

Q. 1 – Q. 25 carry one mark each.

Q.1 The Fourier cosine series for an even function $f(x)$ is given by

$$f(x) = a_0 + \sum_{n=1}^{\infty} a_n \cos(nx).$$

The value of the coefficient a_2 for the function $f(x) = \cos^2(x)$ in $[0, \pi]$ is

- (A) -0.5 (B) 0.0 (C) 0.5 (D) 1.0

Q.2 The divergence of the vector field $\vec{u} = e^x(\cos y \hat{i} + \sin y \hat{j})$ is

- (A) 0 (B) $e^x \cos y + e^x \sin y$
(C) $2e^x \cos y$ (D) $2e^x \sin y$

Q.3 Consider a function u which depends on position x and time t . The partial differential equation

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}$$

is known as the

- (A) Wave equation
(B) Heat equation
(C) Laplace's equation
(D) Elasticity equation

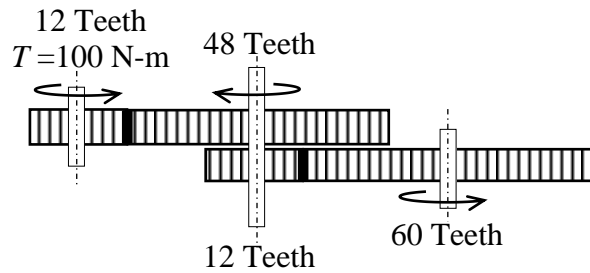
Q.4 If y is the solution of the differential equation $y^3 \frac{dy}{dx} + x^3 = 0$, $y(0) = 1$, the value of $y(-1)$ is

- (A) -2 (B) -1 (C) 0 (D) 1

Q.5 The minimum axial compressive load, P , required to initiate buckling for a pinned-pinned slender column with bending stiffness EI and length L is

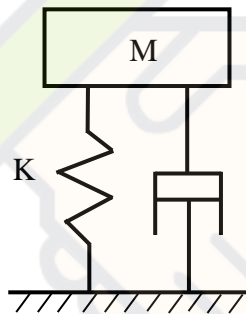
- (A) $P = \frac{\pi^2 EI}{4L^2}$ (B) $P = \frac{\pi^2 EI}{L^2}$ (C) $P = \frac{3\pi^2 EI}{4L^2}$ (D) $P = \frac{4\pi^2 EI}{L^2}$

- Q.6 A frictionless gear train is shown in the figure. The leftmost 12-teeth gear is given a torque of 100 N-m. The output torque from the 60-teeth gear on the right in N-m is



- (A) 5 (B) 20 (C) 500 (D) 2000

- Q.7 In a single degree of freedom underdamped spring-mass-damper system as shown in the figure, an additional damper is added in parallel such that the system still remains underdamped. Which one of the following statements is ALWAYS true?



- (A) Transmissibility will increase.
 (B) Transmissibility will decrease.
 (C) Time period of free oscillations will increase.
 (D) Time period of free oscillations will decrease.

- Q.8 Pre-tensioning of a bolted joint is used to

- (A) strain harden the bolt head (B) decrease stiffness of the bolted joint
 (C) increase stiffness of the bolted joint (D) prevent yielding of the thread root

- Q.9 The peak wavelength of radiation emitted by a black body at a temperature of 2000 K is 1.45 μm . If the peak wavelength of emitted radiation changes to 2.90 μm , then the temperature (in K) of the black body is

- (A) 500 (B) 1000 (C) 4000 (D) 8000

Q.10 For an ideal gas with constant properties undergoing a quasi-static process, which one of the following represents the change of entropy (Δs) from state 1 to 2?

(A) $\Delta s = C_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)$

(B) $\Delta s = C_v \ln\left(\frac{T_2}{T_1}\right) - C_p \ln\left(\frac{V_2}{V_1}\right)$

(C) $\Delta s = C_p \ln\left(\frac{T_2}{T_1}\right) - C_v \ln\left(\frac{P_2}{P_1}\right)$

(D) $\Delta s = C_v \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{V_1}{V_2}\right)$

Q.11 Select the correct statement for 50% reaction stage in a steam turbine.

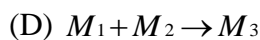
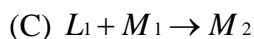
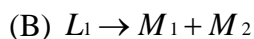
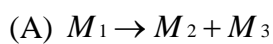
(A) The rotor blade is symmetric.

