 \times 55.84)} = 0.1\,A$$

95. A copper piece originally 305 mm long is pulled in tension with a stress of 276 MPa. If the deformation is entirely elastic and the modulus of elasticity is 110 GPa, the resultant elongation will be nearly

A. 0.43 mm
B. 0.54 mm
C. 0.65 mm
D. 0.77 mm

Ans. D

Sol. Given,

Length of copper piece = 305 mm,

Stress =276 MPa,

modulus of elasticity = 110GPa,

Elongation,

$$\delta\ell = \frac{PL}{AE} = \frac{\sigma L}{E} = \frac{276 \times 305}{110 \times 10^3} = 0.77\,\text{mm}$$

96. The indentation on a steel sample has been taken using 10 mm tungsten carbide ball at 500 kgf load. If the average diameter of the indentation is 2.5 mm, the BHN will be nearly____.

A. 90

B. 100

C. 110

D. 120

Ans. B

Sol. Given,

Ball diameter, D = 10 mm,

Load =500 kgf

Avg. diameter of the indentation, d = 2.5 mm

Brinell hardness number,

$$BHN = \frac{2 \times F}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

$$= \frac{2 \times 500}{\pi \times 10\left[10 - \sqrt{10^2 - 2.5^2}\right]} = 100$$

97. Which of the following statements are correct with respect to inversion of mechanisms?

1. It is a method of obtaining different mechanisms by fixing different links of the same kinematic chain.

2. It is a method of obtaining different mechanisms by fixing the same links of different kinematic chains.

3. In the process of inversion, the relative motions of the links of the mechanisms produced remain unchanged.

4. In the process of inversion, the relative motions of the links of the mechanisms produced will change accordingly.

Select the correct answer using the code given below.

A. 1 and 3 B. 1 and 4

C. 2 and 3 D. 2 and 4

Ans. A

Sol. Following are correct statements with respect to inversion of mechanisms:

1. It is a method of obtaining different mechanisms by fixing different links of the same kinematic chain.

2. In the process of inversion, the relative motions of the links of the mechanisms produced remain unchanged.

98. For the follower with stroke S, following the cycloidal motion, the radius of the rolling circle will be

A. $S \times 2\pi$ B. $\frac{S}{2\pi}$

C. $\frac{2\pi}{S}$ D. $S + 2\pi$

Ans. B

Sol. In cycloidal motion the centre anywhere on the lower portion of the diagonal such that its circumference is equal to the follower displacement,

i.e., $2\pi r = S$ or $r = \frac{S}{2\pi}$

Where r= radius of rolling circle

99. A vertical shaft of 100 mm diameter and 1 m length has its upper end fixed at the top. The other end carries a disc of 5000 N and the modulus of elasticity of the shaft material is 2×10^5 N/mm². Neglecting the weight of the shaft, the frequency of the longitudinal vibrations will be nearly___.

A. 279.5 Hz

B. 266.5 Hz

C. 253.5 Hz

D. 241.5 Hz

Ans. A

Sol. Given,

Vertical shaft,

diameter, d =100 mm,

length = 1m =1000 mm

load W = 5000 N,

modulus of elasticity $E = 2 \times 10^5 \text{ N/mm}^2$,

$$\delta = \frac{WL}{AE} = \frac{5000 \times 1000}{\frac{\pi}{4} \times 100^2 \times 2 \times 10^5} = 3.18 \times 10^{-3} \text{ mm}$$

the frequency of the longitudinal vibrations;

$$\omega_n = \sqrt{\frac{g}{\delta}} = \sqrt{\frac{9.81 \times 10^3}{3.18 \times 10^{-3}}} = 1755.019 \text{ rad/sec}$$

Natural frequency

$\omega_n = 2\pi f$

f=280 Hz

100. The accurate method of finding the natural frequency of transverse vibrations of a system of several loads attached to some shaft is

A. Dunkerley method

B. energy method

C. Stodola method

D. Dunkerley and energy method

Ans. B

Sol.

- The accurate method of finding the natural frequency of transverse vibrations of a system of several loads attached to some shaft is energy method.
- Dunkerley method and Stodola method are approximate methods.

101. The speed at which the shaft runs, so that the deflection of the shaft from the axis of rotation becomes infinite, is known as

A. whipping speed

B. damping speed

C. resonant speed

D. gravitational speed

Ans. A

Sol.

- The rotational speed at which the shaft runs so that the additional deflection of the shaft from the axis of rotation becomes infinite, is known as critical/whipping/whirling speed.

102. Which one of the following is **not** the correct statement with respect to the involute profile toothed gears in mesh?

A. Pressure angle remains constant from the start till the end of the engagement.

B. The base circle diameter and the pitch circle diameter of the two mating involutes are proportional.

C. When two involutes are in mesh, the angular velocity ratio is proportional to the size of the base circles.

D. The shape of the involute profile depends only on the dimensions of the base circle.

Ans. C

Sol. Correct statement with respect to the involute profile toothed gears in mesh:

1. Pressure angle remains constant from the start till the end of the engagement.

2. The base circle diameter and the pitch circle diameter of the two mating involutes are proportional.

3. When two involutes are in mesh, the angular velocity ratio is inversely proportional to the size of the base circles.

4. The shape of the involute profile depends only on the dimensions of the base circle.

103. The centre distance C between two gears, in terms of base circle radii R_1, R_2 and the pressure angle ϕ, is

A. $\frac{\cos\phi}{R_1 + R_2}$

B. $\frac{R_1 + R_2}{\cos\phi}$

C. $\left(\frac{R_1}{R_2}\right).\cos\phi$

D. $\left(\frac{R_2}{R_1}\right).\cos\phi$

Ans. B

Sol.

