

## GA - General Aptitude

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### Q1 - Q5 carry one mark each.

**Q.No. 1** He is known for his unscrupulous ways. He always sheds \_\_\_\_\_ tears to deceive people.

- (A) fox's
- (B) crocodile's
- (C) crocodile
- (D) fox

**Q.No. 2** Jofra Archer, the England fast bowler, is \_\_\_\_\_ than accurate.

- (A) more fast
- (B) faster
- (C) less fast
- (D) more faster

**Q.No. 3** Select the word that fits the analogy:

Build : Building :: Grow : \_\_\_\_\_

- (A) Grown
- (B) Grew
- (C) Growth
- (D) Growed

**Q.No. 4** I do not think you know the case well enough to have opinions. Having said that, I agree with your other point.

What does the phrase "having said that" mean in the given text?

- (A) as opposed to what I have said
- (B) despite what I have said
- (C) in addition to what I have said
- (D) contrary to what I have said

**Q.No. 5** Define  $[x]$  as the greatest integer less than or equal to  $x$ , for each  $x \in (-\infty, \infty)$ . If  $y = [x]$ , then area under  $y$  for  $x \in [1, 4]$  is \_\_\_\_\_.

- (A) 1
- (B) 3
- (C) 4
- (D) 6

### Q6 - Q10 carry two mark each.

**Q.No. 6** Crowd funding deals with mobilisation of funds for a project from a large number of people, who would be willing to invest smaller amounts through web-based platforms in the project.

Based on the above paragraph, which of the following is correct about crowd funding?

- (A) Funds raised through unwilling contributions on web-based platforms.
- (B) Funds raised through large contributions on web-based platforms.
- (C) Funds raised through coerced contributions on web-based platforms.
- (D) Funds raised through voluntary contributions on web-based platforms.

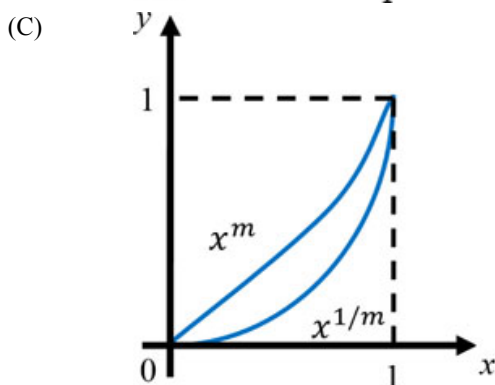
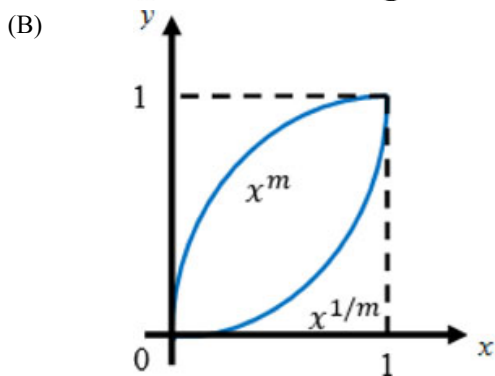
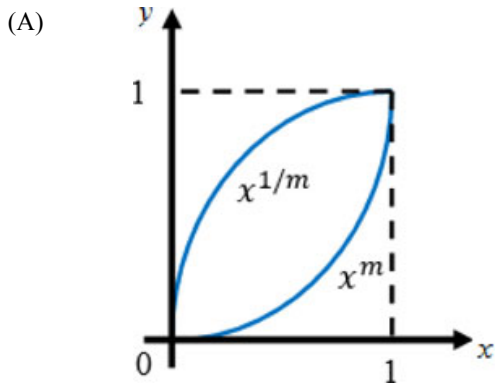
**Q.No. 7** P, Q, R and S are to be uniquely coded using  $\alpha$  and  $\beta$ . If P is coded as  $\alpha\alpha$  and Q as  $\alpha\beta$ , then R and S, respectively, can be coded as \_\_\_\_\_.

- (A)  $\beta\alpha$  and  $\alpha\beta$
- (B)  $\beta\beta$  and  $\alpha\alpha$
- (C)  $\alpha\beta$  and  $\beta\beta$
- (D)  $\beta\alpha$  and  $\beta\beta$

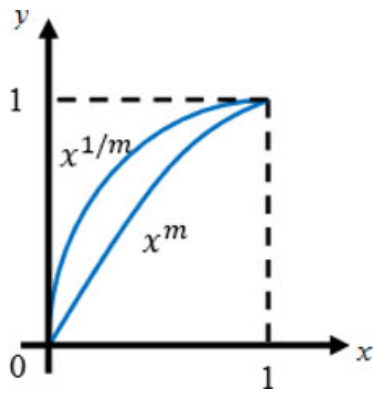
**Q.No. 8** The sum of the first  $n$  terms in the sequence 8, 88, 888, 8888, ... is \_\_\_\_\_.

- (A)  $\frac{81}{80}(10^n - 1) + \frac{9}{8}n$
- (B)  $\frac{81}{80}(10^n - 1) - \frac{9}{8}n$
- (C)  $\frac{80}{81}(10^n - 1) + \frac{8}{9}n$
- (D)  $\frac{80}{81}(10^n - 1) - \frac{8}{9}n$

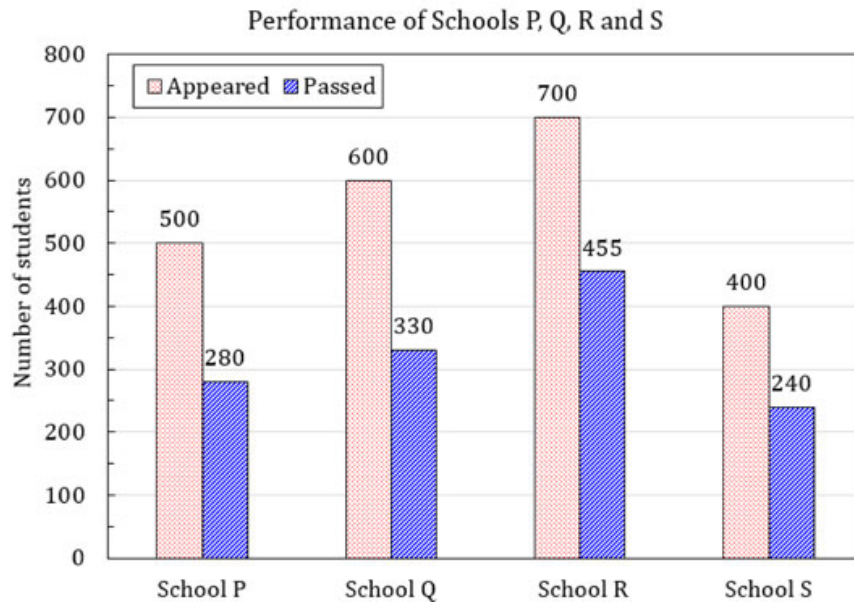
**Q.No. 9** Select the graph that schematically represents BOTH  $y = x^m$  and  $y = x^{1/m}$  properly in the interval  $0 \leq x \leq 1$ , for integer values of  $m$ , where  $m > 1$ .



(D)



Q.No. 10 The bar graph shows the data of the students who appeared and passed in an examination for four schools P, Q, R and S. The average of success rates (in percentage) of these four schools is \_\_\_\_\_.



- (A) 58.5 %
- (B) 58.8 %
- (C) 59.0 %
- (D) 59.3 %

**ME1: Mechanical Engineering**

Q.No. 1 Multiplication of real valued square matrices of same dimension is

- (A) associative
- (B) commutative
- (C) always positive definite
- (D) not always possible to compute

Q.No. 2 The value of

$$\lim_{x \rightarrow 1} \left( \frac{1 - e^{-c(1-x)}}{1 - x e^{-c(1-x)}} \right) \text{ is}$$

- (A)  $c$
- (B)  $c + 1$
- (C)  $\frac{c}{c + 1}$
- (D)  $\frac{c + 1}{c}$

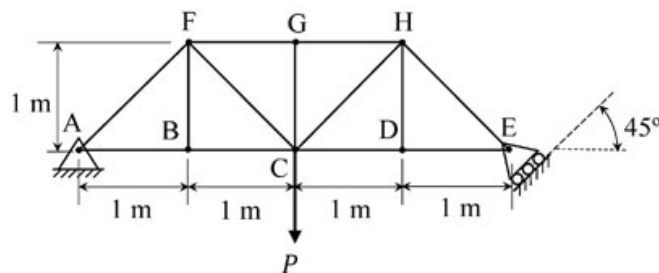
Q.No. 3 The Laplace transform of a function  $f(t)$  is  $\mathcal{L}(f) = \frac{1}{(s^2 + \omega^2)}$ . Then,  $f(t)$  is

- (A)  $f(t) = \frac{1}{\omega^2} (1 - \cos \omega t)$
- (B)  $f(t) = \frac{1}{\omega} \cos \omega t$
- (C)  $f(t) = \frac{1}{\omega} \sin \omega t$
- (D)  $f(t) = \frac{1}{\omega^2} (1 - \sin \omega t)$

Q.No. 4 Which of the following function  $f(z)$ , of the complex variable  $z$ , is **NOT** analytic at all the points of the complex plane?

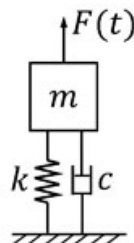
- (A)  $f(z) = z^2$
- (B)  $f(z) = e^z$
- (C)  $f(z) = \sin z$
- (D)  $f(z) = \log z$

Q.No. 5 The members carrying zero force (i.e. zero-force members) in the truss shown in the figure, for any load  $P > 0$  with no appreciable deformation of the truss (i.e. with no appreciable change in angles between the members), are



- (A) BF and DH only
- (B) BF, DH and GC only
- (C) BF, DH, GC, CD and DE only
- (D) BF, DH, GC, FG and GH only

Q.No. 6 A single-degree-of-freedom oscillator is subjected to harmonic excitation  $F(t) = F_0 \cos(\omega t)$  as shown in the figure.



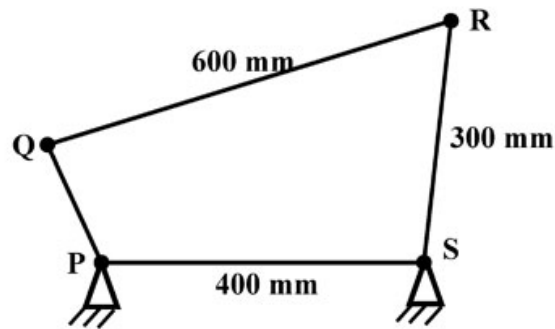
The non-zero value of  $\omega$ , for which the amplitude of the force transmitted to the ground will be  $F_0$ , is

- (A)  $\sqrt{\frac{k}{2m}}$
- (B)

- (C)  $\sqrt{\frac{k}{m}}$
- (D)  $2\sqrt{\frac{k}{m}}$

- Q.No. 7** The stress state at a point in a material under plane stress condition is equi-biaxial tension with a magnitude of 10 MPa. If one unit on the  $\sigma - \tau$  plane is 1 MPa, the Mohr's circle representation of the state-of-stress is given by
- (A) a circle with a radius equal to principal stress and its center at the origin of the  $\sigma - \tau$  plane
- (B) a point on the  $\sigma$  axis at a distance of 10 units from the origin
- (C) a circle with a radius of 10 units on the  $\sigma - \tau$  plane
- (D) a point on the  $\tau$  axis at a distance of 10 units from the origin

- Q.No. 8** A four bar mechanism is shown below.



- For the mechanism to be a crank-rocker mechanism, the length of the link PQ can be
- (A) 80 mm
- (B) 200 mm
- (C) 300 mm
- (D) 350 mm
- Q.No. 9** A helical gear with  $20^\circ$  pressure angle and  $30^\circ$  helix angle mounted at the mid-span of a shaft that is supported between two bearings at the ends. The nature of the stresses induced in the shaft is
- (A) normal stress due to bending only
- (B) normal stress due to bending in one plane and axial loading; shear stress due to torsion
- (C) normal stress due to bending in two planes and axial loading; shear stress due to torsion
- (D) normal stress due to bending in two planes; shear stress due to torsion

- Q.No. 10** The crystal structure of  $\gamma$  iron (austenite phase) is
- (A) BCC

- (B) FCC
- (C) HCP
- (D) BCT

**Q.No. 11** Match the following.

Heat treatment process	Effect
P: Tempering	1. Strengthening
Q: Quenching	2. Toughening
R: Annealing	3. Hardening
S: Normalizing	4. Softening

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

**Q.No. 12** The base of a brass bracket needs rough grinding. For this purpose, the most suitable grinding wheel grade specification is

- (A) C30Q12V
- (B) A50G8V
- (C) C90J4B
- (D) A30D12V

**Q.No. 13** In the Critical Path Method (CPM), the cost-time slope of an activity is given by

- (A)  $\frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Crash Time}}$
- (B)  $\frac{\text{Normal Cost}}{\text{Crash Time}}$
- (C)  $\frac{\text{Crash Time} - \text{Normal Time}}{\text{Crash Cost}}$
- (D)  $\frac{\text{Crash Time} - \text{Normal Time}}{\text{Crash Cost} - \text{Normal Cost}}$

**Q.No. 14** Froude number is the ratio of

- (A) buoyancy forces to viscous forces
- (B) inertia forces to viscous forces
- (C) buoyancy forces to inertia forces
- (D) inertia forces to gravity forces

**Q.No. 15**

Match the following non-dimensional numbers with the corresponding definitions:

Non-dimensional number		Definition	
P	Reynolds number	1	$\frac{\text{Buoyancy force}}{\text{Viscous force}}$
Q	Grashof number	2	$\frac{\text{Momentum diffusivity}}{\text{Thermal diffusivity}}$
R	Nusselt number	3	$\frac{\text{Inertia force}}{\text{Viscous force}}$
S	Prandtl number	4	$\frac{\text{Convective heat transfer}}{\text{Conduction heat transfer}}$

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

Q.No. 16 The velocity field of an incompressible flow in a Cartesian system is represented by

$$\vec{V} = 2(x^2 - y^2)\hat{i} + v\hat{j} + 3\hat{k}$$

Which one of the following expressions for  $v$  is valid?

- (A)  $-4xz + 6xy$   
 (B)  $-4xy - 4xz$   
 (C)  $4xz - 6xy$   
 (D)  $4xy + 4xz$

Q.No. 17 For an ideal gas, the value of the Joule-Thomson coefficient is

- (A) positive  
 (B) negative  
 (C) zero  
 (D) indeterminate

Q.No. 18 For an ideal gas, a constant pressure line and a constant volume line intersect at a point, in the Temperature ( $T$ ) versus specific entropy ( $s$ ) diagram.  $C_p$  is the specific heat at constant pressure and  $C_v$  is the specific heat at constant volume. The ratio of the slopes of the constant pressure and constant volume lines at the point of intersection is

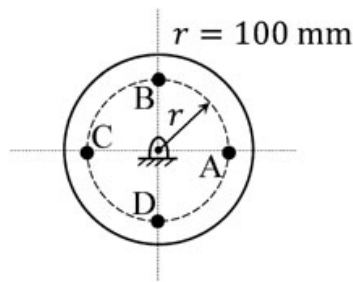
- (A)  $\frac{C_p - C_v}{C_p}$

- (B)  $\frac{C_P}{C_V}$
- (C)  $\frac{C_P - C_V}{C_V}$
- (D)  $\frac{C_V}{C_P}$

Q.No. 19 For three vectors  $\vec{A} = 2\hat{j} - 3\hat{k}$ ,  $\vec{B} = -2\hat{i} + \hat{k}$  and  $\vec{C} = 3\hat{i} - \hat{j}$ , where  $\hat{i}$ ,  $\hat{j}$  and  $\hat{k}$  are unit vectors along the axes of a right-handed rectangular/Cartesian coordinate system, the value of  $(\vec{A} \cdot (\vec{B} \times \vec{C}) + 6)$  is \_\_\_\_\_.