(B) The stator blade is symmetric.

(C) The absolute inlet flow angle is equal to absolute exit flow angle.

(D) The absolute exit flow angle is equal to inlet angle of rotor blade.

Q.12 Denoting L as liquid and M as solid in a phase-diagram with the subscripts representing different phases, a *eutectoid* reaction is described by



Q.13 During solidification of a pure molten metal, the grains in the casting near the mould wall are

(A) coarse and randomly oriented

(B) fine and randomly oriented

(C) fine and ordered

(D) coarse and ordered

Q.14 Match the following products with the suitable manufacturing process

Product		Manufacturing Process	
P	Toothpaste tube	1	Centrifugal casting
Q	Metallic pipes	2	Blow moulding
R	Plastic bottles	3	Rolling
S	Threaded bolts	4	Impact extrusion

(A) P-4, Q-3, R-1, S-2

(B) P-2, Q-1, R-3, S-4

(C) P-4, Q-1, R-2, S-3

(D) P-1, Q-3, R-4, S-2

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Q.15 Feed rate in slab milling operation is equal to

- (A) rotation per minute (rpm)
- (B) product of rpm and number of teeth in the cutter
- (C) product of rpm, feed per tooth and number of teeth in the cutter
- (D) product of rpm, feed per tooth and number of teeth in contact

Q.16 Metal removal in electric discharge machining takes place through

- (A) ion displacement
- (B) melting and vaporization
- (C) corrosive reaction
- (D) plastic shear

Q.17 The preferred option for holding an odd-shaped workpiece in a centre lathe is

- (A) live and dead centres
- (B) three jaw chuck
- (C) lathe dog
- (D) four jaw chuck

Q.18 A local tyre distributor expects to sell approximately 9600 steel belted radial tyres next year. Annual carrying cost is Rs. 16 per tyre and ordering cost is Rs. 75. The economic order quantity of the tyres is

- (A) 64
- (B) 212
- (C) 300
- (D) 1200

Q.19

If $A = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 4 & 5 \\ 0 & 0 & 1 \end{bmatrix}$ then $\det(A^{-1})$ is _____ (correct to two decimal places).

Q.20 A hollow circular shaft of inner radius 10 mm, outer radius 20 mm and length 1 m is to be used as a torsional spring. If the shear modulus of the material of the shaft is 150 GPa, the torsional stiffness of the shaft (in kN-m/rad) is _____ (correct to two decimal places).

Q.21 Fatigue life of a material for a fully reversed loading condition is estimated from

$$\sigma_a = 1100N^{-0.15},$$

where σ_a is the stress amplitude in MPa and N is the failure life in cycles. The maximum allowable stress amplitude (in MPa) for a life of 1×10^5 cycles under the same loading condition is _____ (correct to two decimal places).