- The centre distance C between two gears, in terms of base circle radii R_1, R_2 and the pressure angle ϕ, is

Centre distance =sum of pitch circle radii

$$=\frac{R_1+R_2}{\cos\phi}$$

104. A three-cylinder single-acting engine has its cranks at 120°. The turning moment diagram for each cycle is a triangle for the power stroke with a maximum torque of 60 Nm at 60° after the dead centre of the corresponding crank. There is no torque on the return stroke. The engine runs at 400 rpm. The power developed will be___.

A. 1745 W

B. 1885 W

C. 1935 W

D. 1995 W

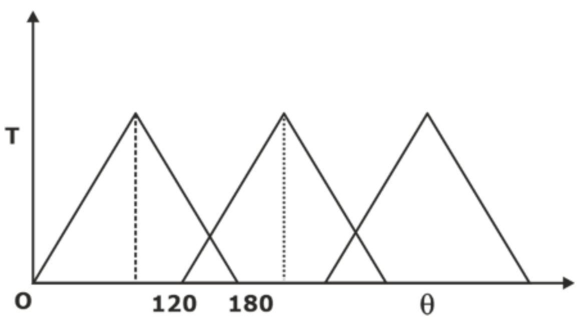
Ans. B

Sol. Given,

three-cylinder single-acting engine has its cranks at 120°,

maximum torque = 60 Nm,

engine speed = 400 rpm,



Work done $=\frac{\pi}{2}\times 60\times 3=90\pi\,N-m$

Mean torque $=\frac{\text{Work Done}}{2\pi}=\frac{90\pi}{2\pi}=45\ N-m$

Power output $P=\frac{2\pi NT}{60}=\frac{2\pi\times 400\times 45}{60}$

P = 1884.9W = 1885W

105. A vertical single-cylinder opposed piston type engine has reciprocating parts of mass 2000 kg for the lower piston and 2750 kg for the upper piston. The lower piston has a stroke of 60 cm and the engine is in primary balance. If the ratio of the length of connecting rod to crank is 4 for the lower piston and 8 for the upper piston, and when the crankshaft speed is of 135 rpm., the maximum secondary unbalanced force will be___.

A. 48935.5 N B. 46946.5 N

C. 44968.5 N D. 42989.5 N

Ans. C

Sol. Given,

lower piston mass m_1 = 2000 kg,

upper piston mass m_2 = 2750 kg,

lower piston radius $r_1=\frac{60}{2}=30\,cm$;

upper piston radius $r_2=?$

$n_1=\frac{\ell_1}{r_1}=4;\ n_2=\frac{\ell_2}{r_2}=8$

$\omega=\frac{2\pi\times 135}{60}=14.137\,rad/sec$

Since the engine is in complete primary balance,

$m_1r_1=m_2r_2$

$r_2=\frac{2000\times 30}{2750}=21.81\,m$

Unbalanced force $=\frac{m_1r_1\omega_1^2}{n_1}+\frac{m_2r_2\omega_2^2}{n_1}$

$=\left(\frac{2000\times 0.3\times 14.137^2}{4}\right)$

$+\left(\frac{2750\times 0.2181\times 14.137^2}{8}\right)$

$=29978.2+14983.48=44,961.6N$

106. The reciprocating mass is balanced when primary force is

1. balanced by the mass $= cmr\omega^2 \cos\theta$

2. unbalanced by the mass $= cmr\omega^2 \cos\theta$

3. balanced by the mass $= (1-c)cmr\omega^2\theta$

4. unbalanced by the mass $= (1-c)cmr\omega^2 \cos\theta$

Select the correct answer using the code given below.

A. 1 and 3 B. 2 and 3

C. 1 and 4 D. 2 and 4

Ans. C

Sol. Here is extra "c" outside the bracket is misprint,

So, The reciprocating mass is balanced when primary force is__

1. Balanced by the mass $= cmr\omega^2 \cos\theta$

2. unbalanced by the mass $= (1-c)mr\omega^2 \cos\theta$

107. The active gyroscopic torque in gyroscope about a horizontal axis represents____.

A. the torque required to cause the axis of spin to precess in the vertical plane,

B. the torque required to cause the axis of spin to precess in the horizontal plane,

C. the force required to cause the axis of spin to precess in the horizontal plane,

D. the force required to cause the axis of spin to precess in the vertical plane,

Ans. B

Sol.

- In order to change in the direction of, an external torque is required is applied to the system, the requirement of external torque is known as Active Gyroscope Couple.
- Therefore, the similar torque is applied by the system to external agency in reverse direction known as Reactive Gyroscope Couple.
- So, The active gyroscopic torque in gyroscope about a horizontal axis represents the torque required to cause the axis of spin to precess in the horizontal plane.

108. The change in governor height for a Watt governor when speed varies from 100 rpm to 101 rpm will be nearly_____.

A. 1.8 mm B. 2.6 mm

C. 3.4 mm D. 4.2 mm

Ans. A

Sol. Given,

Watt governor,

Initial speed =100 rpm,

Final speed =101 rpm,

$$\omega_1 = \frac{2\pi \times 100}{60} = 10.47 \text{ rad/sec}$$

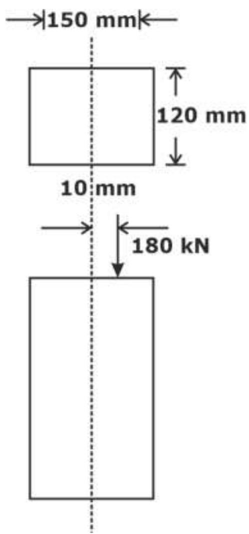
$$\omega_2 = \frac{2\pi \times 101}{60} = 10.57 \text{ rad/sec}$$

Change in governor height;

$$h = \frac{g}{\omega_1^2} - \frac{g}{\omega_2^2} = 9.81\left[\frac{1}{10.47^2} - \frac{1}{10.57^2}\right]$$

$= 1.68$ mm.