Q.No. 20 A flywheel is attached to an engine to keep its rotational speed between 100 rad/s and 110 rad/s. If the energy fluctuation in the flywheel between these two speeds is 1.05 kJ then the moment of inertia of the flywheel is \_\_\_\_\_ kg.m<sup>2</sup> (round off to 2 decimal places).

Q.No. 21 A balanced rigid disc mounted on a rigid rotor has four identical point masses, each of 10 grams, attached to four points on the 100 mm radius circle shown in the figure.



The rotor is driven by a motor at uniform angular speed of 10 rad/s. If one of the masses gets detached then the magnitude of the resultant unbalance force on the rotor is \_\_\_\_\_ N (round off to 2 decimal places).

Q.No. 22 A sheet metal with a stock hardness of 250 HRC has to be sheared using a punch and a die having a clearance of 1 mm between them. If the stock hardness of the sheet metal increases to 400 HRC, the clearance between the punch and the die should be \_\_\_\_\_ mm.

Q.No. 23 A company is hiring to fill four managerial vacancies. The candidates are five men and three women. If every candidate is equally likely to be chosen then the probability that at least one woman will be selected is \_\_\_\_\_ (round off to 2 decimal places).

Q.No. 24

The compressor of a gas turbine plant, operating on an ideal intercooled Brayton cycle, accomplishes an overall compression ratio of 6 in a two-stage compression process. Intercooling is used to cool the air coming out from the first stage to the inlet temperature of the first stage, before its entry to the second stage. Air enters the compressor at 300 K and 100 kPa. If the properties of gas are constant, the intercooling pressure for minimum compressor work is \_\_\_\_\_ kPa (round off to 2 decimal places).

**Q.No. 25** In a concentric tube counter-flow heat exchanger, hot oil enters at 102°C and leaves at 65°C. Cold water enters at 25°C and leaves at 42°C. The log mean temperature difference (LMTD) is \_\_\_\_\_ °C (round off to one decimal place).

**Q.No. 26** The evaluation of the definite integral  $\int_{-1}^{1.4} x|x| dx$  by using Simpson's 1/3<sup>rd</sup> (one-third) rule with step size  $h = 0.6$  yields

(A) 0.914  
 (B) 1.248  
 (C) 0.581  
 (D) 0.592

**Q.No. 27** A vector field is defined as

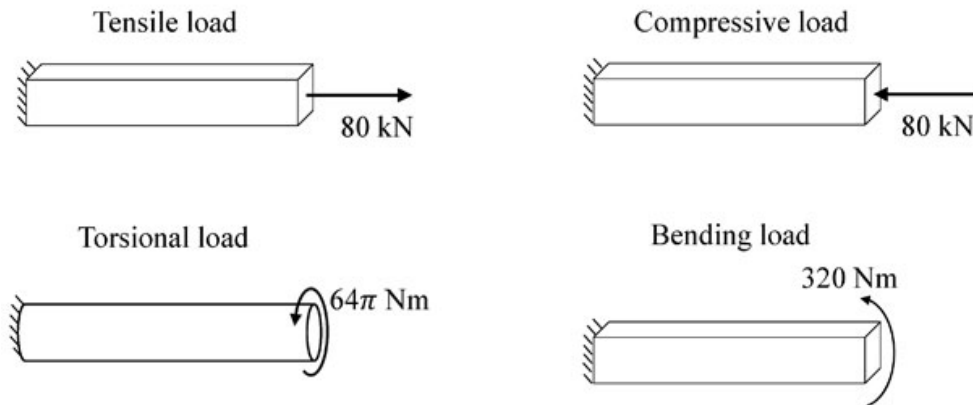
$$\vec{f}(x, y, z) = \frac{x}{[x^2 + y^2 + z^2]^{\frac{3}{2}}} \hat{i} + \frac{y}{[x^2 + y^2 + z^2]^{\frac{3}{2}}} \hat{j} + \frac{z}{[x^2 + y^2 + z^2]^{\frac{3}{2}}} \hat{k}$$

where,  $\hat{i}, \hat{j}, \hat{k}$  are unit vectors along the axes of a right-handed rectangular /Cartesian coordinate system. The surface integral  $\iint \vec{f} \cdot d\vec{S}$  (where  $d\vec{S}$  is an elemental surface area vector) evaluated over the inner and outer surfaces of a spherical shell formed by two concentric spheres with origin as the center, and internal and external radii of 1 and 2, respectively, is

- (A) 0  
 (B)  $2\pi$   
 (C)  $4\pi$   
 (D)  $8\pi$

**Q.No. 28**

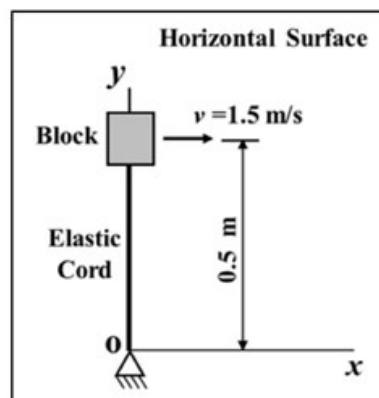
Bars of square and circular cross-section with 0.5 m length are made of a material with shear strength of 20 MPa. The square bar cross-section dimension is 4 cm  $\times$  4 cm and the cylindrical bar cross-section diameter is 4 cm. The specimens are loaded as shown in the figure.



Which specimen(s) will fail due to the applied load as per maximum shear stress theory?

- (A) Tensile and compressive load specimens
- (B) Torsional load specimen
- (C) Bending load specimen
- (D) None of the specimens

**Q.No. 29** The 2 kg block shown in figure (top view) rests on a smooth horizontal surface and is attached to a massless elastic cord that has a stiffness 5 N/m.

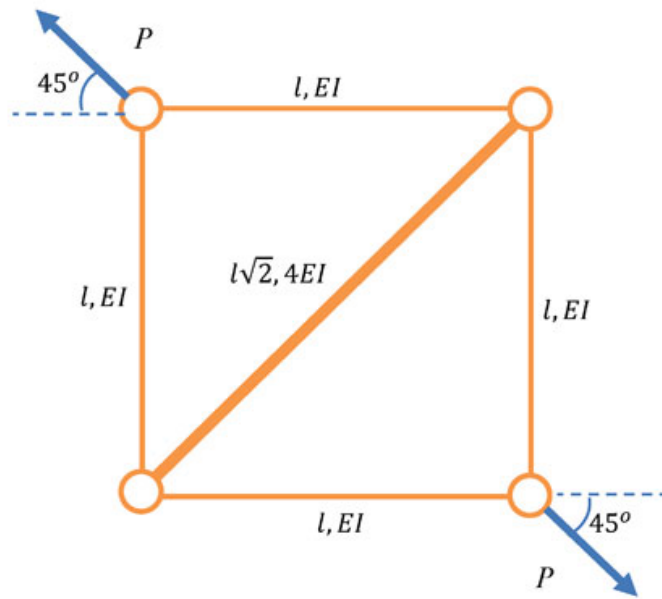


The cord hinged at O is initially unstretched and always remains elastic. The block is given a velocity  $v$  of 1.5 m/s perpendicular to the cord. The magnitude of velocity in m/s of the block at the instant the cord is stretched by 0.4 m is

- (A) 0.83
- (B) 1.07
- (C) 1.36
- (D) 1.50

**Q.No. 30**

The truss shown in the figure has four members of length  $l$  and flexural rigidity  $EI$ , and one member of length  $l\sqrt{2}$  and flexural rigidity  $4EI$ . The truss is loaded by a pair of forces of magnitude  $P$ , as shown in the figure.

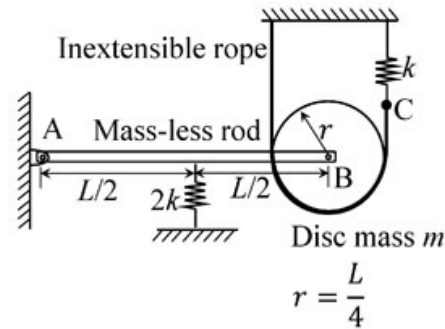


The smallest value of  $P$ , at which any of the truss members will buckle is

- (A)  $\frac{\sqrt{2}\pi^2 EI}{l^2}$   
 (B)  $\frac{\pi^2 EI}{l^2}$   
 (C)  $\frac{2\pi^2 EI}{l^2}$   
 (D)  $\frac{\pi^2 EI}{2l^2}$

Q.No. 31

A rigid mass-less rod of length  $L$  is connected to a disc (pulley) of mass  $m$  and radius  $r = L/4$  through a friction-less revolute joint. The other end of that rod is attached to a wall through a friction-less hinge. A spring of stiffness  $2k$  is attached to the rod at its mid-span. An inextensible rope passes over half the disc periphery and is securely tied to a spring of stiffness  $k$  at point C as shown in the figure. There is no slip between the rope and the pulley. The system is in static equilibrium in the configuration shown in the figure and the rope is always taut.



Neglecting the influence of gravity, the natural frequency of the system for small amplitude vibration is

- (A)  $\sqrt{\frac{3}{2}} \sqrt{\frac{k}{m}}$   
 (B)  $\frac{3}{\sqrt{2}} \sqrt{\frac{k}{m}}$   
 (C)  $\sqrt{3} \sqrt{\frac{k}{m}}$   
 (D)  $\sqrt{\frac{k}{m}}$

**Q.No. 32** A strip of thickness 40 mm is to be rolled to a thickness of 20 mm using a two-high mill having rolls of diameter 200 mm. Coefficient of friction and arc length in mm, respectively are

- (A) 0.45 and 38.84  
 (B) 0.39 and 38.84  
 (C) 0.39 and 44.72  
 (D) 0.45 and 44.72

**Q.No. 33** For an assembly line, the production rate was 4 pieces per hour and the average processing time was 60 minutes. The WIP inventory was calculated. Now, the production rate is kept the same, and the average processing time is brought down by 30 percent. As a result of this change in the processing time, the WIP inventory

- (A) decreases by 25%  
 (B) increases by 25%  
 (C) decreases by 30%  
 (D) increases by 30%

**Q.No. 34** A small metal bead (radius 0.5 mm), initially at 100°C, when placed in a stream of fluid at 20°C, attains a temperature of 28°C in 4.35 seconds. The density and specific heat of the metal are 8500 kg/m<sup>3</sup> and 400 J/kg.K, respectively. If the bead is considered as lumped system, the convective heat transfer coefficient (in W/m<sup>2</sup>.K) between the metal bead and the fluid stream is

- (A) 283.3
- (B) 299.8
- (C) 149.9
- (D) 449.7

**Q.No. 35** Consider two exponentially distributed random variables X and Y, both having a mean of 0.50. Let  $Z = X + Y$  and  $r$  be the correlation coefficient between X and Y. If the variance of Z equals 0, then the value of  $r$  is \_\_\_\_\_ (round off to 2 decimal places).

**Q.No. 36** An analytic function of a complex variable  $z = x + iy$  ( $i = \sqrt{-1}$ ) is defined as

$$f(z) = x^2 - y^2 + i \psi(x, y),$$

where  $\psi(x, y)$  is a real function. The value of the imaginary part of  $f(z)$  at  $z = (1 + i)$  is \_\_\_\_\_ (round off to 2 decimal places).

**Q.No. 37** In a disc-type axial clutch, the frictional contact takes place within an annular region with outer and inner diameters 250 mm and 50 mm, respectively. An axial force  $F_1$  is needed to transmit a torque by a new clutch. However, to transmit the same torque, one needs an axial force  $F_2$  when the clutch wears out. If contact pressure remains uniform during operation of a new clutch while the wear is assumed to be uniform for an old clutch, and the coefficient of friction does not change, then the ratio  $F_1/F_2$  is \_\_\_\_\_ (round off to 2 decimal places).

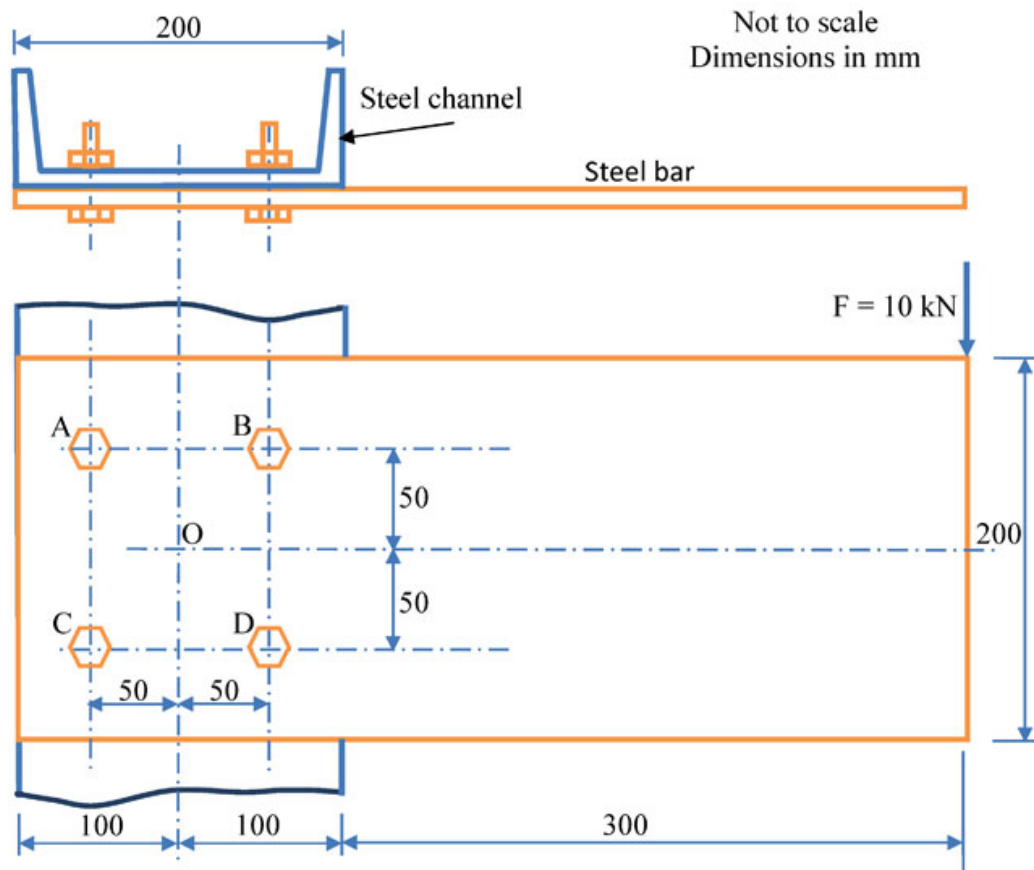
**Q.No. 38** A cam with a translating flat-face follower is desired to have the follower motion

$$y(\theta) = 4 [ 2\pi\theta - \theta^2 ], \quad 0 \leq \theta \leq 2\pi .$$

Contact stress considerations dictate that the radius of curvature of the cam profile should not be less than 40 mm anywhere. The minimum permissible base circle radius is \_\_\_\_\_ mm (round off to one decimal place).