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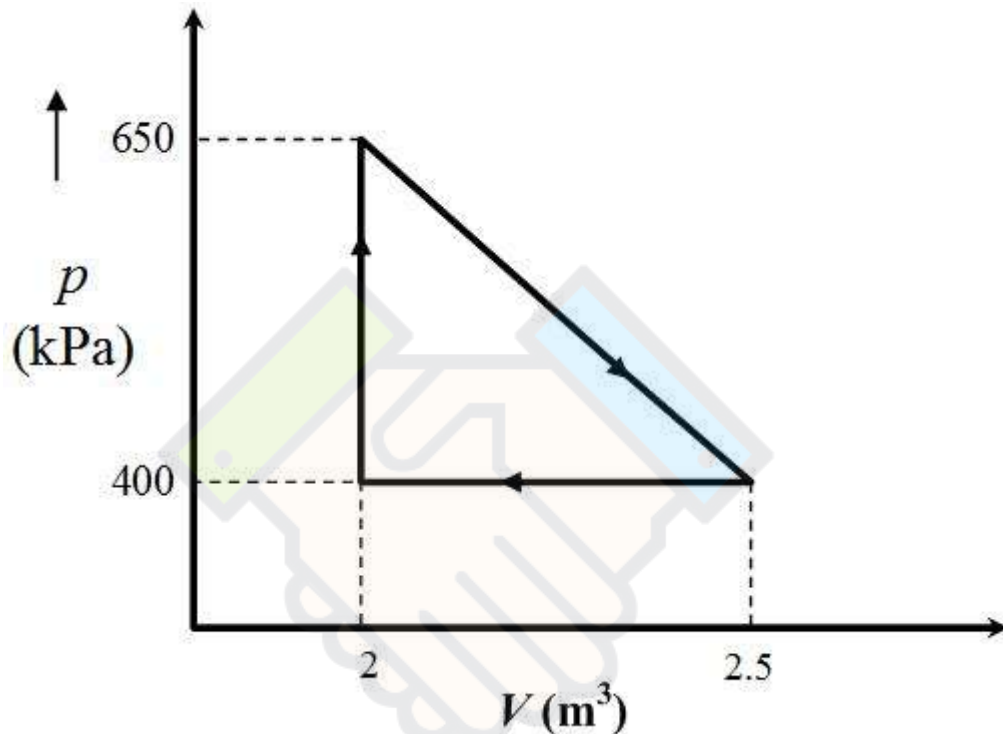
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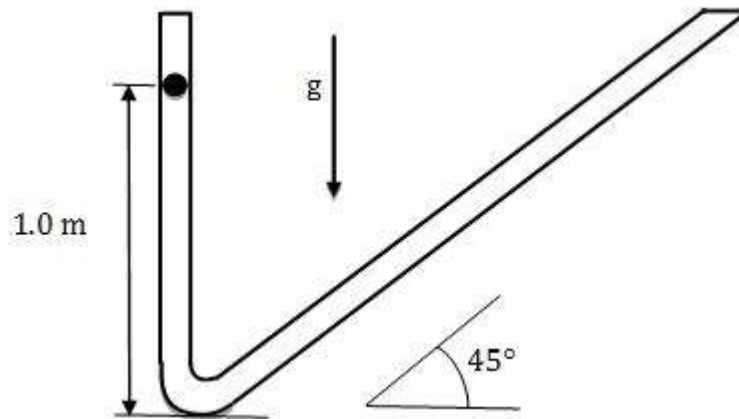
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- Q.22 The viscous laminar flow of air over a flat plate results in the formation of a boundary layer. The boundary layer thickness at the end of the plate of length L is δ_L . When the plate length is increased to twice its original length, the percentage change in laminar boundary layer thickness at the end of the plate (with respect to δ_L) is _____ (correct to two decimal places).
- Q.23 An engine operates on the reversible cycle as shown in the figure. The work output from the engine (in kJ/cycle) is _____ (correct to two decimal places).



- Q.24 The arrival of customers over fixed time intervals in a bank follow a Poisson distribution with an average of 30 customers/hour. The probability that the time between successive customer arrival is between 1 and 3 minutes is _____ (correct to two decimal places).

- Q.25 A ball is dropped from rest from a height of 1 m in a frictionless tube as shown in the figure. If the tube profile is approximated by two straight lines (ignoring the curved portion), the total distance travelled (in m) by the ball is _____ (correct to two decimal places).



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Q. 26 – Q. 55 carry two marks each.

- Q.26 Let z be a complex variable. For a counter-clockwise integration around a unit circle C , centred at origin,

$$\oint_C \frac{1}{5z-4} dz = A\pi i,$$

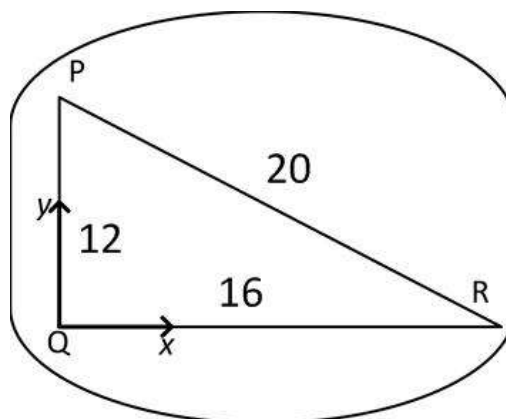
the value of A is

- (A) 2/5 (B) 1/2 (C) 2 (D) 4/5
- Q.27 Let X_1 and X_2 be two independent exponentially distributed random variables with means 0.5 and 0.25, respectively. Then $Y = \min(X_1, X_2)$ is
- (A) exponentially distributed with mean 1/6
 (B) exponentially distributed with mean 2
 (C) normally distributed with mean 3/4
 (D) normally distributed with mean 1/6