109. A rectangular strut is 150 mm wide and 120 mm thick. It carries a load of 180 kN at an eccentricity of 10 mm in a plane bisecting the thickness as shown in the figure:



The maximum intensity of stress in the section will be____.

A. 14 MPa B. 12 MPa

C. 10 MPa D. 8 MPa

Ans. A

Sol. Given,

Rectangular strut,

width =150 mm

thickness = 120 mm

load = 180 kN,

eccentricity = 10 mm

maximum stress;

$$\sigma_{max} = \frac{My}{I} + \frac{P}{A} = \frac{Pey}{I} + \frac{P}{A}$$

$$\sigma_{max} = \left(\frac{180 \times 10^3 \times 10 \times 75}{\frac{120 \times 150^3}{12}}\right) + \left(\frac{180 \times 10^3}{120 \times 150}\right)$$

σ_{max} = 4 + 10 = 14MPa

110. The theory of failure used in designing the ductile materials in a most accurate way is by

1. maximum principal stress theory
2. distortion energy theory
3. maximum strain theory

Select the correct answer using the code given below.

A. 1, 2 and 3

B. 1 only

C. 2 only

D. 3 only

Ans. C

Sol.

- For ductile materials, the most appropriate failure theory is Maximum shear stress theory (over safe, not economical) and maximum distortion energy theory (safe and economical).

111. When a load of 20kN is gradually applied at a particular point in a beam, it produces a maximum bending stress of 20 MPa and a deflection of 10 mm. What will be the height from which a load of 5 kN should fall onto the beam at the same point if the maximum bending stress is 40 MPa?

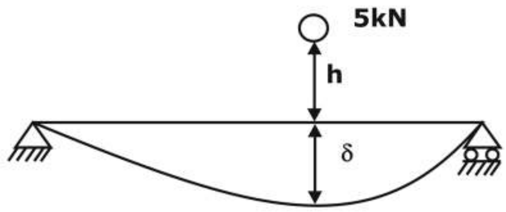
A. 80 mm B. 70 mm

C. 60 mm D. 50 mm

Ans. C

Sol. Given,

Deflection $\delta = 10\,mm$,



Case-1:

P_{static} = 20kN, σ_{static} = 20MPa

δ_{static} = 10 mm

δ_{static} corresponding to 5kN

$$\sigma_{impact} = \sigma_{static}\left[1 + \sqrt{1 + \frac{2h}{\delta_{static}}}\right]$$

$$\delta_{static} = \frac{PL}{AE}$$

$P_{static} \; \alpha \; \delta_{static}$

$$\frac{(P_{static})_1}{(P_{static})_2} = \frac{(\delta_{static})_1}{(\delta_{static})_2}$$

$$\frac{(P_{static})_1}{(\delta_{static})_1} = \frac{(P_{static})_2}{(\delta_{static})_2}$$

$$\frac{20}{10} = \frac{5}{(\delta_{static})_2}$$

$(\delta_{static})_2$ = 2.5 mm

then σ_{static} =?

Bending stress $\sigma = \frac{My}{I}$

$$\sigma = \left(\frac{PL}{4}\right)\frac{y}{I}$$

Rest is const. only depends on P

$$\frac{(\sigma_{static})_1}{(P_{static})_1} = \frac{(\sigma_{static})_2}{(P_{static})_2}$$

$$\frac{20}{20} = \frac{(\sigma_{static})_2}{5}$$

$(\sigma_{static})_2 = 5$

Now,

$$\sigma_{impact} = \sigma_{static}\left[1+\sqrt{1+\frac{2h}{\delta_{static}}}\right]$$

$$\sigma_{Impact} = \sigma_{static}\left[1+\sqrt{1+\frac{2h}{2.5}}\right]$$

$$40 = 5\left[1+\sqrt{1+\frac{2h}{2.5}}\right]$$

$$49 = 1+\frac{2h}{2.5}$$

h = 60 mm

112. The areas of fatigue failure in a part may be in the

1. region having slow growth of crack with a fine fibrous appearance.

2. region having faster growth of crack with a fine fibrous appearance.

3. region of sudden fracture with a coarse granular appearance.

4. region of gradual fracture with a coarse granular appearance.

Select the correct answer using the code given below.

A. 2 and 3 B. 2 and 4

C. 1 and 4 D. 1 and 3

Ans. D

Sol. The areas of fatigue failure in a part may be in the_____.

1. Region having slow growth of crack with a fine fibrous appearance.

2. Region of sudden fracture with a coarse granular appearance.

113. The shock-absorbing capacity (resilience) of bolts can be increased by

A. increasing the shank diameter above the core diameter of threads.

B. reducing the shank diameter to the core diameter of threads.

C. decreasing the length of shank portion of the bolt.

D. pre-heating of the shank portion of the bolt

Ans. B

Sol.

- If the shank of the bolt is turned down to a diameter equal to even slightly less than the core diameter of the thread, then the shank of the bolt will undergo a higher stress.
- This means that the shank will absorb a large portion of the energy thus relieving the material at the section near the thread.
- The bolt in this way becomes stronger and lighter and it increases the shock absorbing capacity of the bolt.

114. The torque required to tighten the bolt comprises of the___.

A. torque required in overcoming thread friction only.

B. torque required in inducing the pre-load only.

C. torque required in overcoming circumferential hoop stress.

D. torque required in overcoming thread friction and inducing the pre-load and also the torque required to overcome collar friction between the nut and the washer.