**Q.No. 39**

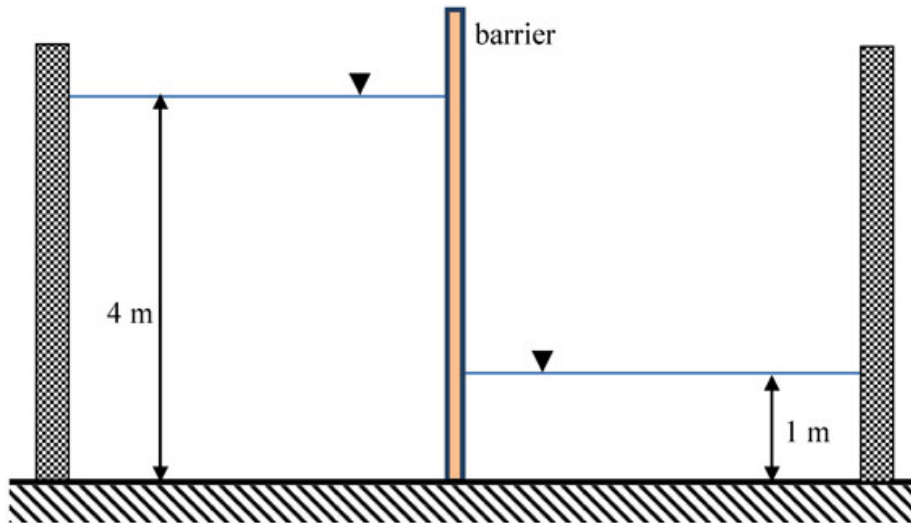
A rectangular steel bar of length 500 mm, width 100 mm, and thickness 15 mm is cantilevered to a 200 mm steel channel using 4 bolts, as shown.



For an external load of 10 kN applied at the tip of the steel bar, the resultant shear load on the bolt at B, is \_\_\_\_\_ kN (round off to one decimal place).

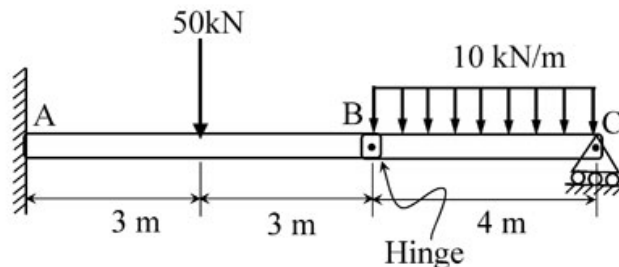
Q.No. 40

The barrier shown between two water tanks of unit width (1 m) into the plane of the screen is modeled as a cantilever.



Taking the density of water as  $1000 \text{ kg/m}^3$ , and the acceleration due to gravity as  $10 \text{ m/s}^2$ , the maximum absolute bending moment developed in the cantilever is \_\_\_\_\_  $\text{kN}\cdot\text{m}$  (round off to the nearest integer).

Q.No. 41 The magnitude of reaction force at joint C of the hinge-beam shown in the figure is \_\_\_\_\_  $\text{kN}$  (round off to 2 decimal places).



Q.No. 42 A slot of  $25 \text{ mm} \times 25 \text{ mm}$  is to be milled in a workpiece of  $300 \text{ mm}$  length using a side and face milling cutter of diameter  $100 \text{ mm}$ , width  $25 \text{ mm}$  and having 20 teeth.

For a depth of cut  $5 \text{ mm}$ , feed per tooth  $0.1 \text{ mm}$ , cutting speed  $35 \text{ m/min}$  and approach and over travel distance of  $5 \text{ mm}$  each, the time required for milling the slot is \_\_\_\_\_ minutes (round off to one decimal place).

Q.No. 43

The following data applies to basic shaft system:

tolerance for hole = 0.002 mm,

tolerance for shaft = 0.001 mm,

allowance = 0.003 mm,

basic size = 50 mm.

The maximum hole size is \_\_\_\_\_ mm (*round off to 3 decimal places*).

- Q.No. 44** A steel part with surface area of 125 cm<sup>2</sup> is to be chrome coated through an electroplating process using chromium acid sulphate as an electrolyte. An increasing current is applied to the part according to the following current time relation:

$$I = 12 + 0.2t$$

where,  $I$  = current (A) and  $t$  = time (minutes). The part is submerged in the plating solution for a duration of 20 minutes for plating purpose. Assuming the cathode efficiency of chromium to be 15% and the plating constant of chromium acid sulphate to be  $2.50 \times 10^{-2}$  mm<sup>3</sup>/A·s, the resulting coating thickness on the part surface is \_\_\_\_\_  $\mu\text{m}$  (*round off to one decimal place*).

- Q.No. 45** In a turning process using orthogonal tool geometry, a chip length of 100 mm is obtained for an uncut chip length of 250 mm.

The cutting conditions are: cutting speed = 30 m/min, rake angle = 20°.

The shear plane angle is \_\_\_\_\_ degrees (*round off to one decimal place*).

- Q.No. 46** The thickness of a steel plate with material strength coefficient of 210 MPa, has to be reduced from 20 mm to 15 mm in a single pass in a two-high rolling mill with a roll radius of 450 mm and rolling velocity of 28 m/min. If the plate has a width of 200 mm and its strain hardening exponent,  $n$  is 0.25, the rolling force required for the operation is \_\_\_\_\_ kN (*round off to 2 decimal places*).

Note: *Average Flow Stress* = *Material Strength Coefficient*  $\times \frac{(\text{True Strain})^n}{(1+n)}$

- Q.No. 47**

Two business owners Shveta and Ashok run their businesses in two different states. Each of them, independent of the other, produces two products A and B, sells them at Rs. 2,000 per kg and Rs. 3,000 per kg, respectively, and uses Linear Programming to determine the optimal quantity of A and B to maximize their respective daily revenue. Their constraints are as follows: i) for each business owner, the production process is such that the daily production of A has to be at least as much as B, and the upper limit for production of B is 10 kg per day, and ii) the respective state regulations restrict Shveta's production of A to less than 20 kg per day, and Ashok's production of A to less than 15 kg per day. The demand of both A and B in both the states is very high and everything produced is sold.

The absolute value of the difference in daily (optimal) revenue of Shveta and Ashok is \_\_\_\_\_ thousand Rupees (*round off to 2 decimal places*).

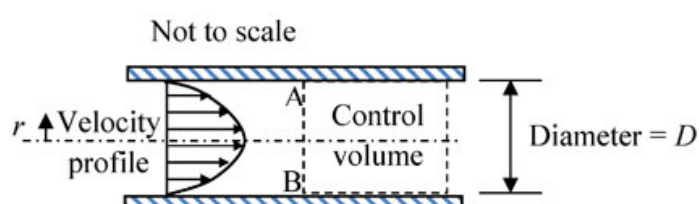
**Q.No. 48 Consider two cases as below.**

**Case 1:** A company buys 1000 pieces per year of a certain part from vendor 'X'. The changeover time is 2 hours and the price is Rs. 10 per piece. The holding cost rate per part is 10% per year.

**Case 2:** For the same part, another vendor 'Y' offers a design where the changeover time is 6 minutes, with a price of Rs. 5 per piece, and a holding cost rate per part of 100% per year. The order size is 800 pieces per year from 'X' and 200 pieces per year from 'Y'.

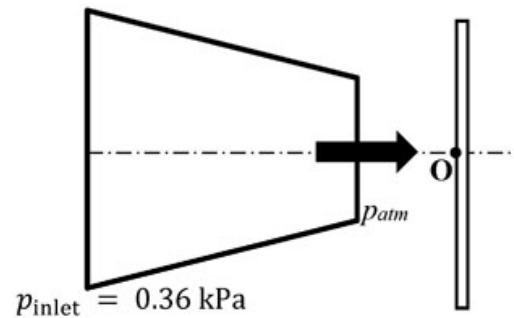
Assume the cost of downtime as Rs. 200 per hour. The percentage reduction in the annual cost for Case 2, as compared to Case 1 is \_\_\_\_\_ (*round off to 2 decimal places*).

**Q.No. 49** Consider steady, viscous, fully developed flow of a fluid through a circular pipe of internal diameter  $D$ . We know that the velocity profile forms a paraboloid about the pipe centre line, given by:  $V = -C \left( r^2 - \frac{D^2}{4} \right)$  m/s, where  $C$  is a constant. The rate of kinetic energy (in J/s) at the control surface A-B, as shown in the figure, is proportional to  $D^n$ . The value of  $n$  is \_\_\_\_\_.



**Q.No. 50**

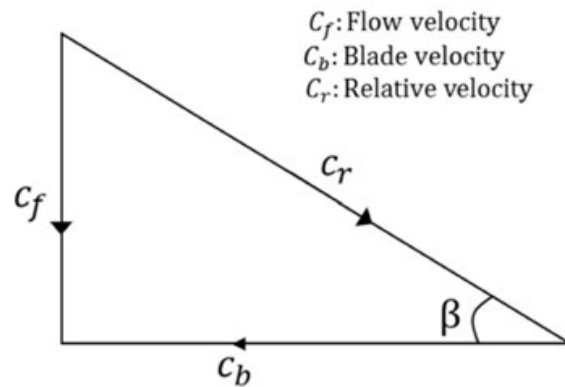
Air discharges steadily through a horizontal nozzle and impinges on a stationary vertical plate as shown in figure.



The inlet and outlet areas of the nozzle are  $0.1 \text{ m}^2$  and  $0.02 \text{ m}^2$ , respectively. Take air density as constant and equal to  $1.2 \text{ kg/m}^3$ . If the inlet gauge pressure of air is  $0.36 \text{ kPa}$ , the gauge pressure at point **O** on the plate is \_\_\_\_\_  $\text{kPa}$  (round off to two decimal places).

- Q.No. 51** Air (ideal gas) enters a perfectly insulated compressor at a temperature of  $310 \text{ K}$ . The pressure ratio of the compressor is 6. Specific heat at constant pressure for air is  $1005 \text{ J/kg.K}$  and ratio of specific heats at constant pressure and constant volume is 1.4. Assume that specific heats of air are constant. If the isentropic efficiency of the compressor is 85 percent, the difference in enthalpies of air between the exit and the inlet of the compressor is \_\_\_\_\_  $\text{kJ/kg}$  (round off to nearest integer).
- Q.No. 52** One kg of air, initially at a temperature of  $127^\circ\text{C}$ , expands reversibly at a constant pressure until the volume is doubled. If the gas constant of air is  $287 \text{ J/kg.K}$ , the magnitude of work transfer is \_\_\_\_\_  $\text{kJ}$  (round off to 2 decimal places).
- Q.No. 53** For an ideal Rankine cycle operating between pressures of 30 bar and 0.04 bar, the work output from the turbine is  $903 \text{ kJ/kg}$  and the work input to the feed pump is  $3 \text{ kJ/kg}$ . The specific steam consumption is \_\_\_\_\_  $\text{kg/kW.h}$  (round off to 2 decimal places).
- Q.No. 54**

For a Kaplan (axial flow) turbine, the outlet blade velocity diagram at a section is shown in figure.



The diameter at this section is 3 m. The hub and tip diameters of the blade are 2 m and 4 m, respectively. The water volume flow rate is  $100 \text{ m}^3/\text{s}$ . The rotational speed of the turbine is 300 rpm. The blade outlet angle  $\beta$  is \_\_\_\_\_ degrees (*round off to one decimal place*).

**Q.No. 55** The indicated power developed by an engine with compression ratio of 8, is calculated using an air-standard Otto cycle (constant properties). The rate of heat addition is 10 kW. The ratio of specific heats at constant pressure and constant volume is 1.4. The mechanical efficiency of the engine is 80 percent.

The brake power output of the engine is \_\_\_\_\_ kW (*round off to one decimal place*).

Q.No.	Session	Que.Type	Sec. Name	Key	Marks
1	1	MCQ	GA	C	1
2	1	MCQ	GA	A	1
3	1	MCQ	GA	C	1
4	1	MCQ	GA	B	1
5	1	MCQ	GA	D	1
6	1	MCQ	GA	D	2
7	1	MCQ	GA	D	2
8	1	MCQ	GA	D	2
9	1	MCQ	GA	A	2
10	1	MCQ	GA	C	2
1	1	MCQ	ME	A	1
2	1	MCQ	ME	C	1
3	1	MCQ	ME	C	1
4	1	MCQ	ME	D	1
5	1	MCQ	ME	C	1
6	1	MCQ	ME	C	1
7	1	MCQ	ME	B	1
8	1	MCQ	ME	A	1
9	1	MCQ	ME	C	1
10	1	MCQ	ME	B	1
11	1	MCQ	ME	A	1
12	1	MCQ	ME	A	1
13	1	MCQ	ME	D	1
14	1	MCQ	ME	D	1
15	1	MCQ	ME	D	1
16	1	MCQ	ME	B	1
17	1	MCQ	ME	C	1
18	1	MCQ	ME	D	1
19	1	NAT	ME	6 to 6	1
20	1	NAT	ME	0.98 to 1.02	1
21	1	NAT	ME	0.09 to 0.11	1
22	1	NAT	ME	1 to 1	1
23	1	NAT	ME	0.90 to 0.95	1
24	1	NAT	ME	243 to 247	1
25	1	NAT	ME	48.8 to 49.8	1
26	1	MCQ	ME	D	2
27	1	MCQ	ME	A	2
28	1	MCQ	ME	A	2
29	1	MCQ	ME	C	2
30	1	MCQ	ME	C	2
31	1	MCQ	ME	C	2
32	1	MCQ	ME	D	2
33	1	MCQ	ME	C	2
34	1	MCQ	ME	B	2
35	1	NAT	ME	-1.00 to -0.98	2
36	1	NAT	ME	1.99 to 2.01	2
37	1	NAT	ME	0.85 to 0.89	2
38	1	NAT	ME	47.9 to 48.1	2
39	1	NAT	ME	15.9 to 16.1	2
40	1	NAT	ME	105 to 105	2
41	1	NAT	ME	19.95 to 20.05	2
42	1	NAT	ME	1.5 to 1.7	2
43	1	NAT	ME	50.005 to 50.005	2
44	1	NAT	ME	0 to 0	2
45	1	NAT	ME	21 to 25	2
46	1	NAT	ME	1166 to 1168	2
47	1	NAT	ME	9.90 to 10.10	2
48	1	NAT	ME	8.19 to 8.23	2
49	1	NAT	ME	8 to 8	2
50	1	NAT	ME	0.37 to 0.45	2
51	1	NAT	ME	244 to 246	2
52	1	NAT	ME	114.6 to 115.0	2
53	1	NAT	ME	3.98 to 4.02	2
54	1	NAT	ME	11.0 to 14.0	2
55	1	NAT	ME	4.4 to 4.6	2

## GA - General Aptitude

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### Q1 - Q5 carry one mark each.

**Q.No. 1** While I agree \_\_\_\_\_ his proposal this time, I do not often agree \_\_\_\_\_ him.

- (A) to, with
- (B) with, to
- (C) with, with
- (D) to, to

**Q.No. 2** The recent measures to improve the output would \_\_\_\_\_ the level of production to our satisfaction.

- (A) increase
- (B) decrease
- (C) speed
- (D) equalise

**Q.No. 3** Select the word that fits the analogy:

White: Whitening : : Light: \_\_\_\_\_

- (A) Lightning
- (B) Lightening
- (C) Lighting
- (D) Enlightening

**Q.No. 4** In one of the greatest innings ever seen in 142 years of Test history, Ben Stokes upped the tempo in a five-and-a-half hour long stay of 219 balls including 11 fours and 8 sixes that saw him finish on a 135 not out as England squared the five-match series.

Based on their connotations in the given passage, which one of the following meanings DOES NOT match?

- (A) upped = increased
- (B) squared = lost
- (C) tempo = enthusiasm
- (D) saw = resulted in

**Q.No. 5** There are five levels {P, Q, R, S, T} in a linear supply chain before a product reaches customers, as shown in the figure.



At each of the five levels, the price of the product is increased by 25%. If the product is produced at level P at the cost of Rs. 120 per unit, what is the price paid (in rupees) by the customers?