- Q.28 For a position vector $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ the norm of the vector can be defined as $|\vec{r}| = \sqrt{x^2 + y^2 + z^2}$. Given a function $\phi = \ln|\vec{r}|$, its gradient $\nabla\phi$ is

- (A) \vec{r} (B) $\frac{\vec{r}}{|\vec{r}|}$ (C) $\frac{\vec{r}}{\vec{r}\cdot\vec{r}}$ (D) $\frac{\vec{r}}{|\vec{r}|^3}$

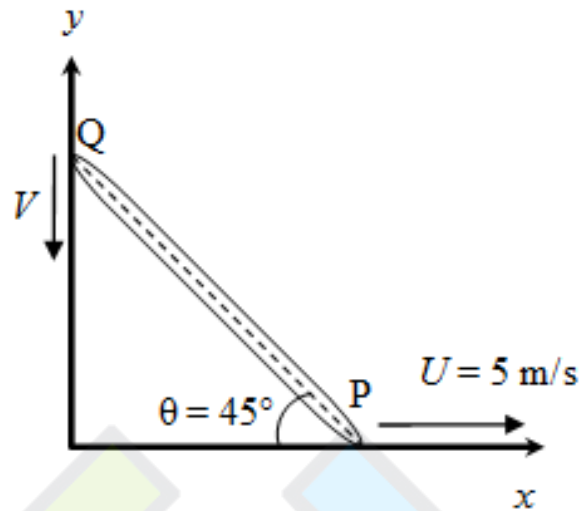
- Q.29 In a rigid body in plane motion, the point R is accelerating with respect to point P at $10\angle 180^\circ \text{ m/s}^2$. If the instantaneous acceleration of point Q is zero, the acceleration (in m/s^2) of point R is



- (A) $8\angle 233^\circ$ (B) $10\angle 225^\circ$ (C) $10\angle 217^\circ$ (D) $8\angle 217^\circ$

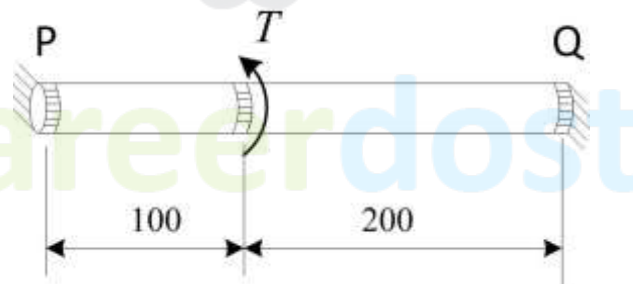
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- Q.30 A rigid rod of length 1 m is resting at an angle $\theta = 45^\circ$ as shown in the figure. The end P is dragged with a velocity of $U = 5$ m/s to the right. At the instant shown, the magnitude of the velocity V (in m/s) of point Q as it moves along the wall without losing contact is



- (A) 5 (B) 6 (C) 8 (D) 10

- Q.31 A bar of circular cross section is clamped at ends P and Q as shown in the figure. A torsional moment $T = 150$ Nm is applied at a distance of 100 mm from end P. The torsional reactions (T_P, T_Q) in Nm at the ends P and Q respectively are



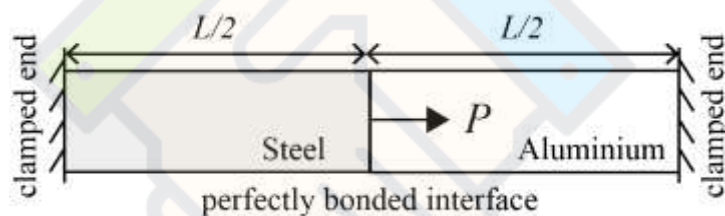
(All dimensions are in mm)

- (A) (50, 100) (B) (75, 75) (C) (100, 50) (D) (120, 30)

Q.32 In a cam-follower, the follower rises by h as the cam rotates by δ (radians) at constant angular velocity ω (radians/s). The follower is uniformly accelerating during the first half of the rise period and it is uniformly decelerating in the latter half of the rise period. Assuming that the magnitudes of the acceleration and deceleration are same, the maximum velocity of the follower is