Ans. D

Sol. The torque required to tighten the bolt comprises of the;

- Torque required in overcoming thread friction,
- Inducing the pre-load and also the torque required to overcome collar friction between the nut and the washer.

115. A steel spindle transmits 4 kW at 800 rpm. The angular deflection should not exceed 0.25°/m length of the spindle. If the modulus of rigidity for the material of the spindle is 84 GPa, the diameter of the spindle will be___.

A. 46 mm B. 42 mm

C. 38 mm D. 34 mm

Ans. D

Sol. Power transmits, P = 4 kW,

Angular deflection =0.25°/m length of the spindle

Speed, N= 800 rpm

modulus of rigidity for the material, G = 84GPa

$$\text{Torque}, T = \frac{P \times 60000}{2\pi N} = \frac{4 \times 60,000}{2\pi \times 800}$$

$= 47.74 \text{ N} - \text{m}$

$$\theta = \frac{TL}{GJ}$$

$$\frac{0.25 \times \pi}{180} = \frac{47.74 \times 10^3 \times 1000}{84 \times 10^3 \times \frac{\pi}{32} d^4}$$

$\Rightarrow d = 34\,\text{mm}$

116. A taper roller bearing has a dynamic load capacity of 26 kN. The desired life for 90% of the bearings is 8000 hr and the speed is 300 rpm. The equivalent radial load that the bearing can carry will be nearly.

A. 5854 N B. 5645 N

C. 5436 N D. 5227 N

Ans. A

Sol. Given,

dynamic load capacity $C = 26\,\text{kN}$,

Desired life $L_h = 8000\,\text{hrs}$,

Speed $N = 300\text{rpm}$

$$L_{90} = \frac{L_h \times N \times 60}{10^6} = \frac{8000 \times 300 \times 60}{10^6}$$

$= 144\,\text{mill rev}$

Equivalent radial load;

$$P_e = \frac{C}{(L_{90})^{3/10}} = \frac{26000}{144^{0.3}} = 5854\,\text{N}$$

117. Hollow shafts are stronger than solid shafts having same weight because

A. the stiffness of hollow shaft is less than that of solid shaft

B. the strength of hollow shaft is more than that of solid shaft

C. the natural frequency of hollow shaft is less than that of solid shaft

D. in hollow shafts, material is not spread at large radius

Ans. B

Sol.

- Strength of hollow shaft is more than that of solid shaft because polar section modulus of hollow shaft is greater than that of solid shaft.

118. A propeller shaft is required to transmit 45 kW power at 500 rpm. It is a hollow shaft having inside diameter 0.6 times the outside diameter. It is made of plain carbon steel and the permissible shear stress is 84 N/mm^2. The inner and outer diameters of the shaft are nearly.

A. 21.7 mm and 39.1 mm

B. 23.5 mm and 39.1 mm

C. 21.7 mm and 32.2 mm

D. 23.5 mm and 32.2 mm

Ans. B

Sol. Given,

Power transmits $P = 45\,\text{kW}$,

Speed $N = 500\,\text{rpm}$,

$$\text{Torque}, T = \frac{P \times 60000}{2\pi N}$$

$$= \frac{45 \times 60000}{2\pi \times 500} = 859.436 \text{ N} - \text{m}$$

$D_i = 0.6 D_\circ$,

Permissible shear stress $\tau = 84 \text{ N/mm}^2$

$$\tau = \frac{16 \times T}{\pi D_\circ^3 \left(1 - k^4\right)}$$

$$84 = \frac{16 \times 859.436 \times 10^3}{\pi \times D_o^3 \left(1 - 0.6^4\right)}$$

$D_o = 39.11$ mm, $D_i = 23.47$ mm

119. A bicycle and rider travelling at 12 km/hr on a level road have a mass of 105 kg. A brake is applied to a rear wheel having 800 mm diameter. The pressure on the brake is 80 N and the coefficient of friction is 0.06. The number of turns of the wheel before coming to rest will be______.

A. 48.3 revolutions

B. 42.6 revolutions

C. 38.3 revolutions

D. 32.6 revolutions

Ans. A

Sol. Given,

Velocity of bicycle $V = 12\,\text{kmph}$

Mass $m = 105\,\text{kg}$,

Wheel Diameter $D = 800\,\text{mm}$

pressure on the brake P = 80 N,

coefficient of friction is 0.06,

KE = Work done

$$\frac{1}{2} \times mv^2 = F \times \text{distance}$$

$$\frac{1}{2} \times 105 \times \left(12 \times \frac{5}{18}\right)^2 = (0.06 \times 80) \times \text{distance}$$

Distance = 121.52 m

$$\text{Number of revolution} = \frac{\text{Distance}}{\text{Circumference}}$$

$$= \frac{121.52}{2\pi \times 0.4} = 48.3\,\text{rev}$$

120. To avoid self-engagement in cone clutch, its semi-cone angle is always kept.

A. smaller than the angle of static friction

B. equal to the angle of static friction

C. greater than the angle of static friction

D. half of the angle of static friction

Ans. C

Sol.

- If the semi-cone angle is made greater than angle of static friction, then the self-alignment of the clutch can be avoided.