- (A) 187.50
- (B) 234.38
- (C) 292.96
- (D) 366.21

### Q6 - Q10 carry two mark each.

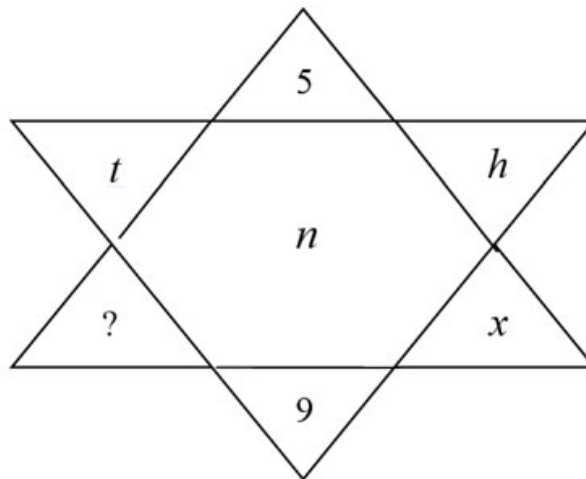
**Q.No. 6**

Climate change and resilience deal with two aspects – reduction of sources of non-renewable energy resources and reducing vulnerability of climate change aspects. The terms ‘mitigation’ and ‘adaptation’ are used to refer to these aspects, respectively.

Which of the following assertions is best supported by the above information?

- (A) Mitigation deals with consequences of climate change.
- (B) Adaptation deals with causes of climate change.
- (C) Mitigation deals with actions taken to reduce the use of fossil fuels.
- (D) Adaptation deals with actions taken to combat green-house gas emissions.

**Q.No. 7** Find the missing element in the following figure.

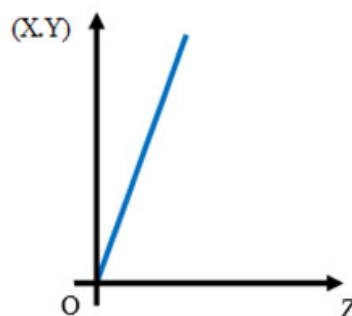


- (A)  $d$
- (B)  $e$
- (C)  $w$
- (D)  $y$

**Q.No. 8** It was estimated that 52 men can complete a strip in a newly constructed highway connecting cities P and Q in 10 days. Due to an emergency, 12 men were sent to another project. How many number of days, more than the original estimate, will be required to complete the strip?

- (A) 3 days
- (B) 5 days
- (C) 10 days
- (D) 13 days

**Q.No. 9** An engineer measures THREE quantities X, Y and Z in an experiment. She finds that they follow a relationship that is represented in the figure below: (the product of X and Y linearly varies with Z)



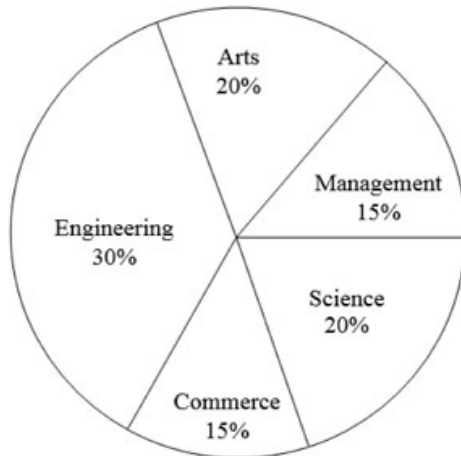
Then, which of the following statements is FALSE?

- (A) For fixed Z; X is proportional to Y

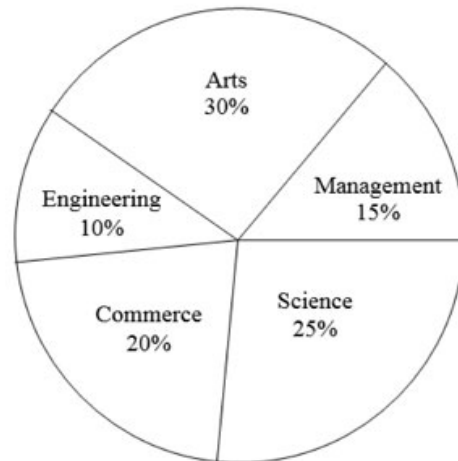
- (B) For fixed Y; X is proportional to Z
- (C) For fixed X; Z is proportional to Y
- (D) XY/Z is constant

**Q.No. 10** The two pie-charts given below show the data of total students and only girls registered in different streams in a university. If the total number of students registered in the university is 5000, and the total number of the registered girls is 1500; then, the ratio of boys enrolled in Arts to the girls enrolled in Management is \_\_\_\_\_.

Percentage of students enrolled in different streams in a University



Percentage of girls enrolled in different streams



- (A) 2 : 1
- (B) 9 : 22
- (C) 11 : 9
- (D) 22 : 9

**ME2: Mechanical Engineering**

- Q.No. 1** The sum of two normally distributed random variables X and Y is
- (A) always normally distributed
  - (B) normally distributed, only if X and Y are independent
  - (C) normally distributed, only if X and Y have the same standard deviation
  - (D) normally distributed, only if X and Y have the same mean

**Q.No. 2** A matrix P is decomposed into its symmetric part S and skew symmetric part V.  
If

$$S = \begin{pmatrix} -4 & 4 & 2 \\ 4 & 3 & 7/2 \\ 2 & 7/2 & 2 \end{pmatrix}, \quad V = \begin{pmatrix} 0 & -2 & 3 \\ 2 & 0 & 7/2 \\ -3 & -7/2 & 0 \end{pmatrix},$$

then matrix P is

- (A)  $\begin{pmatrix} -4 & 6 & -1 \\ 2 & 3 & 0 \\ 5 & 7 & 2 \end{pmatrix}$
- (B)  $\begin{pmatrix} -4 & 2 & 5 \\ 6 & 3 & 7 \\ -1 & 0 & 2 \end{pmatrix}$
- (C)

(D) 
$$\begin{pmatrix} 4 & -6 & 1 \\ -2 & -3 & 0 \\ -5 & -7 & -2 \end{pmatrix}$$

(D) 
$$\begin{pmatrix} -2 & 9/2 & -1 \\ -1 & 81/4 & 11 \\ -2 & 45/2 & 73/4 \end{pmatrix}$$

**Q.No. 3** Let  $I = \int_{x=0}^1 \int_{y=0}^{x^2} xy^2 dy dx$ . Then,  $I$  may also be expressed as

- (A) 
$$\int_{y=0}^1 \int_{x=0}^{\sqrt{y}} xy^2 dx dy$$
- (B) 
$$\int_{y=0}^1 \int_{x=\sqrt{y}}^1 yx^2 dx dy$$
- (C) 
$$\int_{y=0}^1 \int_{x=\sqrt{y}}^1 xy^2 dx dy$$
- (D) 
$$\int_{y=0}^1 \int_{x=0}^{\sqrt{y}} yx^2 dx dy$$

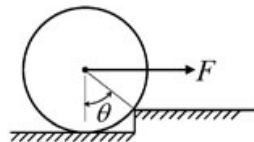
**Q.No. 4** The solution of

$$\frac{d^2y}{dt^2} - y = 1,$$

which additionally satisfies  $y|_{t=0} = \frac{dy}{dt}|_{t=0} = 0$  in the Laplace  $s$ -domain is

- (A) 
$$\frac{1}{s(s+1)(s-1)}$$
- (B) 
$$\frac{1}{s(s+1)}$$
- (C) 
$$\frac{1}{s(s-1)}$$
- (D) 
$$\frac{1}{s-1}$$

**Q.No. 5** An attempt is made to pull a roller of weight  $W$  over a curb (step) by applying a horizontal force  $F$  as shown in the figure.

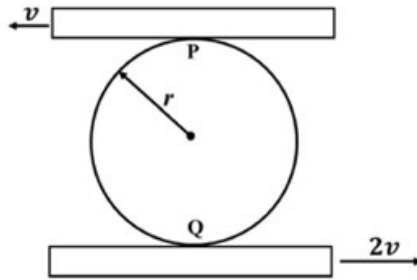


The coefficient of static friction between the roller and the ground (including the edge of the step) is  $\mu$ . Identify the correct free body diagram (FBD) of the roller when the roller is just about to climb over the step.

- (A)
- (B)

- (C)
- (D)

**Q.No. 6** A circular disk of radius  $r$  is confined to roll without slipping at P and Q as shown in the figure.



- If the plates have velocities as shown, the magnitude of the angular velocity of the disk is
- (A)  $\frac{v}{r}$
- (B)  $\frac{v}{2r}$
- (C)  $\frac{2v}{3r}$
- (D)  $\frac{3v}{2r}$

**Q.No. 7** The equation of motion of a spring-mass-damper system is given by

$$\frac{d^2x}{dt^2} + 3\frac{dx}{dt} + 9x = 10 \sin(5t)$$

The damping factor for the system is

- (A) 0.25
- (B) 0.5
- (C) 2
- (D) 3

**Q.No. 8**

The number of qualitatively distinct kinematic inversions possible for a Grashof chain with four revolute pairs is

- (A) 1
- (B) 2
- (C) 3
- (D) 4

**Q.No. 9** The process, that uses a tapered horn to amplify and focus the mechanical energy for machining of glass, is

- (A) electrochemical machining
- (B) electrical discharge machining
- (C) ultrasonic machining
- (D) abrasive jet machining

**Q.No. 10** Two plates, each of 6 mm thickness, are to be butt-welded. Consider the following processes and select the correct sequence in increasing order of size of the heat affected zone.

1. Arc welding
2. MIG welding
3. Laser beam welding
4. Submerged arc welding

- (A) 1-4-2-3
- (B) 3-4-2-1
- (C) 4-3-2-1
- (D) 3-2-4-1

**Q.No. 11** Which one of the following statements about a phase diagram is

**INCORRECT?**

- (A) It indicates the temperature at which different phases start to melt
- (B) Relative amount of different phases can be found under given equilibrium conditions
- (C) It gives information on transformation rates
- (D) Solid solubility limits are depicted by it

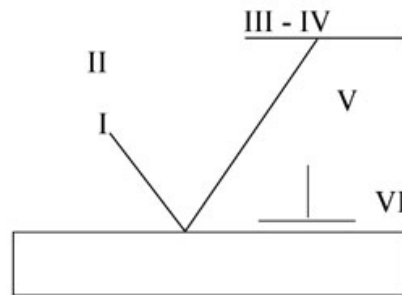
**Q.No. 12**

The figure below shows a symbolic representation of the surface texture in a perpendicular lay orientation with indicative values (I through VI) marking the various specifications whose definitions are listed below.

P: Maximum Waviness Height (mm); Q: Maximum Roughness Height (mm);

R: Minimum Roughness Height (mm); S: Maximum Waviness Width (mm);

T: Maximum Roughness Width (mm); U: Roughness Width Cutoff (mm).



The correct match between the specifications and the symbols (I to VI) is

- (A) I-R, II-Q, III-P, IV-S, V-U, VI-T
- (B) I-R, II-P, III-U, IV-S, V-T, VI-Q
- (C) I-U, II-S, III-Q, IV-T, V-R, VI-P
- (D) I-Q, II-U, III-R, IV-T, V-S, VI-P

**Q.No. 13** In Materials Requirement Planning, if the inventory holding cost is very high and the setup cost is zero, which one of the following lot sizing approaches should be used?

- (A) Economic Order Quantity
- (B) Lot-for-Lot
- (C) Base Stock Level
- (D) Fixed Period Quantity, for 2 periods

**Q.No. 14** Which of the following conditions is used to determine the stable equilibrium of all partially submerged floating bodies?

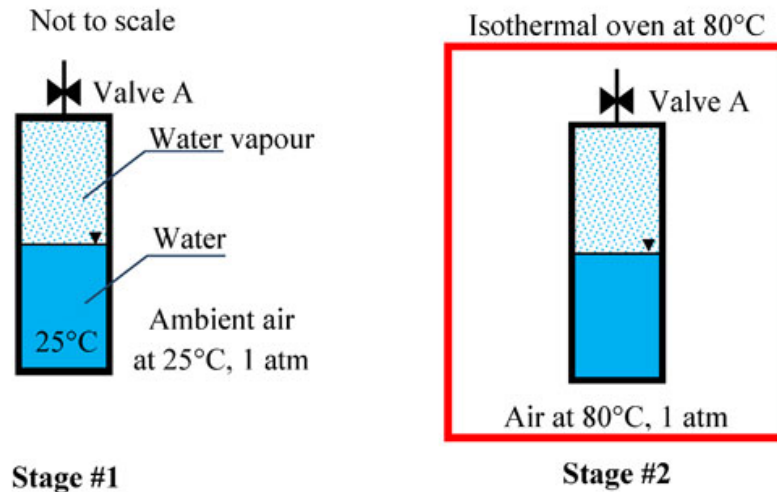
- (A) Centre of buoyancy must be above the centre of gravity
- (B) Centre of buoyancy must be below the centre of gravity
- (C) Metacentre must be at a higher level than the centre of gravity
- (D) Metacentre must be at a lower level than the centre of gravity

**Q.No. 15** In the space above the mercury column in a barometer tube, the gauge pressure of the vapour is

- (A) positive, but more than one atmosphere
- (B) negative
- (C) zero
- (D) positive, but less than one atmosphere

**Q.No. 16**

A closed vessel contains pure water, in thermal equilibrium with its vapour at 25°C (Stage #1), as shown.



The vessel in this stage is then kept inside an isothermal oven which is having an atmosphere of hot air maintained at 80°C. The vessel exchanges heat with the oven atmosphere and attains a new thermal equilibrium (Stage #2). If the Valve A is now opened inside the oven, what will happen immediately after opening the valve?

- (A) Water vapor inside the vessel will come out of the Valve A
- (B) Hot air will go inside the vessel through Valve A
- (C) Nothing will happen – the vessel will continue to remain in equilibrium
- (D) All the vapor inside the vessel will immediately condense

**Q.No. 17** For an air-standard Diesel cycle,

- (A) heat addition is at constant volume and heat rejection is at constant pressure
- (B) heat addition is at constant pressure and heat rejection is at constant pressure
- (C) heat addition is at constant pressure and heat rejection is at constant volume
- (D) heat addition is at constant volume and heat rejection is at constant volume

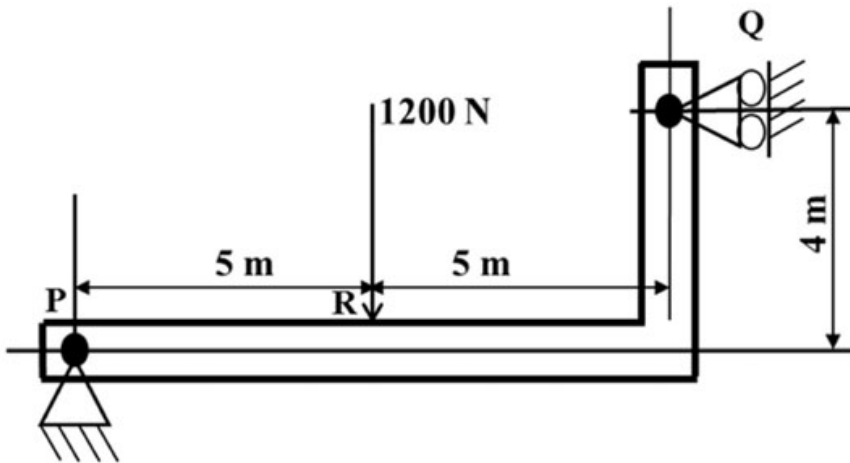
**Q.No. 18** The values of enthalpies at the stator inlet and rotor outlet of a hydraulic turbomachine stage are  $h_1$  and  $h_3$  respectively. The enthalpy at the stator outlet (or, rotor inlet) is  $h_2$ . The condition  $(h_2 - h_1) = (h_3 - h_2)$  indicates that the degree of reaction of this stage is

- (A) zero
- (B) 50%
- (C) 75%
- (D) 100%

**Q.No. 19** Let **I** be a 100 dimensional identity matrix and **E** be the set of its distinct (no value appears more than once in **E**) real eigenvalues. The number of elements in **E** is \_\_\_\_\_.