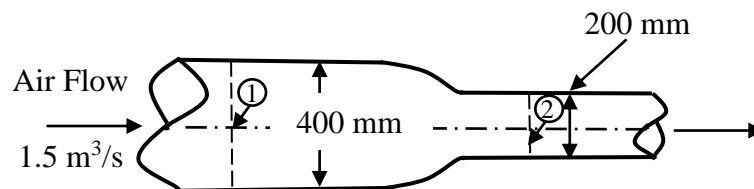
- (A) $\frac{4h\omega}{\delta}$ (B) $h\omega$ (C) $\frac{2h\omega}{\delta}$ (D) $2h\omega$

Q.33 A bimetallic cylindrical bar of cross sectional area 1 m^2 is made by bonding Steel (Young's modulus = 210 GPa) and Aluminium (Young's modulus = 70 GPa) as shown in the figure. To maintain tensile axial strain of magnitude 10^{-6} in Steel bar and compressive axial strain of magnitude 10^{-6} in Aluminium bar, the magnitude of the required force P (in kN) along the indicated direction is



- (A) 70 (B) 140 (C) 210 (D) 280

Q.34 Air flows at the rate of $1.5 \text{ m}^3/\text{s}$ through a horizontal pipe with a gradually reducing cross-section as shown in the figure. The two cross-sections of the pipe have diameters of 400 mm and 200 mm. Take the air density as 1.2 kg/m^3 and assume inviscid incompressible flow. The change in pressure ($p_2 - p_1$) (in kPa) between sections 1 and 2 is



- (A) -1.28 (B) 2.56 (C) -2.13 (D) 1.28

Q.35 The problem of maximizing $z = x_1 - x_2$ subject to constraints $x_1 + x_2 \leq 10$, $x_1 \geq 0$, $x_2 \geq 0$ and $x_2 \leq 5$ has

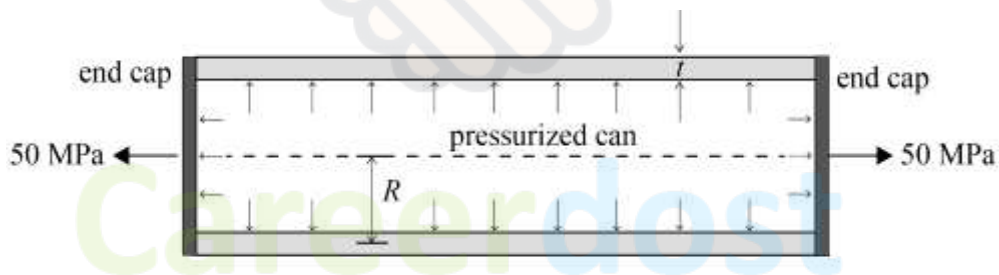
- (A) no solution
- (B) one solution
- (C) two solutions
- (D) more than two solutions

Q.36 Given the ordinary differential equation

$$\frac{d^2 y}{dx^2} + \frac{dy}{dx} - 6y = 0$$

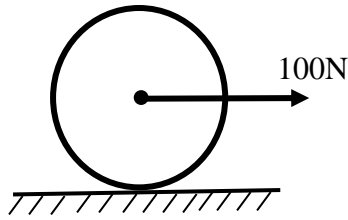
with $y(0) = 0$ and $\frac{dy}{dx}(0) = 1$, the value of $y(1)$ is _____ (correct to two decimal places).

Q.37 A thin-walled cylindrical can with rigid end caps has a mean radius $R = 100$ mm and a wall thickness of $t = 5$ mm. The can is pressurized and an additional tensile stress of 50 MPa is imposed along the axial direction as shown in the figure. Assume that the state of stress in the wall is uniform along its length. If the magnitudes of axial and circumferential components of stress in the can are equal, the pressure (in MPa) inside the can is _____ (correct to two decimal places).

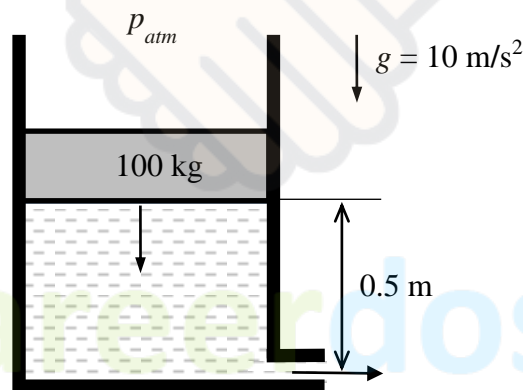


Q.38 A bar is subjected to a combination of a steady load of 60 kN and a load fluctuating between -10 kN and 90 kN. The corrected endurance limit of the bar is 150 MPa, the yield strength of the material is 480 MPa and the ultimate strength of the material is 600 MPa. The bar cross-section is square with side a . If the factor of safety is 2, the value of a (in mm), according to the modified Goodman's criterion, is _____ (correct to two decimal places).