121. In case of arc welding of steel with a potential of 20 V and current of 200 A, the travel speed is 5 mm/s and the cross-sectional area of the joint is 20 mm^2. The heat required for melting steel may be taken as 10 J/mm^3 and heat transfer efficiency as 0.85. The melting efficiency will be nearly

A. 18% B. 29%

C. 36% D. 42%

Ans. B

Sol. Given,

Voltage, $V = 20V$

Current, $I = 200\,A$

Welding speed, $v = 5\,\text{mm/s}$

Cross-sectional area, $A = 20\,\text{mm}^2$

Heat required to melt steel $= 10\,\text{J/mm}^3 = H_m$

Heat transfer efficiency, $\eta_{th} = 0.85$

Melting efficiency, $\eta_m = ?$

$$\eta_m = \frac{\text{H.R.}}{\text{H.S.}} = \frac{10}{\frac{VI \times \eta_{h.t.}}{A \times v}}$$

$$= \frac{10}{\frac{20 \times 200 \times 0.85}{20 \times 5}} = 29.41\%$$

122. What is the force required for 90° bending of St50 steel of 2 mm thickness in a V-die, if the die opening is taken as 8 times the thickness and the length of the bent part is 1 m, ultimate tensile strength is 500 MPa and K = 1.33?

A. 166.25 kN

B. 155.45 kN

C. 154.65 kN

D. 143.85 kN

Ans. A

Sol. Ultimate tensile strength, $UTS = 500\,MPa$

Thickness, $t = 2\,mm$

Length of bent part, $L = 1m$

Width of die opening,

$W = 8 \times \text{thickness} = 8 \times 2 = 16\,mm$

$K = 1.33$ for V-die

Bending force,

$$F = \frac{k \times L\sigma_{ut} \times t^2}{w}$$

$$F = \frac{1.33 \times \left(1 \times 10^3\right) \times 500 \times 2^2}{16}$$

$= 16,6250\,N = 166.25\,kN$

123. A graph is drawn to a vertical magnification of 10000 and horizontal magnification of 100, and the areas above and below the datum line are as follows:

The average roughness R_a for sampling length of 0.8 mm will be___

Above	150 mm^2	80 mm^2	170 mm^2	40 mm^2
Below	80 mm^2	60 mm^2	150 mm^2	120 mm^2

A. 1.14 μm B. 1.10 μm

C. 1.06 μm D. 1.02 μm

Ans. C

Sol. Given,

Vertical magnification, $VM = 10,000$

Horizontal magnification, $HM = 100$

Sum of areas above and below datum line,

$\Sigma A = 150 + 80 + 170 + 40 + 80 + 60 + 150 + 120$

$= 850\,mm^2$

Sampling length, $L = 0.8\,mm$

Average roughness,

$$R_a = \frac{\Sigma A}{L} \times \frac{1}{\text{vertical scale}} \times \frac{1}{\text{horizontal scale}}$$

$$R_a = \frac{\Sigma A}{L} \times \frac{1}{10^4} \times \frac{1}{10^2}$$

$$= \frac{850}{0.8} \times \frac{1}{10^6}$$

$R_a = 1.06\ \mu m$

124. The radius of arc is measured by allowing a 20 mm diameter roller to oscillate to and fro on it and the time for 25 oscillations is noted at 56.25 s. The radius of arc will be

A. 865 mm B. 850 mm

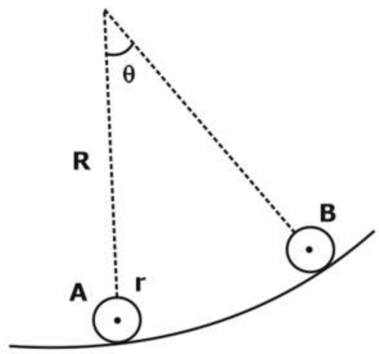
C. 835 mm D. 820 mm

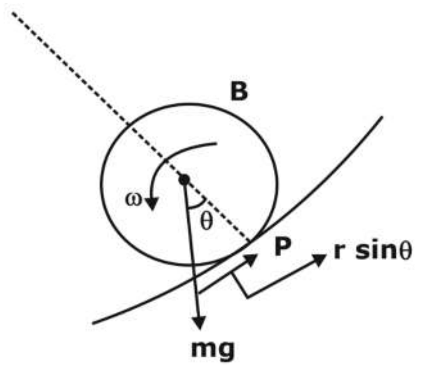
Ans. B

Sol. Given,

Diameter of roller, $d = 20\,mm$

Time period, $T = \frac{56.25}{25} = 2.25$





Disturbing force + Restoring force = 0

$I\alpha + mg\ r\sin\theta = 0$ ------- (1)

Moment of inertia $I = mr^2 + \frac{mr^2}{2} = \frac{3}{2}mr^2$

For pure rolling condition,

$V = (R - r)\dot{\theta} = r\omega$

$\omega = \left(\frac{R-r}{r}\right)\dot{\theta}$

$\alpha = \frac{d\omega}{dt} = \left(\frac{R-r}{r}\right)\ddot{\theta}$ put in ------- (1)

$\frac{3}{2}mr^2\left(\frac{R-r}{r}\right)\ddot{\theta} + mgr\ \sin\theta = 0$

$\omega_n = \sqrt{\frac{2g(\sin\theta)}{3(R-r)}}$

For small oscillation,

Sinθ = θ

$\omega_n = \sqrt{\frac{2g}{3(R-r)}}$

$T = \frac{2\pi}{\omega_n} = 2\pi\sqrt{\frac{3(R-r)}{2g}}$

$2.25 = 2\pi\sqrt{\frac{3(R-0.01)}{2\times 9.81}}$

$R = 0.848m \approx 850$ mm

125. Which one of the following systems is consisting of processing stations, material handling and storage, computer control system and human labour?

A. Portable manufacturing system

B. Focused integrated system

C. Flexible manufacturing system

D. Automated integrated system

Ans. C

Sol.

- FMS is an automated, mid volume manufacturing system.
- All components are computer controlled.
- It has independent CNC machines capable of performing multiple functions and having automated tool changer.
- All components are computer controlled.
- Equipment such as coordinate measurement machines are also present.