**Q.No. 20**

A beam of negligible mass is hinged at support P and has a roller support Q as shown in the figure.

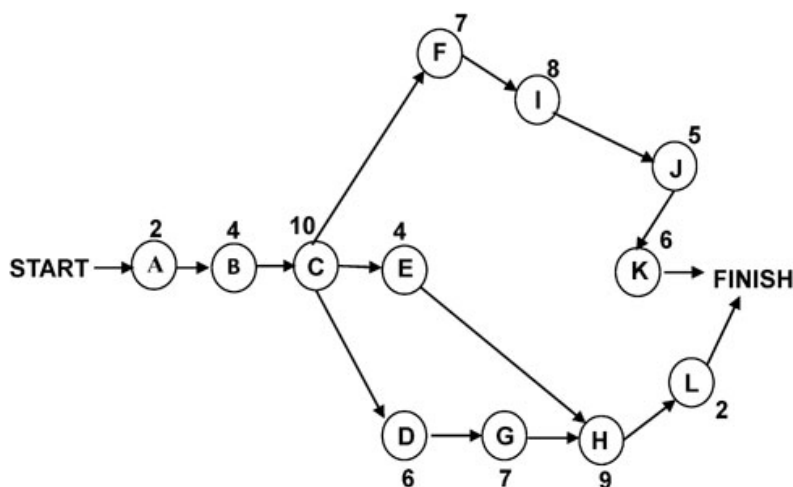


A point load of 1200 N is applied at point R. The magnitude of the reaction force at support Q is \_\_\_\_\_ N.

Q.No. 21 A machine member is subjected to fluctuating stress  $\sigma = \sigma_0 \cos(8\pi t)$ . The endurance limit of the material is 350 MPa. If the factor of safety used in the design is 3.5 then the maximum allowable value of  $\sigma_0$  is \_\_\_\_\_ MPa (round off to 2 decimal places).

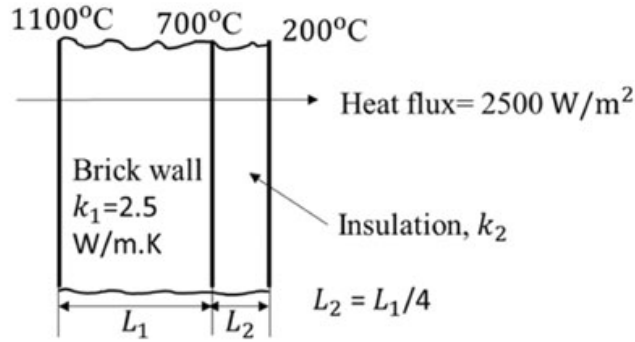
Q.No. 22 A bolt head has to be made at the end of a rod of diameter  $d = 12$  mm by localized forging (upsetting) operation. The length of the unsupported portion of the rod is 40 mm. To avoid buckling of the rod, a closed forging operation has to be performed with a maximum die diameter of \_\_\_\_\_ mm.

Q.No. 23 Consider the following network of activities, with each activity named A–L, illustrated in the nodes of the network.



The number of hours required for each activity is shown alongside the nodes. The slack on the activity L, is \_\_\_\_\_ hours.

**Q.No. 24** In a furnace, the inner and outer sides of the brick wall ( $k_1 = 2.5 \text{ W/m.K}$ ) are maintained at  $1100^\circ\text{C}$  and  $700^\circ\text{C}$ , respectively as shown in figure.



The brick wall is covered by an insulating material of thermal conductivity  $k_2$ . The thickness of the insulation is  $1/4^{\text{th}}$  of the thickness of the brick wall. The outer surface of the insulation is at  $200^\circ\text{C}$ . The heat flux through the composite walls is  $2500 \text{ W/m}^2$ .

The value of  $k_2$  is \_\_\_\_\_  $\text{W/m.K}$  (round off to one decimal place).

**Q.No. 25** If a reversed Carnot cycle operates between the temperature limits of  $27^\circ\text{C}$  and  $-3^\circ\text{C}$ , then the ratio of the COP of a refrigerator to that of a heat pump (COP of refrigerator / COP of heat pump) based on the cycle is \_\_\_\_\_ (round off to 2 decimal places).

**Q.No. 26** The directional derivative of  $f(x, y, z) = xyz$  at point  $(-1, 1, 3)$  in the direction of vector  $\hat{i} - 2\hat{j} + 2\hat{k}$  is

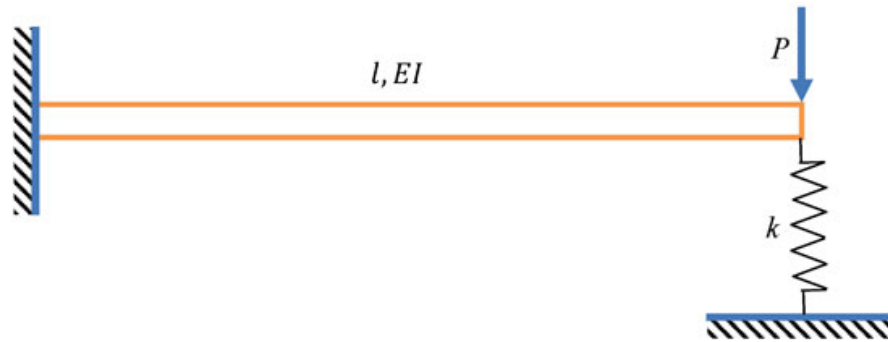
- (A)  $3\hat{i} - 3\hat{j} - \hat{k}$
- (B)  $-\frac{7}{3}$
- (C)  $\frac{7}{3}$
- (D)  $7$

**Q.No. 27** The function  $f(z)$  of complex variable  $z = x + iy$ , where  $i = \sqrt{-1}$ , is given as  $f(z) = (x^3 - 3xy^2) + iv(x, y)$ . For this function to be analytic,  $v(x, y)$  should be

- (A)  $(3xy^2 - y^3) + \text{constant}$
- (B)  $(3x^2y^2 - y^3) + \text{constant}$
- (C)  $(x^3 - 3x^2y) + \text{constant}$
- (D)  $(3x^2y - y^3) + \text{constant}$

**Q.No. 28**

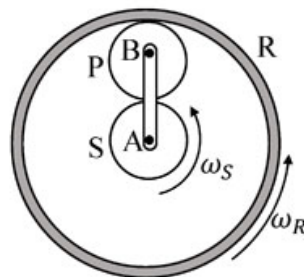
A cantilever of length  $l$ , and flexural rigidity  $EI$ , stiffened by a spring of stiffness  $k$ , is loaded by a transverse force  $P$ , as shown.



The transverse deflection under the load is

- (A)  $\frac{Pl^3}{3EI} \left[ \frac{3EI}{3EI + 2kl^3} \right]$   
 (B)  $\frac{Pl^3}{3EI} \left[ \frac{6EI - kl^3}{6EI} \right]$   
 (C)  $\frac{Pl^3}{3EI} \left[ \frac{3EI - kl^3}{3EI} \right]$   
 (D)  $\frac{Pl^3}{3EI} \left[ \frac{3EI}{3EI + kl^3} \right]$

Q.No. 29 The sun (S) and the planet (P) of an epicyclic gear train shown in the figure have identical number of teeth.

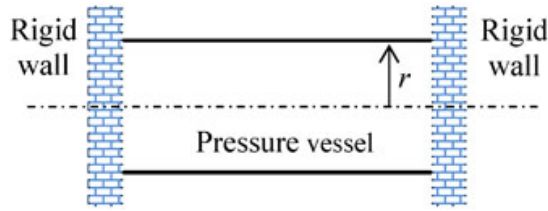


If the sun (S) and the outer ring (R) gears are rotated in the same direction with angular speed  $\omega_S$  and  $\omega_R$ , respectively, then the angular speed of the arm AB is

- (A)  $\frac{3}{4}\omega_R + \frac{1}{4}\omega_S$   
 (B)  $\frac{1}{4}\omega_R + \frac{3}{4}\omega_S$   
 (C)  $\frac{1}{2}\omega_R - \frac{1}{2}\omega_S$   
 (D)  $\frac{3}{4}\omega_R - \frac{1}{4}\omega_S$

Q.No. 30

A thin-walled cylinder of radius  $r$  and thickness  $t$  is open at both ends, and fits snugly between two rigid walls under ambient conditions, as shown in the figure.



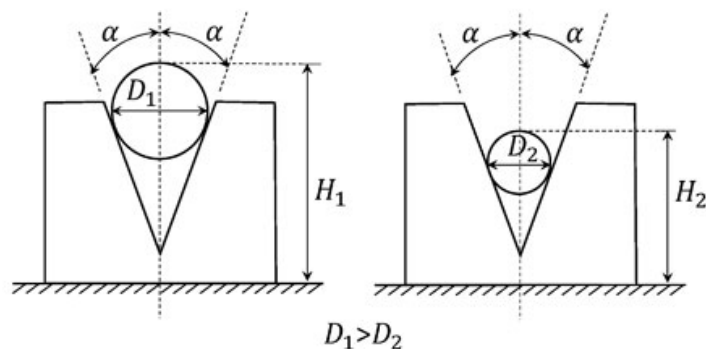
The material of the cylinder has Young's modulus  $E$ , Poisson's ratio  $\nu$ , and coefficient of thermal expansion  $\alpha$ . What is the minimum rise in temperature  $\Delta T$  of the cylinder (assume uniform cylinder temperature with no buckling of the cylinder) required to prevent gas leakage if the cylinder has to store the gas at an internal pressure of  $p$  above the atmosphere?

- (A)  $\Delta T = \frac{3\nu pr}{2\alpha t E}$   
 (B)  $\Delta T = \left(\nu - \frac{1}{4}\right) \frac{pr}{\alpha t E}$   
 (C)  $\Delta T = \frac{\nu pr}{\alpha t E}$   
 (D)  $\Delta T = \left(\nu + \frac{1}{2}\right) \frac{pr}{\alpha t E}$

**Q.No. 31** A helical spring has spring constant  $k$ . If the wire diameter, spring diameter and the number of coils are all doubled then the spring constant of the new spring becomes

- (A)  $k/2$   
 (B)  $k$   
 (C)  $8k$   
 (D)  $16k$

**Q.No. 32** Two rollers of diameters  $D_1$  (in mm) and  $D_2$  (in mm) are used to measure the internal taper angle in the V-groove of a machined component. The heights  $H_1$  (in mm) and  $H_2$  (in mm) are measured by using a height gauge after inserting the rollers into the same V-groove as shown in the figure.



Which one of the following is the correct relationship to evaluate the angle  $\alpha$  as shown in the figure?

- (A)  $\sin \alpha = \frac{(D_1 - D_2)}{2(H_1 - H_2) - (D_1 - D_2)}$
- (B)  $\cos \alpha = \frac{(D_1 - D_2)}{2(H_1 - H_2) - 2(D_1 - D_2)}$
- (C)  $\operatorname{cosec} \alpha = \frac{(H_1 - H_2) - (D_1 - D_2)}{2(D_1 - D_2)}$
- (D)  $\sin \alpha = \frac{(H_1 - H_2)}{(D_1 - D_2)}$

**Q.No. 33** The forecast for the monthly demand of a product is given in the table below.

Month	Forecast	Actual Sales
1	32.00	30.00
2	31.80	32.00
3	31.82	30.00

The forecast is made by using the exponential smoothing method. The exponential smoothing coefficient used in forecasting the demand is

- (A) 0.10
- (B) 0.40
- (C) 0.50
- (D) 1.00

**Q.No. 34** One kg of air in a closed system undergoes an irreversible process from an initial state of  $p_1 = 1$  bar (absolute) and  $T_1 = 27^\circ\text{C}$ , to a final state of  $p_2 = 3$  bar (absolute) and  $T_2 = 127^\circ\text{C}$ . If the gas constant of air is  $287 \text{ J/kg.K}$  and the ratio of the specific heats  $\gamma = 1.4$ , then the change in the specific entropy (in  $\text{J/kg.K}$ ) of the air in the process is

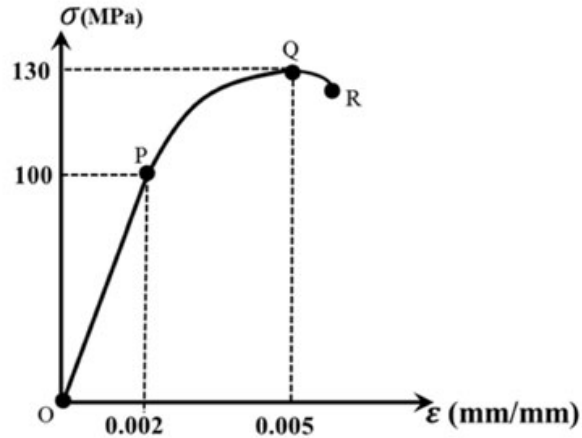
- (A)  $-26.3$
- (B)  $28.4$
- (C)  $172.0$
- (D) indeterminate, as the process is irreversible

**Q.No. 35** For the integral  $\int_0^{\pi/2} (8 + 4 \cos x) dx$ , the absolute percentage error in numerical evaluation with the Trapezoidal rule, using only the end points, is \_\_\_\_\_ (round off to one decimal place).

**Q.No. 36** A fair coin is tossed 20 times. The probability that 'head' will appear exactly 4 times in the first ten tosses, and 'tail' will appear exactly 4 times in the next ten tosses is \_\_\_\_\_ (round off to 3 decimal places).

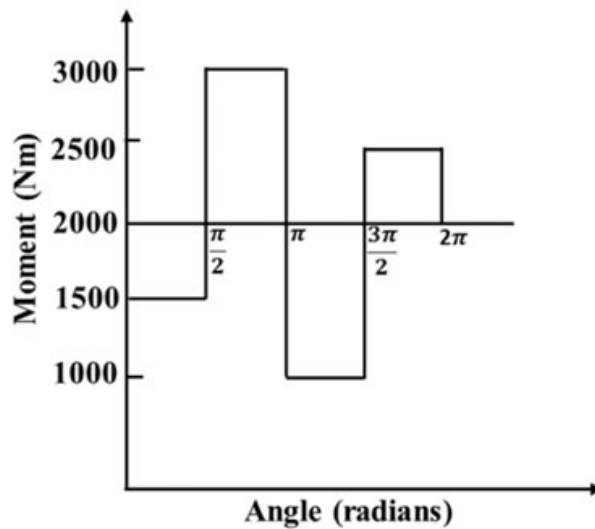
**Q.No. 37** A hollow spherical ball of radius 20 cm floats in still water, with half of its volume submerged. Taking the density of water as  $1000 \text{ kg/m}^3$ , and the acceleration due to gravity as  $10 \text{ m/s}^2$ , the natural frequency of small oscillations of the ball, normal to the water surface is \_\_\_\_\_ radians/s (round off to 2 decimal places).

Q.No. 38 Uniaxial compression test data for a solid metal bar of length 1 m is shown in the figure.



The bar material has a linear elastic response from O to P followed by a nonlinear response. The point P represents the yield point of the material. The rod is pinned at both the ends. The minimum diameter of the bar so that it does not buckle under axial loading before reaching the yield point is \_\_\_\_\_ mm (round off to one decimal place).