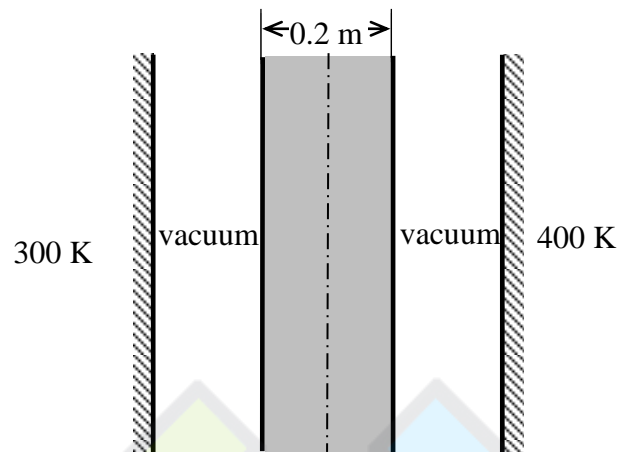
- Q.39 A force of 100 N is applied to the centre of a circular disc, of mass 10 kg and radius 1 m, resting on a floor as shown in the figure. If the disc rolls without slipping on the floor, the linear acceleration (in m/s^2) of the centre of the disc is _____ (correct to two decimal places).



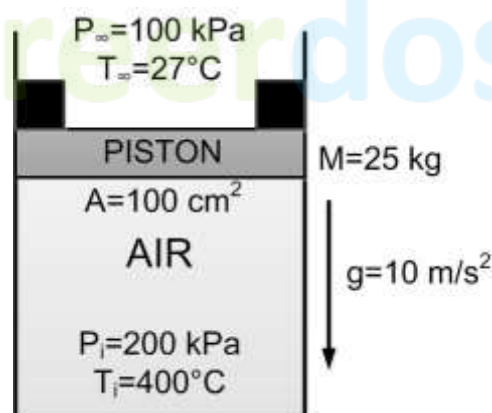
- Q.40 A frictionless circular piston of area 10^{-2} m^2 and mass 100 kg sinks into a cylindrical container of the same area filled with water of density 1000 kg/m^3 as shown in the figure. The container has a hole of area 10^{-3} m^2 at the bottom that is open to the atmosphere. Assuming there is no leakage from the edges of the piston and considering water to be incompressible, the magnitude of the piston velocity (in m/s) at the instant shown is _____ (correct to three decimal places).



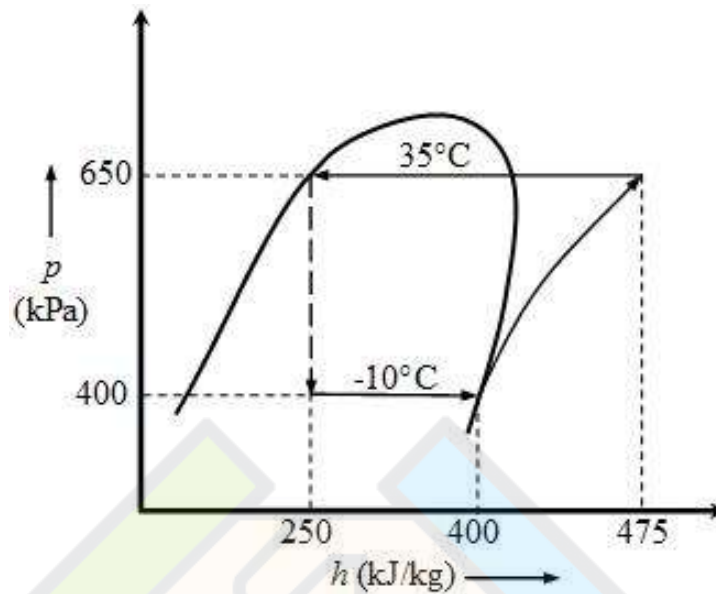
- Q.41 A 0.2 m thick infinite black plate having a thermal conductivity of 3.96 W/m-K is exposed to two infinite black surfaces at 300 K and 400 K as shown in the figure. At steady state, the surface temperature of the plate facing the cold side is 350 K. The value of Stefan-Boltzmann constant, σ , is $5.67 \times 10^{-8} \text{ W/m}^2 \text{ K}^4$. Assuming 1-D heat conduction, the magnitude of heat flux through the plate (in W/m^2) is _____ (correct to two decimal places).