126. A project initially costs Rs. 5,000 and generates year-end cash inflows of Rs. 1,800, Rs. 1,600, Rs. 1,400, Rs. 1,200 and Rs. 1,000 respectively in five years of its life. If the rate of return is 10%, the net present value (NPV) will be______.

A. Rs. 500 B. Rs. 450

C. Rs. 400 D. Rs. 350

Ans. B

Sol. Given,

Project initially cost = Rs. 5,000

year-end cash inflows of Rs. 1,800, Rs. 1,600, Rs. 1,400, Rs. 1,200 and Rs. 1,000

rate of return = 10%,

$NPV = \left[\frac{1800}{1.1} + \frac{1600}{1.1^2} + \frac{1400}{1.1^3} + \frac{1200}{1.1^4} + \frac{1000}{1.1^5}\right] - 5000$

$= \left[1636.36 + 1322.31 + 1051.84 + 819.62 + 620.92\right]$

$= 451.055 \cong 450$

127. What is the mode for the following distribution?

Gross profit as percentage of sales	Number of companies
0-7	19
7-14	25
14-21	36
21-28	72
28-35	51
35-42	43
42-49	28

A. 19.55 B. 21.40

C. 23.25 D. 25.10

Ans. D

Sol. Given,

Here maximum frequency is 72 corresponding to the 21-28.

So, lower limit (L) = 21,

Range (h) = 7,

$$\text{Mode} = L + \left[\frac{(f_n - f_{n-1})}{(f_n - f_{n-1}) + (f_n - f_{n+1})}\right] \times h$$

$$= 21 + \frac{(72-36)}{(72-36)+(72-51)} \times 7$$

$$= 21 + \frac{36}{36+21} \times 7 = 25.42$$

128. Consider the following data for quality acceptance process:

N= 10000

n = 89

c = 2

p = 0.01 (incoming lots of quality)

P_a = 0.9397

The AOQ will be____.

A. 0.93% B. 0.84%

C. 0.75% D. 0.66%

Ans. A

Sol. Given,

Lot size, N= 10000

Sample size, n = 89

Fraction defective, p = 0.01 (incoming lots of quality)

Probability of acceptance, P_a = 0.9397

Average outgoing quality,

$$AOQ = \frac{(N-n)P_aP}{N}$$

$$= \frac{(10000-89) \times 0.9397 \times 0.01}{10000}$$

$$= 0.0093 \text{ or } 0.93\%$$

129. An engine is to be designed to have a minimum reliability of 0.8 and minimum availability of 0.98 over a period of 2×10^3 hr. The MTTR is nearly

A. 168 hr B. 174 hr

C. 183 hr D. 188 hr

Ans. C

Sol. Given,

$R(t) = 0.8$ for $t = 2 \times 10^3$ hr ,

$R(t) = e^{-\lambda t}$

$$\therefore \lambda = -\frac{\ln(0.8)}{2 \times 10^3} = 1.12 \times 10^{-4} \text{ / hr}$$

Steady state availability,

$$0.98 = \frac{\mu}{\mu + \lambda}$$

$$\Rightarrow \mu = 5.49 \times 10^{-3} \text{ / hr}$$

$$\therefore \text{mean time to repair (MTTR)} = \frac{1}{\mu}$$

$$= \frac{10^3}{5.49} = 182.2 \text{ hrs}$$

130. Which one of the following relations with usual notations will hold good in a dynamic vibration absorber system under tuned conditions?

A. $k_1k_2 = m_1m_2$ B. $k_1m_2 = m_1k_2$

C. $k_1m_1 = k_2m_2$ D. $k_1 + k_2 = m_1 + m_2$

Ans. B

Sol. Dynamic vibration absorber system,

For dynamic system of vibration absorbed,

$f_1 = f_2$ (Frequency is equal)

$$\frac{1}{2\pi}\sqrt{\frac{k_1}{m_1}} = \frac{1}{2\pi}\sqrt{\frac{k_2}{m_2}}$$

$$\therefore k_1m_2 = k_2m_1$$

131. In ultrasonic waves, the frequencies for non-destructive testing of materials are in the range of

A. 0.5 MHz to 10 MHz

B. 10 MHz to 20 MHz

C. 20 MHz to 30 MHz

D. 30 MHz to 40 MHz

Ans. A

Sol.

- In ultrasonic waves, the frequencies for non-destructive testing of materials are approximate in the range of 0.5 MHz to 10 MHz.

132. The Curie point for most ferrous magnetic materials is about____.

A. 390 °C B. 540 °C

C. 760 °C D. 880 °C

Ans. C

- Most of ferromagnetic substances have a relatively high Curie temperature.
- For nickel (Non-ferrous) the Curie temperature is about 360°C, iron (ferrous) 770°C, cobalt 1121°C.
- Gadolinium used in this experiment has a Curie temperature of about 20°C.

133. Which of the following is one of the basic units of memory controller in micro-controller?

A. Microcode engine

B. Master program counter

C. Program status word

D. Slave program counter

Ans. D

Sol.

- Slave program counter is one of the basic units of memory controller in micro-controller.

134. Which one of the following ways will be adopted to store the program counter contents?

A. Last-in-First-out (LIFO)

B. First-in-First-out (FIFO)

C. Last-in-Last-out (LILO)

D. First-in-Last-out (FILO)

Ans. A

Sol.

- Last-in-First-out way adopted to store the program counter contents.
- A program counter is a register in a computer processor that contains the address location of the instruction being executed at the current time. It is also known Instruction Pointer

135. In ladder logic programming, an alternative in place of using same internal relay contact for every rung is to use____.