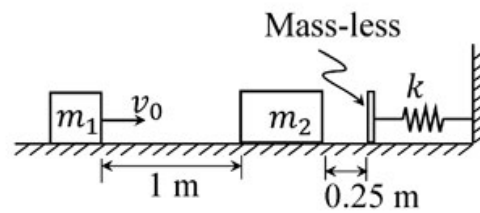
Q.No. 39 The turning moment diagram of a flywheel fitted to a fictitious engine is shown in the figure.



The mean turning moment is 2000 Nm. The average engine speed is 1000 rpm. For fluctuation in the speed to be within  $\pm 2\%$  of the average speed, the mass moment of inertia of the flywheel is \_\_\_\_\_  $\text{kg.m}^2$ .

Q.No. 40

A rigid block of mass  $m_1 = 10$  kg having velocity  $v_0 = 2$  m/s strikes a stationary block of mass  $m_2 = 30$  kg after traveling 1 m along a frictionless horizontal surface as shown in the figure.



The two masses stick together and jointly move by a distance of 0.25 m further along the same frictionless surface, before they touch the mass-less buffer that is connected to the rigid vertical wall by means of a linear spring having a spring constant  $k = 10^5$  N/m. The maximum deflection of the spring is \_\_\_\_\_ cm (round off to 2 decimal places).

- Q.No. 41 A steel spur pinion has a module ( $m$ ) of 1.25 mm, 20 teeth and  $20^\circ$  pressure angle. The pinion rotates at 1200 rpm and transmits power to a 60 teeth gear. The face width ( $F$ ) is 50 mm, Lewis form factor  $Y = 0.322$  and a dynamic factor  $K_v = 1.26$ . The bending stress ( $\sigma$ ) induced in a tooth can be calculated by using the Lewis formula given below.

If the maximum bending stress experienced by the pinion is 400 MPa, the power transmitted is \_\_\_\_\_ kW (round off to one decimal place).

Lewis formula:  $\sigma = \frac{K_v W^t}{F m Y}$ , where  $W^t$  is the tangential load acting on the pinion.

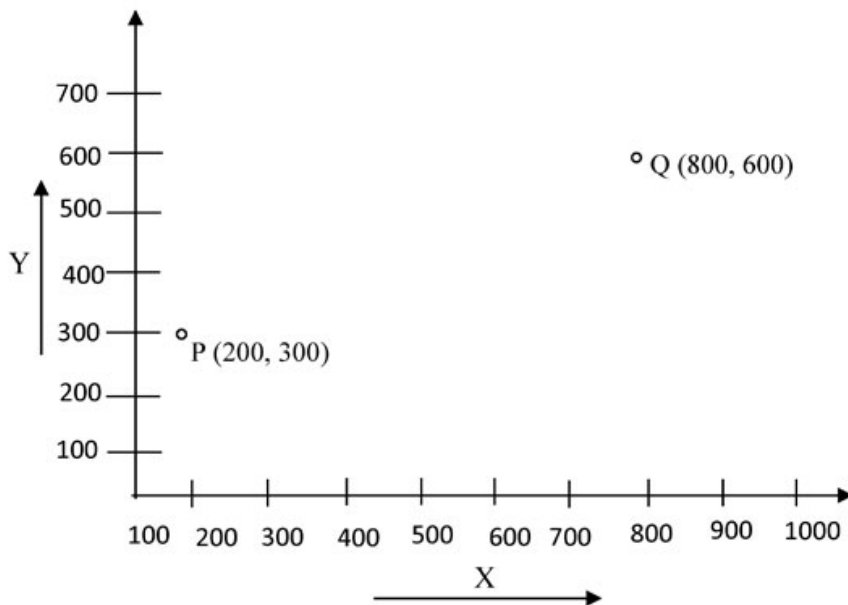
- Q.No. 42 A mould cavity of  $1200 \text{ cm}^3$  volume has to be filled through a sprue of 10 cm length feeding a horizontal runner. Cross-sectional area at the base of the sprue is  $2 \text{ cm}^2$ . Consider acceleration due to gravity as  $9.81 \text{ m/s}^2$ . Neglecting frictional losses due to molten metal flow, the time taken to fill the mould cavity is \_\_\_\_\_ seconds (round off to 2 decimal places).

- Q.No. 43 A cylindrical bar with 200 mm diameter is being turned with a tool having geometry  $0^\circ - 9^\circ - 7^\circ - 8^\circ - 15^\circ - 30^\circ - 0.05$  inch (Coordinate system, ASA) resulting in a cutting force  $F_{c1}$ . If the tool geometry is changed to  $0^\circ - 9^\circ - 7^\circ - 8^\circ - 15^\circ - 0^\circ - 0.05$  inch (Coordinate system, ASA) and all other parameters remain unchanged, the cutting force changes to  $F_{c2}$ . Specific cutting energy (in  $\text{J/mm}^3$ ) is  $U_c = U_0 (t_1)^{-0.4}$ , where  $U_0$  is the specific energy coefficient, and  $t_1$  is the uncut thickness in mm. The value of percentage change in cutting force  $F_{c2}$ , i.e.  $\left(\frac{F_{c2} - F_{c1}}{F_{c1}}\right) \times 100$ , is \_\_\_\_\_ (round off to one decimal place).

Q.No. 44 There are two identical shaping machines  $S_1$  and  $S_2$ . In machine  $S_2$ , the width of the workpiece is increased by 10% and the feed is decreased by 10%, with respect to that of  $S_1$ . If all other conditions remain the same then the ratio of total time per pass in  $S_1$  and  $S_2$  will be \_\_\_\_\_ (round off to one decimal place).

Q.No. 45 Bars of 250 mm length and 25 mm diameter are to be turned on a lathe with a feed of 0.2 mm/rev. Each regrinding of the tool costs Rs. 20. The time required for each tool change is 1 min. Tool life equation is given as  $VT^{0.2} = 24$  (where cutting speed  $V$  is in m/min and tool life  $T$  is in min). The optimum tool cost per piece for maximum production rate is Rs. \_\_\_\_\_ (round off to 2 decimal places).

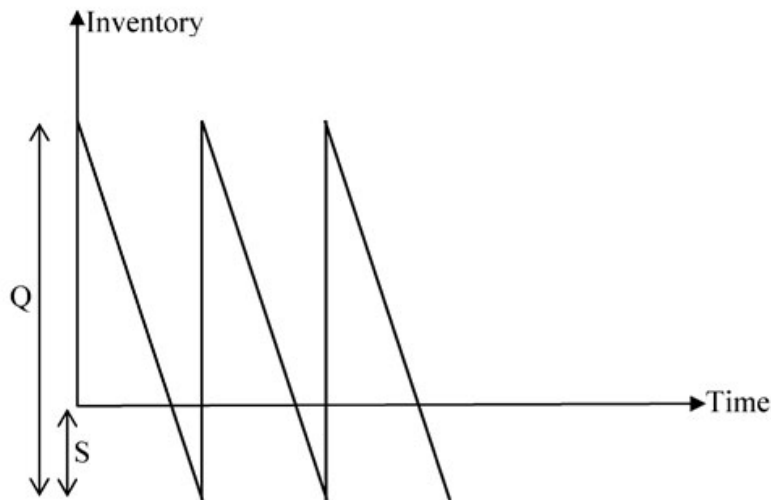
Q.No. 46 A point 'P' on a CNC controlled XY- stage is moved to another point 'Q' using the coordinate system shown in the figure below and rapid positioning command (G00).



A pair of stepping motors with maximum speed of 800 rpm, controlling both the X and Y motion of the stage, are directly coupled to a pair of lead screws, each with a uniform pitch of 0.5 mm. The time needed to position the point 'P' to the point 'Q' is \_\_\_\_\_ minutes (round off to 2 decimal places).

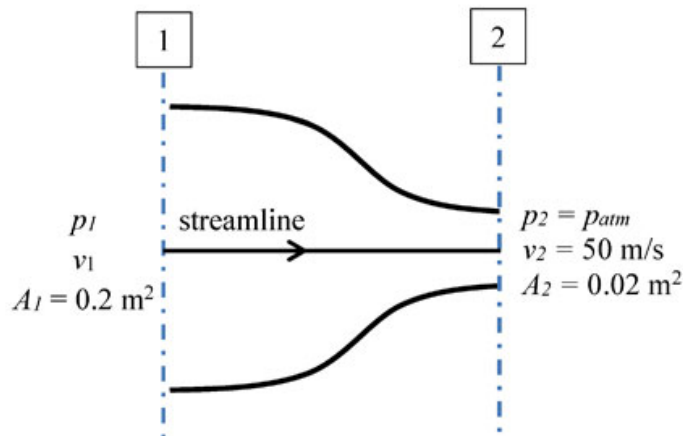
Q.No. 47

For a single item inventory system, the demand is continuous, which is 10000 per year. The replenishment is instantaneous and backorders ( $S$  units) per cycle are allowed as shown in the figure.



As soon as the quantity ( $Q$  units) ordered from the supplier is received, the backordered quantity is issued to the customers. The ordering cost is Rs. 300 per order. The carrying cost is Rs. 4 per unit per year. The cost of backordering is Rs. 25 per unit per year. Based on the total cost minimization criteria, the maximum inventory reached in the system is \_\_\_\_\_ (round off to nearest integer).

Q.No. 48 Consider a flow through a nozzle, as shown in the figure below.



The air flow is steady, incompressible and inviscid. The density of air is  $1.23 \text{ kg/m}^3$ . The pressure difference,  $(p_1 - p_{atm})$  is \_\_\_\_\_ kPa (round off to 2 decimal places).

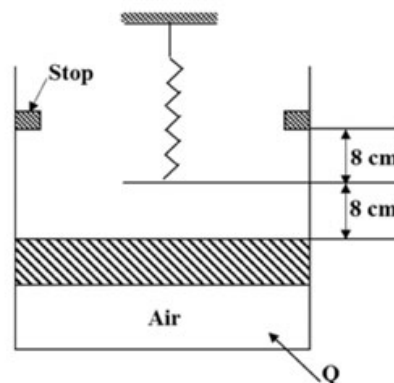
Q.No. 49

Water (density  $1000 \text{ kg/m}^3$ ) flows through an inclined pipe of uniform diameter. The velocity, pressure and elevation at section **A** are  $V_A = 3.2 \text{ m/s}$ ,  $p_A = 186 \text{ kPa}$  and  $z_A = 24.5 \text{ m}$ , respectively, and those at section **B** are  $V_B = 3.2 \text{ m/s}$ ,  $p_B = 260 \text{ kPa}$  and  $z_B = 9.1 \text{ m}$ , respectively. If acceleration due to gravity is  $10 \text{ m/s}^2$  then the head lost due to friction is \_\_\_\_\_ m (round off to one decimal place).

**Q.No. 50** The spectral distribution of radiation from a black body at  $T_1 = 3000 \text{ K}$  has a maximum at wavelength  $\lambda_{\text{max}}$ . The body cools down to a temperature  $T_2$ . If the wavelength corresponding to the maximum of the spectral distribution at  $T_2$  is 1.2 times of the original wavelength  $\lambda_{\text{max}}$ , then the temperature  $T_2$  is \_\_\_\_\_ K (round off to the nearest integer).

**Q.No. 51** Water flows through a tube of 3 cm internal diameter and length 20 m. The outside surface of the tube is heated electrically so that it is subjected to uniform heat flux circumferentially and axially. The mean inlet and exit temperatures of the water are  $10^\circ\text{C}$  and  $70^\circ\text{C}$ , respectively. The mass flow rate of the water is  $720 \text{ kg/h}$ . Disregard the thermal resistance of the tube wall. The internal heat transfer coefficient is  $1697 \text{ W/m}^2\cdot\text{K}$ . Take specific heat  $C_p$  of water as  $4.179 \text{ kJ/kg}\cdot\text{K}$ . The inner surface temperature at the exit section of the tube is \_\_\_\_\_  $^\circ\text{C}$  (round off to one decimal place).

**Q.No. 52** Air is contained in a frictionless piston-cylinder arrangement as shown in the figure.



The atmospheric pressure is  $100 \text{ kPa}$  and the initial pressure of air in the cylinder is  $105 \text{ kPa}$ . The area of piston is  $300 \text{ cm}^2$ . Heat is now added and the piston moves slowly from its initial position until it reaches the stops. The spring constant of the linear spring is  $12.5 \text{ N/mm}$ . Considering the air inside the cylinder as the system, the work interaction is \_\_\_\_\_ J (round off to the nearest integer).

**Q.No. 53**

Moist air at 105 kPa, 30°C and 80% relative humidity flows over a cooling coil in an insulated air-conditioning duct. Saturated air exits the duct at 100 kPa and 15°C. The saturation pressures of water at 30°C and 15°C are 4.24 kPa and 1.7 kPa respectively. Molecular weight of water is 18 g/mol and that of air is 28.94 g/mol. The mass of water condensing out from the duct is \_\_\_\_\_ g/kg of dry air (*round off to the nearest integer*).

**Q.No. 54** In a steam power plant, superheated steam at 10 MPa and 500°C, is expanded isentropically in a turbine until it becomes a saturated vapour. It is then reheated at constant pressure to 500°C. The steam is next expanded isentropically in another turbine until it reaches the condenser pressure of 20 kPa. Relevant properties of steam are given in the following two tables. The work done by both the turbines together is \_\_\_\_\_ kJ/kg (*round off to the nearest integer*).

Superheated Steam Table:

Pressure, $p$ (MPa)	Temperature, $T$ (°C)	Enthalpy, $h$ (kJ/kg)	Entropy, $s$ (kJ/kg.K)
10	500	3373.6	6.5965
1	500	3478.4	7.7621

Saturated Steam Table:

Pressure, $p$	Sat.Temp. $T_{\text{sat}}$ (°C)	Enthalpy, $h$ (kJ/kg)		Entropy, $s$ (kJ/kg.K)	
		$h_f$	$h_g$	$s_f$	$s_g$
1 MPa	179.91	762.9	2778.1	2.1386	6.5965
20 kPa	60.06	251.38	2609.7	0.8319	7.9085

**Q.No. 55** Keeping all other parameters identical, the Compression Ratio (CR) of an air standard diesel cycle is increased from 15 to 21. Take ratio of specific heats = 1.3 and cut-off ratio of the cycle  $r_c = 2$ .