- Q.42 Air is held inside a non-insulated cylinder using a piston (mass $M=25 \text{ kg}$ and area $A=100 \text{ cm}^2$) and stoppers (of negligible area), as shown in the figure. The initial pressure P_i and temperature T_i of air inside the cylinder are 200 kPa and 400°C , respectively. The ambient pressure P_∞ and temperature T_∞ are 100 kPa and 27°C , respectively. The temperature of the air inside the cylinder ($^\circ\text{C}$) at which the piston will begin to move is _____ (correct to two decimal places).



- Q.43 A standard vapor compression refrigeration cycle operating with a condensing temperature of 35°C and an evaporating temperature of -10°C develops 15 kW of cooling. The p - h diagram shows the enthalpies at various states. If the isentropic efficiency of the compressor is 0.75, the magnitude of compressor power (in kW) is _____ (correct to two decimal places).



- Q.44 Ambient air is at a pressure of 100 kPa, dry bulb temperature of 30°C and 60% relative humidity. The saturation pressure of water at 30°C is 4.24 kPa. The specific humidity of air (in g/kg of dry air) is _____ (correct to two decimal places).
- Q.45 A test is conducted on a one-fifth scale model of a Francis turbine under a head of 2 m and volumetric flow rate of $1 \text{ m}^3/\text{s}$ at 450 rpm. Take the water density and the acceleration due to gravity as 10^3 kg/m^3 and 10 m/s^2 , respectively. Assume no losses both in model and prototype turbines. The power (in MW) of a full sized turbine while working under a head of 30 m is _____ (correct to two decimal places).

Q.46 The true stress (in MPa) versus true strain relationship for a metal is given by

$$\sigma = 1020 \varepsilon^{0.4}$$

The cross-sectional area at the start of a test (when the stress and strain values are equal to zero) is 100 mm². The cross-sectional area at the time of necking (in mm²) is _____ (correct to two decimal places)

Q.47 A steel wire is drawn from an initial diameter (d_i) of 10 mm to a final diameter (d_f) of 7.5 mm. The half cone angle (α) of the die is 5° and the coefficient of friction (μ) between the die and the wire is 0.1. The average of the initial and final yield stress [$(\sigma_Y)_{avg}$] is 350 MPa. The equation for drawing stress σ_f , (in MPa) is given as:

$$\sigma_f = (\sigma_Y)_{avg} \left\{ 1 + \frac{1}{\mu \cot \alpha} \right\} \left[1 - \left(\frac{d_f}{d_i} \right)^{2\mu \cot \alpha} \right]$$

The drawing stress (in MPa) required to carry out this operation is _____ (correct to two decimal places).

Q.48 Following data correspond to an orthogonal turning of a 100 mm diameter rod on a lathe. Rake angle: +15°; Uncut chip thickness: 0.5 mm; nominal chip thickness after the cut: 1.25 mm. The shear angle (in degrees) for this process is _____ (correct to two decimal places).

Q.49 Taylor's tool life equation is used to estimate the life of a batch of identical HSS twist drills by drilling through holes at constant feed in 20 mm thick mild steel plates. In test 1, a drill lasted 300 holes at 150 rpm while in test 2, another drill lasted 200 holes at 300 rpm. The maximum number of holes that can be made by another drill from the above batch at 200 rpm is _____ (correct to two decimal places).

Q.50 For sand-casting a steel rectangular plate with dimensions 80 mm × 120 mm × 20 mm, a cylindrical riser has to be designed. The height of the riser is equal to its diameter. The total solidification time for the casting is 2 minutes. In Chvorinov's law for the estimation of the total solidification time, exponent is to be taken as 2. For a solidification time of 3 minutes in the riser, the diameter (in mm) of the riser is _____ (correct to two decimal places).