A. battery-backed relay

B. dummy relay

C. one-shot operation

D. master control relay

Ans. D

Sol.

- Some internal relay contacts in each output rung are used to turn off or on the whole block of outputs simultaneously.
- An alternative way of programming to achieve the same effect is to use a master control relay.

136. Consider the following statements:

1. The term 'attenuation' is used to describe the process of removing a certain band of frequencies from a signal and permitting others to be transmitted.

2. The Wheatstone bridge can be used to convert a voltage change to an electrical resistance change.

Which of the above statements is/are correct?

A. 1 only B. 2 only

C. Both 1and 2 D. Neither 1 nor 2

Ans. D.

Sol.

- The wheat stone bridge can be used to convert a resistance change to a voltage change.
- The Wheatstone bridge circuit cannot be used to measure very large resistance as the galvanometer becomes insensitive in such cases. Very high currents produce heat and can damage the resistors.
- The term ‘filtering’ is used to describe the process of removing a certain band of frequencies from a signal and permitting others to be transmitted.

137. At time t, the excitation voltage to a resolver is 24 V. The shaft angle is 90°. The output signals from the resolver V_{s1} and V_{s2} will be

A. 12 V and 0 V
B. 24 V and 0 V
C. 12 V and 12 V
D. 24 V and 12 V

Ans. B

Sol. Given,

Excitation voltage to a resolver = 24 V,

Shaft angle = 90°,

Output signals of resolver are;

$V_{s1} = V_1 \sin\alpha;$

$V_{s2} = V_1 \cos\alpha$

For $\alpha = 90°$

$V_{s1} = 24V$ and $V_{s2} = 0V$

138. An actuator having a stem movement at full travel of 30 mm is mounted with a control valve having an equal percentage plug and with minimum flow rate of 2 m^3/s and maximum flow rate of 24 m^3 /s. When the stem movement is 10 mm, the flow rate will be

A. 3.4 m^3/s
B. 3.8 m^3 /s
C. 4.2 m^3 /s
D. 4.6 m^3 /s

Ans. D

Sol. Given:

Maximum flow rate (Q_{max}) = 24 m^3/s,

Minimum flow rate (Q_{min}) = 2 m^3/s,

Value Range Ability (R)

$= \frac{\text{maximum flow rate}}{\text{minimum flow rate}} = \frac{24}{2} = 12$

maximum valve Travel (T) = 30mm, when

x = 10mm

the flow rate $Q = Q_0 R^{\left(\frac{x}{T}-1\right)}$

$Q = 24 \times (12)^{\left\{\frac{10}{30}-1\right)}$

Q = 4.57 m^3/s

139. In a rack and pinion system, rack is an element moving in translational direction and pinion is a rotary gear. Which one of the following statements is correct?

A. Translational acceleration is directly proportional to the moment of inertia of pinion.

B. Translational acceleration is inversely proportional to the moment of inertia of pinion.

C. Angular acceleration is inversely proportional to the torque on pinion shaft.

D. Translational velocity is directly proportional to the moment of inertia of pinion.

Ans. B

Sol. Translational acceleration $a_t = r\alpha$

Where r = radius of pinion,

α = angular acceleration of pinion

$\text{Torque} = I_{pinion}\alpha$

$\alpha = \frac{\text{Torque}}{I_{pinion}}$

$a_t = \frac{Tr}{I_{pinion}}$

$a_t \propto \frac{1}{I_{pinion}}$

140. For the control signal to change at a rate proportional to the error signal, the robotic controller must employ_____.

A. integral control

B. proportional-plus-integral control

C. proportional-plus-derivative control

D. proportional-plus-integral-plus-derivative control

Ans. A

Sol. Integral control:

Given that control signal should change at rate proportional to error signal i.e.

$\frac{d}{dt}\left[\Delta f(t)\right] \propto E(t)$

$\Delta f(t) = k\int E(t)\,dt$

Δ f(t) = Change of control signal (controller output)

E(t) = error signal

As the change of control signal is proportional to integral of error is represents 'Integral controller'

141. What is the minimum number of degrees of freedom that a robot needs to have in order to locate its end effectors at an arbitrary point with an arbitrary orientation in space?

A. 3 B. 4

C. 5 D. 6

Ans. D

Sol.

- The minimum number of degrees of freedom that a robot needs to have in order to locate its end effectors at an arbitrary point with an arbitrary orientation in space is 6.

142. Using a robot with 1 degree of freedom and having 1 sliding joint with a full range of 1 m, if the robot's control memory has a 12-bit storage capacity, the control resolution for the axis of motion will be

A. 0.236 mm B. 0.244 mm

C. 0.252 mm D. 0.260 mm

Ans. B

Sol. Given:

Total range of sliding joint = 1000mm

Control memory = 12 bit

No. of increments = 2^{12} = 4096

$$\text{Control Resolution} = \frac{\text{Stroke length}}{\text{Number of increment}}$$

$$\text{Control resolution} = \frac{1000}{2^n}$$

$$\text{Control resolution} = \frac{1000}{2^{12}} = 0.244\text{mm}$$

143. Assume that the joint mechanisms at serial link manipulators are frictionless. The joint torque τ required to bear an arbitrary end point force F is_____.

A. $J^{-1}F$

B. JF

C. J^TF

D. $J^{-1}F^T$

Ans. C

Sol. Joint torque:

$\tau = J^T.F$

Where,

J^T = Transpose of Jacobian matrix

F = End point force vector.

144. Rotate the vector $v = 5\hat{i} + 3\hat{j} + 8\hat{k}$ by an angle of 90° about the x-axis. The rotated vector (Hv) would be___.