The difference between the new and the old efficiency values, in percentage,

$$(\eta_{\text{new}}|_{\text{CR}=21}) - (\eta_{\text{old}}|_{\text{CR}=15}) = \text{_____ \% (round off to one decimal place).}$$

Q.No.	Session	Que.Type	Sec. Name	Key	Marks
1	2	MCQ	GA	A	1
2	2	MCQ	GA	A	1
3	2	MCQ	GA	B	1
4	2	MCQ	GA	B	1
5	2	MCQ	GA	D	1
6	2	MCQ	GA	C	2
7	2	MCQ	GA	A	2
8	2	MCQ	GA	A	2
9	2	MCQ	GA	A	2
10	2	MCQ	GA	D	2
1	2	MCQ	ME	A	1
2	2	MCQ	ME	B	1
3	2	MCQ	ME	C	1
4	2	MCQ	ME	A	1
5	2	MCQ	ME	B	1
6	2	MCQ	ME	D	1
7	2	MCQ	ME	B	1
8	2	MCQ	ME	C	1
9	2	MCQ	ME	C	1
10	2	MCQ	ME	D	1
11	2	MCQ	ME	C	1
12	2	MCQ	ME	A	1
13	2	MCQ	ME	B	1
14	2	MCQ	ME	C	1
15	2	MCQ	ME	B	1
16	2	MCQ	ME	B	1
17	2	MCQ	ME	C	1
18	2	MCQ	ME	B	1
19	2	NAT	ME	1 to 1	1
20	2	NAT	ME	1500 to 1500	1
21	2	NAT	ME	99.98 to 100.02	1
22	2	NAT	ME	18 to 18	1
23	2	NAT	ME	2 to 2	1
24	2	NAT	ME	0.5 to 0.5	1
25	2	NAT	ME	0.89 to 0.91	1
26	2	MCQ	ME	C	2
27	2	MCQ	ME	D	2
28	2	MCQ	ME	D	2
29	2	MCQ	ME	A	2
30	2	MCQ	ME	C	2
31	2	MCQ	ME	B	2
32	2	MCQ	ME	A	2
33	2	MCQ	ME	A	2
34	2	MCQ	ME	A	2
35	2	NAT	ME	5.1 to 5.3	2
36	2	NAT	ME	0.041 to 0.043	2
37	2	NAT	ME	8.60 to 8.70	2
38	2	NAT	ME	55.0 to 58.0	2
39	2	NAT	ME	745 to 755	2
40	2	NAT	ME	0.98 to 1.02	2
41	2	NAT	ME	9.8 to 10.8	2
42	2	NAT	ME	4.20 to 4.30	2
43	2	NAT	ME	-5.8 to -5.5	2
44	2	NAT	ME	0.7 to 0.9	2
45	2	NAT	ME	26.00 to 28.00	2
46	2	NAT	ME	1.40 to 1.60	2
47	2	NAT	ME	1130 to 1140	2
48	2	NAT	ME	1.50 to 1.55	2
49	2	NAT	ME	7.9 to 8.1	2
50	2	NAT	ME	2499 to 2501	2
51	2	NAT	ME	85.1 to 86.1	2
52	2	NAT	ME	543 to 545	2
53	2	NAT	ME	10 to 10	2
54	2	NAT	ME	1500 to 1525	2
55	2	NAT	ME	4.6 to 4.9	2

**Q. 1 – Q. 5 carry one mark each.**

- Q.1 “Going by the \_\_\_\_\_ that many hands make light work, the school \_\_\_\_\_ involved all the students in the task.”

The words that best fill the blanks in the above sentence are

- (A) principle, principal                      (B) principal, principle  
(C) principle, principle                      (D) principal, principal

- Q.2 “Her \_\_\_\_\_ should not be confused with miserliness; she is ever willing to assist those in need.”

The word that best fills the blank in the above sentence is

- (A) cleanliness              (B) punctuality              (C) frugality              (D) greatness

- Q.3 Seven machines take 7 minutes to make 7 identical toys. At the same rate, how many minutes would it take for 100 machines to make 100 toys?

- (A) 1                      (B) 7                      (C) 100                      (D) 700

- Q.4 A rectangle becomes a square when its length and breadth are reduced by 10 m and 5 m, respectively. During this process, the rectangle loses  $650 \text{ m}^2$  of area. What is the area of the original rectangle in square meters?

- (A) 1125                      (B) 2250                      (C) 2924                      (D) 4500

- Q.5 A number consists of two digits. The sum of the digits is 9. If 45 is subtracted from the number, its digits are interchanged. What is the number?

- (A) 63                      (B) 72                      (C) 81                      (D) 90

**Q. 6 – Q. 10 carry two marks each.**

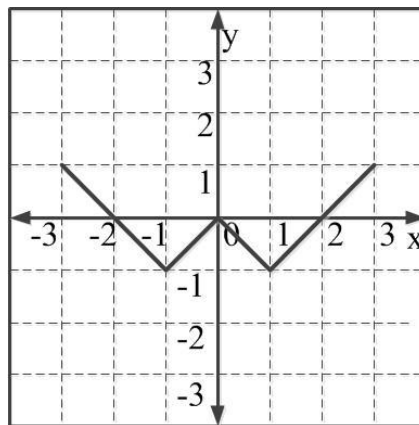
- Q.6 For integers  $a$ ,  $b$  and  $c$ , what would be the minimum and maximum values respectively of  $a + b + c$  if  $\log |a| + \log |b| + \log |c| = 0$ ?

- (A) -3 and 3                      (B) -1 and 1                      (C) -1 and 3                      (D) 1 and 3

- Q.7 Given that  $a$  and  $b$  are integers and  $a + a^2 b^3$  is odd, which one of the following statements is correct?
- (A)  $a$  and  $b$  are both odd  
 (B)  $a$  and  $b$  are both even  
 (C)  $a$  is even and  $b$  is odd  
 (D)  $a$  is odd and  $b$  is even

- Q.8 From the time the front of a train enters a platform, it takes 25 seconds for the back of the train to leave the platform, while travelling at a constant speed of 54 km/h. At the same speed, it takes 14 seconds to pass a man running at 9 km/h in the same direction as the train. What is the length of the train and that of the platform in meters, respectively?
- (A) 210 and 140  
 (B) 162.5 and 187.5  
 (C) 245 and 130  
 (D) 175 and 200

- Q.9 Which of the following functions describe the graph shown in the below figure?



- (A)  $y = ||x| + 1| - 2$   
 (B)  $y = ||x| - 1| - 1$   
 (C)  $y = ||x| + 1| - 1$   
 (D)  $y = ||x - 1| - 1|$
- Q.10 Consider the following three statements:
- (i) Some roses are red.
  - (ii) All red flowers fade quickly.
  - (iii) Some roses fade quickly.

Which of the following statements can be logically inferred from the above statements?

- (A) If (i) is true and (ii) is false, then (iii) is false.  
 (B) If (i) is true and (ii) is false, then (iii) is true.  
 (C) If (i) and (ii) are true, then (iii) is true.  
 (D) If (i) and (ii) are false, then (iii) is false.

**END OF THE QUESTION PAPER**

**Q. 1 – Q. 25 carry one mark each.**

Q.1 Four red balls, four green balls and four blue balls are put in a box. Three balls are pulled out of the box at random one after another without replacement. The probability that all the three balls are red is

- (A)  $1/72$                       (B)  $1/55$                       (C)  $1/36$                       (D)  $1/27$

Q.2 The rank of the matrix  $\begin{bmatrix} -4 & 1 & -1 \\ -1 & -1 & -1 \\ 7 & -3 & 1 \end{bmatrix}$  is

- (A) 1                      (B) 2                      (C) 3                      (D) 4

Q.3 According to the Mean Value Theorem, for a continuous function  $f(x)$  in the interval  $[a, b]$ ,

there exists a value  $\xi$  in this interval such that  $\int_a^b f(x)dx =$

- (A)  $f(\xi)(b-a)$                       (B)  $f(b)(\xi-a)$   
 (C)  $f(a)(b-\xi)$                       (D) 0

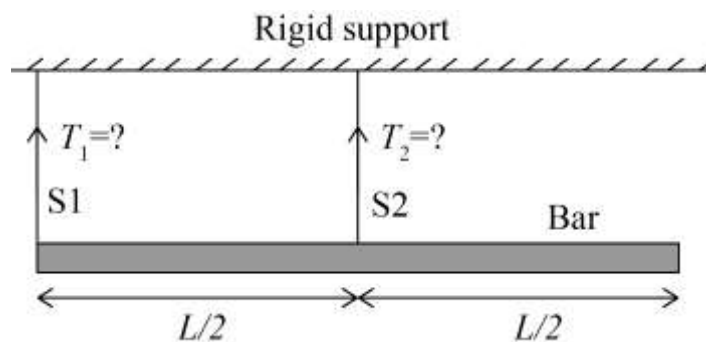
Q.4  $F(z)$  is a function of the complex variable  $z = x + iy$  given by

$$F(z) = iz + k \operatorname{Re}(z) + i \operatorname{Im}(z).$$

For what value of  $k$  will  $F(z)$  satisfy the Cauchy-Riemann equations?

- (A) 0                      (B) 1                      (C) -1                      (D)  $y$

Q.5 A bar of uniform cross section and weighing 100 N is held horizontally using two massless and inextensible strings S1 and S2 as shown in the figure.



The tensions in the strings are

- (A)  $T_1 = 100 \text{ N}$  and  $T_2 = 0 \text{ N}$                       (B)  $T_1 = 0 \text{ N}$  and  $T_2 = 100 \text{ N}$   
 (C)  $T_1 = 75 \text{ N}$  and  $T_2 = 25 \text{ N}$                       (D)  $T_1 = 25 \text{ N}$  and  $T_2 = 75 \text{ N}$

Q.6 If  $\sigma_1$  and  $\sigma_3$  are the algebraically largest and smallest principal stresses respectively, the value of the maximum shear stress is

- (A)  $\frac{\sigma_1 + \sigma_3}{2}$       (B)  $\frac{\sigma_1 - \sigma_3}{2}$       (C)  $\sqrt{\frac{\sigma_1 + \sigma_3}{2}}$       (D)  $\sqrt{\frac{\sigma_1 - \sigma_3}{2}}$

Q.7 The equation of motion for a spring-mass system excited by a harmonic force is

$$M\ddot{x} + Kx = F \cos(\omega t),$$

where  $M$  is the mass,  $K$  is the spring stiffness,  $F$  is the force amplitude and  $\omega$  is the angular frequency of excitation. Resonance occurs when  $\omega$  is equal to

- (A)  $\sqrt{\frac{M}{K}}$       (B)  $\frac{1}{2\pi} \sqrt{\frac{K}{M}}$       (C)  $2\pi \sqrt{\frac{K}{M}}$       (D)  $\sqrt{\frac{K}{M}}$

Q.8 For an Oldham coupling used between two shafts, which among the following statements are correct?

- I. Torsional load is transferred along shaft axis.
- II. A velocity ratio of 1:2 between shafts is obtained without using gears.
- III. Bending load is transferred transverse to shaft axis.
- IV. Rotation is transferred along shaft axis.

- (A) I and III      (B) I and IV      (C) II and III      (D) II and IV

Q.9 For a two-dimensional incompressible flow field given by  $\vec{u} = A(x\hat{i} - y\hat{j})$ , where  $A > 0$ , which one of the following statements is FALSE?

- (A) It satisfies continuity equation.
- (B) It is unidirectional when  $x \rightarrow 0$  and  $y \rightarrow \infty$ .
- (C) Its streamlines are given by  $x = y$ .
- (D) It is irrotational.

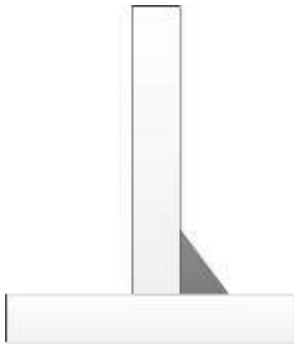
Q.10 Which one of the following statements is correct for a superheated vapour?

- (A) Its pressure is less than the saturation pressure at a given temperature.
- (B) Its temperature is less than the saturation temperature at a given pressure.
- (C) Its volume is less than the volume of the saturated vapour at a given temperature.
- (D) Its enthalpy is less than the enthalpy of the saturated vapour at a given pressure.

Q.11 In a linearly hardening plastic material, the true stress beyond initial yielding

- (A) increases linearly with the true strain
- (B) decreases linearly with the true strain
- (C) first increases linearly and then decreases linearly with the true strain
- (D) remains constant

Q.12 The type of weld represented by the shaded region in the figure is



- (A) groove
- (B) spot
- (C) fillet
- (D) plug

Q.13 Using the Taylor's tool life equation with exponent  $n = 0.5$ , if the cutting speed is reduced by 50%, the ratio of new tool life to original tool life is

- (A) 4
- (B) 2
- (C) 1
- (D) 0.5

Q.14 A grinding ratio of 200 implies that the

- (A) grinding wheel wears 200 times the volume of the material removed
- (B) grinding wheel wears 0.005 times the volume of the material removed
- (C) aspect ratio of abrasive particles used in the grinding wheel is 200
- (D) ratio of volume of abrasive particle to that of grinding wheel is 200

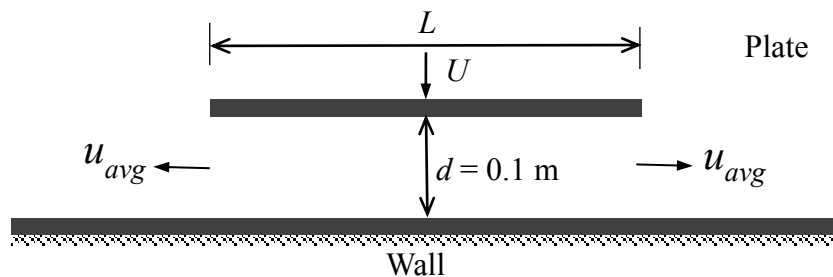
Q.15 Interpolator in a CNC machine

- (A) controls spindle speed
- (B) coordinates axes movements
- (C) operates tool changer
- (D) commands canned cycle

Q.16 The time series forecasting method that gives equal weightage to each of the  $m$  most recent observations is

- (A) Moving average method
- (B) Exponential smoothing with linear trend
- (C) Triple Exponential smoothing
- (D) Kalman Filter

- Q.17 The number of atoms per unit cell and the number of slip systems, respectively, for a face-centered cubic (FCC) crystal are  
 (A) 3, 3 (B) 3, 12 (C) 4, 12 (D) 4, 48
- Q.18 A six-faced fair dice is rolled five times. The probability (in %) of obtaining “ONE” at least four times is  
 (A) 33.3 (B) 3.33 (C) 0.33 (D) 0.0033
- Q.19 A steel column of rectangular section ( $15 \text{ mm} \times 10 \text{ mm}$ ) and length  $1.5 \text{ m}$  is simply supported at both ends. Assuming modulus of elasticity,  $E = 200 \text{ GPa}$  for steel, the critical axial load (in kN) is \_\_\_\_ (correct to two decimal places).
- Q.20 A four bar mechanism is made up of links of length  $100, 200, 300$  and  $350 \text{ mm}$ . If the  $350 \text{ mm}$  link is fixed, the number of links that can rotate fully is \_\_\_\_\_.
- Q.21 If the wire diameter of a compressive helical spring is increased by  $2\%$ , the change in spring stiffness (in %) is \_\_\_\_ (correct to two decimal places).
- Q.22 A flat plate of width  $L = 1 \text{ m}$  is pushed down with a velocity  $U = 0.01 \text{ m/s}$  towards a wall resulting in the drainage of the fluid between the plate and the wall as shown in the figure. Assume two-dimensional incompressible flow and that the plate remains parallel to the wall. The average velocity,  $u_{avg}$  of the fluid (in m/s) draining out at the instant shown in the figure is \_\_\_\_\_ (correct to three decimal places).



- Q.23 An ideal gas undergoes a process from state 1 ( $T_1 = 300$  K,  $p_1 = 100$  kPa) to state 2 ( $T_2 = 600$  K,  $p_2 = 500$  kPa). The specific heats of the ideal gas are :  $c_p = 1$  kJ/kg-K and  $c_v = 0.7$  kJ/kg-K. The change in specific entropy of the ideal gas from state 1 to state 2 (in kJ/kg-K) is \_\_\_\_\_(correct to two decimal places).
- Q.24 For a Pelton wheel with a given water jet velocity, the maximum output power from the Pelton wheel is obtained when the ratio of the bucket speed to the water jet speed is \_\_\_\_\_ (correct to two decimal places).
- Q.25 The height (in mm) for a 125 mm sine bar to measure a taper of  $27^\circ 32'$  on a flat work piece is \_\_\_\_\_ (correct to three decimal places).