A. $\begin{bmatrix}1\\3\\-8\\5\end{bmatrix}$ B. $\begin{bmatrix}-8\\5\\1\\3\end{bmatrix}$

C. $\begin{bmatrix}3\\-8\\5\\1\end{bmatrix}$ D. $\begin{bmatrix}5\\-8\\3\\1\end{bmatrix}$

Ans. D

Sol. Given,

Rotate the vector $v = 5i + 3j + 8k$ by an angle of 90° about the x-axis.

$$R_{(x,\theta)} = \begin{bmatrix}1 & 0 & 0\\0 & \text{Cos}\theta & -\text{Sin}\theta\\0 & \text{Sin}\theta & \text{Cos}\theta\end{bmatrix}$$

$$\begin{bmatrix}1 & 0 & 0\\0 & \text{Cos}90^\circ & -\text{Sin}90^\circ\\0 & \text{Cos}90^\circ & \text{Cos}90^\circ\end{bmatrix}\begin{bmatrix}5\\3\\8\end{bmatrix} = \begin{bmatrix}5\\-8\\3\\1\end{bmatrix}$$

145. Statement (I) : The function of arithmetic logic unit (ALU) in microprocessor is to perform data manipulation.

Statement (II) : The status register is where data for an input to the arithmetic and logic unit is temporarily stored.

A. Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

B. Both Statement (I) and Statement (II) are individually true but Statement (II) is **not** the correct explanation of Statement (I)

C. Statement (I) is true but Statement (II) is false

D. Statement (I) is false but Statement (II) is true

Ans. C

Sol.

- The function of arithmetic logic unit (ALU) in microprocessor is to perform data manipulation.
- Data for input to the arithmetic & logical unit is temporarily stored in 8-bit register called Accumulator.

146. Statement (I): To use a sensor, we generally need to add signal conditioning circuitry, such as circuits which amplify and convert from analog to digital, to get the sensor signal in the right form, take account of any non-linearities, and calibrate it.

Statement (II): A smart sensor is integrated with the required buffering and conditioning circuitry in a single element and provides functions beyond that of just a sensor.

A. Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

B. Both Statement (I) and Statement (II) are individually true but Statement (II) is **not** the correct explanation of Statement (I)

C. Statement (I) is true but Statement (II) is false

D. Statement (I) is false but Statement (II) is true

Ans. B

Sol.

- To use a sensor, we generally need to add signal conditioning circuitry, such as circuits which amplify and convert from analog to digital, to get the sensor signal in the right form, take account of any non-linearities, and calibrate it.
- A smart sensor is integrated with the required buffering and conditioning circuitry in a single element and provides functions beyond that of just a sensor.

147. Statement (I): The count-up overflow (OV) bit is 1 when the up-counter increments above the maximum positive value.

Statement (II): The count-down underflow (UN) bit is 1 when the counter, decrements below the minimum negative value.

A. Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

B. Both Statement (I) and Statement (II) are individually true but Statement (II) is **not** the correct explanation of Statement (I)

C. Statement (I) is true but Statement (II) is false

D. Statement (I) is false but Statement (II) is true

Ans. C

Sol.

- A typical counter count from 0 up to a predetermined value, called the "preset" value. In count down counters, the accumulated value will be decremented by one count, each time the instruction sees a false-to-true transition.
- The countdown (UN) bit is 1 when be counter decrements below maximum negative value.
- Count-down underflow (UN) decrements the accumulate value at each false to true transition and retains the accumulated value when the instruction goes false or when power cycle occurs. If the accumulation value is below the minimum range, then the underflow (UN) bit will be true.

148. Statement (I): The multiplexer is essentially an electronic switching device which enables each of the inputs to be sampled in turn.

Statement (II): A multiplexer is a circuit that is able to have inputs of data from a number of sources and then, by selecting an input channel, gives an output from just one of them.

A. Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

B. Both Statement (I) and Statement (II) are individually true but Statement (II) is **not** the correct explanation of Statement (I)

C. Statement (I) is true but Statement (II) is false

D. Statement (I) is false but Statement (II) is true

Ans. A

Sol.

- A multiplexer (or MUX) is a device that selects one of several analog or digital input signals and forwards the selected input into a single line, depending on the active select lines.
- A multiplexer connects one the input to the output according to the data on select lines so it is called as data selector.

149. Statement (I): The term 'encoder' is used for a device that provides an analog output as a result of angular or linear displacement.

Statement (II): An increment encoder detects changes in angular or linear displacement from some datum position where as an absolute encoder gives the actual angular or linear position.

A. Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

B. Both Statement (I) and Statement (II) are individually true but Statement (II) is **not** the correct explanation of Statement (I)

C. Statement (I) is true but Statement (II) is false

D. Statement (I) is false but Statement (II) is true

Ans. D

Sol.

- An encoder is a device that provides a digital output as a result of a linear or angular displacement.
- Incremental encoders, which detect changes in rotation from some datum position while absolute encoders, which give the actual angular position.

150. Statement (I): Process control valves are used to control the rate of fluid flow and are used where, perhaps, the rate of flow of a liquid into a tank has to be controlled.

Statement (II) : A common form of pneumatic actuator used with process control valves is the diaphragm actuator.

A. Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

B. Both Statement (I) and Statement (II) are individually true but Statement (II) is **not** the correct explanation of Statement (I)

C. Statement (I) is true but Statement (II) is false

D. Statement (I) is false but Statement (II) is true

Ans. B

Sol.

- Process control valves are used to control the rate of fluid flow and are used where perhaps the rate of flow of liquid into tank has to be controlled.
- A common form of pneumatic actuator used width process control valve is a diaphragm with input pressure signal from controller on one side and atmospheric pressure on the other side and the difference in pressure is termed as gauge pressure.

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