**Q. 26 – Q. 55 carry two marks each.**

- Q.26 Let  $X_1, X_2$  be two independent normal random variables with means  $\mu_1, \mu_2$  and standard deviations  $\sigma_1, \sigma_2$ , respectively. Consider  $Y = X_1 - X_2$ ;  $\mu_1 = \mu_2 = 1, \sigma_1 = 1, \sigma_2 = 2$ . Then,
- (A)  $Y$  is normally distributed with mean 0 and variance 1
  - (B)  $Y$  is normally distributed with mean 0 and variance 5
  - (C)  $Y$  has mean 0 and variance 5, but is NOT normally distributed
  - (D)  $Y$  has mean 0 and variance 1, but is NOT normally distributed

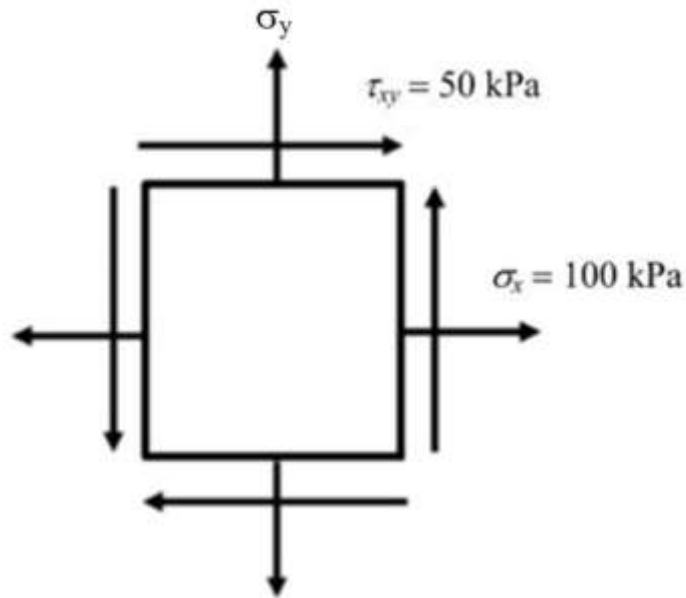
- Q.27 The value of the integral

$$\oiint_S \vec{r} \cdot \vec{n} \, dS$$

over the closed surface  $S$  bounding a volume  $V$ , where  $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$  is the position vector and  $\vec{n}$  is the normal to the surface  $S$ , is

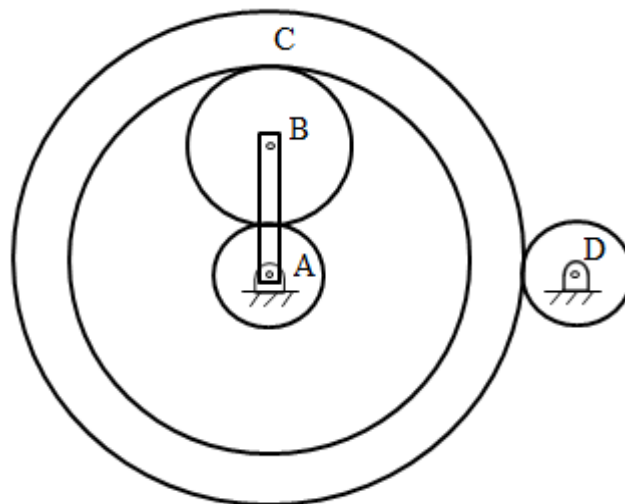
- (A)  $V$                       (B)  $2V$                       (C)  $3V$                       (D)  $4V$
- Q.28 A point mass is shot vertically up from ground level with a velocity of 4 m/s at time,  $t = 0$ . It loses 20% of its impact velocity after each collision with the ground. Assuming that the acceleration due to gravity is  $10 \text{ m/s}^2$  and that air resistance is negligible, the mass stops bouncing and comes to complete rest on the ground after a total time (in seconds) of
- (A) 1                      (B) 2                      (C) 4                      (D)  $\infty$

Q.29 The state of stress at a point, for a body in plane stress, is shown in the figure below. If the minimum principal stress is 10 kPa, then the normal stress  $\sigma_y$  (in kPa) is



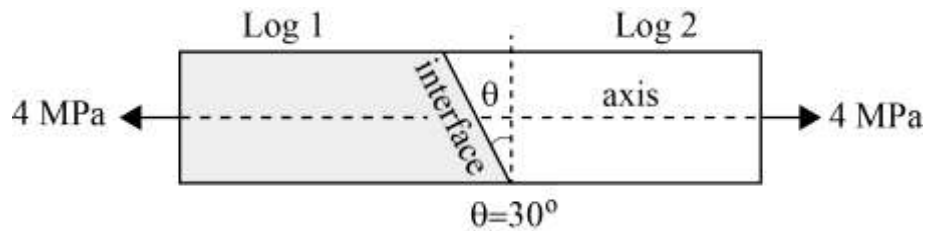
- (A) 9.45                      (B) 18.88                      (C) 37.78                      (D) 75.50

Q.30 An epicyclic gear train is shown in the figure below. The number of teeth on the gears A, B and D are 20, 30 and 20, respectively. Gear C has 80 teeth on the inner surface and 100 teeth on the outer surface. If the carrier arm AB is fixed and the sun gear A rotates at 300 rpm in the clockwise direction, then the rpm of D in the clockwise direction is



- (A) 240                      (B) -240                      (C) 375                      (D) -375

- Q.31 A carpenter glues a pair of cylindrical wooden logs by bonding their end faces at an angle of  $\theta = 30^\circ$  as shown in the figure.



The glue used at the interface fails if

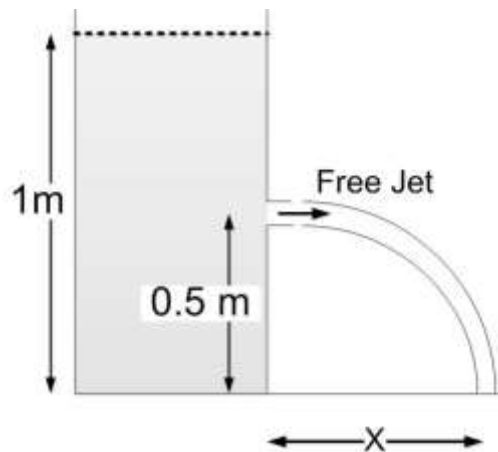
Criterion 1: the maximum normal stress exceeds 2.5 MPa.

Criterion 2: the maximum shear stress exceeds 1.5 MPa.

Assume that the interface fails before the logs fail. When a uniform tensile stress of 4 MPa is applied, the interface

- (A) fails only because of criterion 1  
 (B) fails only because of criterion 2  
 (C) fails because of both criteria 1 and 2  
 (D) does not fail
- Q.32 A self-aligning ball bearing has a basic dynamic load rating ( $C_{10}$ , for  $10^6$  revolutions) of 35 kN. If the equivalent radial load on the bearing is 45 kN, the expected life (in  $10^6$  revolutions) is
- (A) below 0.5      (B) 0.5 to 0.8      (C) 0.8 to 1.0      (D) above 1.0

- Q.33 A tank open at the top with a water level of 1 m, as shown in the figure, has a hole at a height of 0.5 m. A free jet leaves horizontally from the smooth hole. The distance  $X$  (in m) where the jet strikes the floor is



- (A) 0.5      (B) 1.0      (C) 2.0      (D) 4.0

Q.34 In a Lagrangian system, the position of a fluid particle in a flow is described as  $x = x_0 e^{-kt}$  and  $y = y_0 e^{kt}$  where  $t$  is the time while  $x_0$ ,  $y_0$ , and  $k$  are constants. The flow is

- (A) unsteady and one-dimensional
- (B) steady and two-dimensional
- (C) steady and one-dimensional
- (D) unsteady and two-dimensional

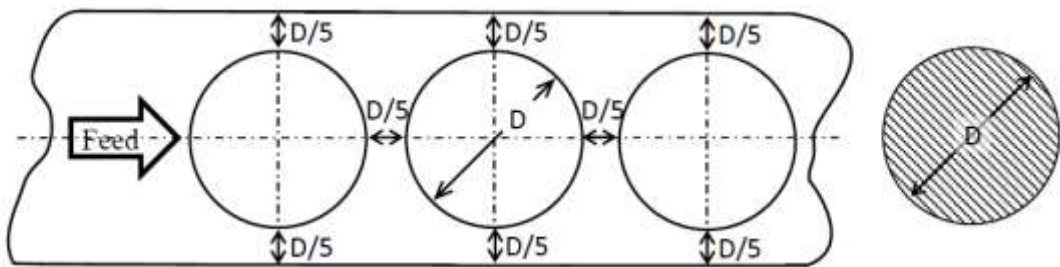
Q.35 The maximum reduction in cross-sectional area per pass ( $R$ ) of a cold wire drawing process is

$$R = 1 - e^{-(n+1)},$$

where  $n$  represents the strain hardening coefficient. For the case of a perfectly plastic material,  $R$  is

- (A) 0.865
- (B) 0.826
- (C) 0.777
- (D) 0.632

Q.36 The percentage scrap in a sheet metal blanking operation of a continuous strip of sheet metal as shown in the figure is \_\_\_\_\_ (correct to two decimal places).



Q.37 An explicit forward Euler method is used to numerically integrate the differential equation

$$\frac{dy}{dt} = y$$

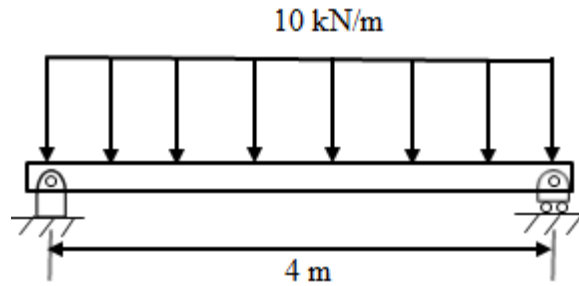
using a time step of 0.1. With the initial condition  $y(0) = 1$ , the value of  $y(1)$  computed by this method is \_\_\_\_\_ (correct to two decimal places).

Q.38  $F(s)$  is the Laplace transform of the function

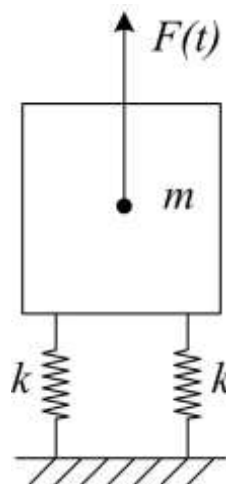
$$f(t) = 2t^2 e^{-t}$$

$F(1)$  is \_\_\_\_\_ (correct to two decimal places).

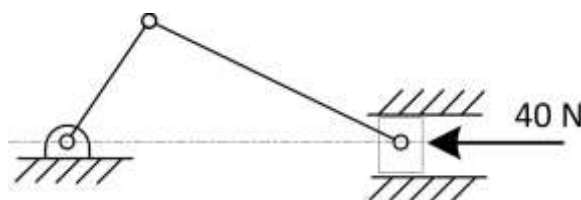
- Q.39 A simply supported beam of width 100 mm, height 200 mm and length 4 m is carrying a uniformly distributed load of intensity 10 kN/m. The maximum bending stress (in MPa) in the beam is \_\_\_\_\_ (correct to one decimal place).



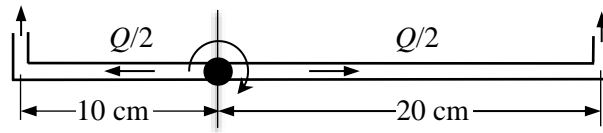
- Q.40 A machine of mass  $m = 200$  kg is supported on two mounts, each of stiffness  $k = 10$  kN/m. The machine is subjected to an external force (in N)  $F(t) = 50 \cos 5t$ . Assuming only vertical translatory motion, the magnitude of the dynamic force (in N) transmitted from each mount to the ground is \_\_\_\_\_ (correct to two decimal places).



- Q.41 A slider crank mechanism is shown in the figure. At some instant, the crank angle is  $45^\circ$  and a force of 40 N is acting towards the left on the slider. The length of the crank is 30 mm and the connecting rod is 70 mm. Ignoring the effect of gravity, friction and inertial forces, the magnitude of the crankshaft torque (in Nm) needed to keep the mechanism in equilibrium is \_\_\_\_\_ (correct to two decimal places).

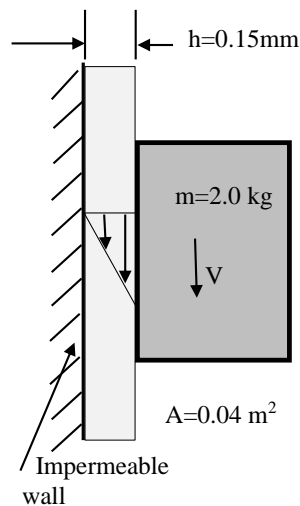


- Q.42 A sprinkler shown in the figure rotates about its hinge point in a horizontal plane due to water flow discharged through its two exit nozzles.



The total flow rate  $Q$  through the sprinkler is 1 litre/sec and the cross-sectional area of each exit nozzle is  $1 \text{ cm}^2$ . Assuming equal flow rate through both arms and a frictionless hinge, the steady state angular speed of rotation (in rad/s) of the sprinkler is \_\_\_\_\_ (correct to two decimal places).

- Q.43 A solid block of 2.0 kg mass slides steadily at a velocity  $V$  along a vertical wall as shown in the figure below. A thin oil film of thickness  $h = 0.15 \text{ mm}$  provides lubrication between the block and the wall. The surface area of the face of the block in contact with the oil film is  $0.04 \text{ m}^2$ . The velocity distribution within the oil film gap is linear as shown in the figure. Take dynamic viscosity of oil as  $7 \times 10^{-3} \text{ Pa}\cdot\text{s}$  and acceleration due to gravity as  $10 \text{ m/s}^2$ . Neglect weight of the oil. The terminal velocity  $V$  (in m/s) of the block is \_\_\_\_\_ (correct to one decimal place).



- Q.44 A tank of volume  $0.05 \text{ m}^3$  contains a mixture of saturated water and saturated steam at  $200^\circ\text{C}$ . The mass of the liquid present is 8 kg. The entropy (in kJ/kg K) of the mixture is \_\_\_\_\_ (correct to two decimal places).

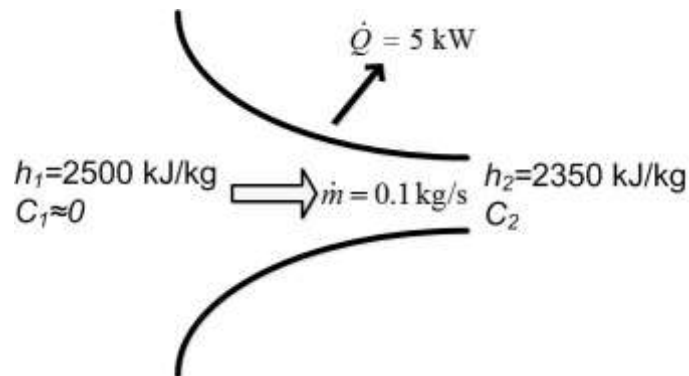
Property data for saturated steam and water are:

At  $200^\circ\text{C}$ ,  $p_{sat} = 1.5538 \text{ MPa}$

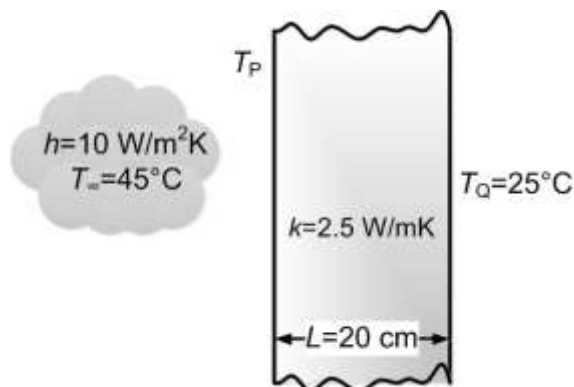
$v_f = 0.001157 \text{ m}^3/\text{kg}$ ,  $v_g = 0.12736 \text{ m}^3/\text{kg}$

$s_{fg} = 4.1014 \text{ kJ/kg K}$ ,  $s_f = 2.3309 \text{ kJ/kg K}$

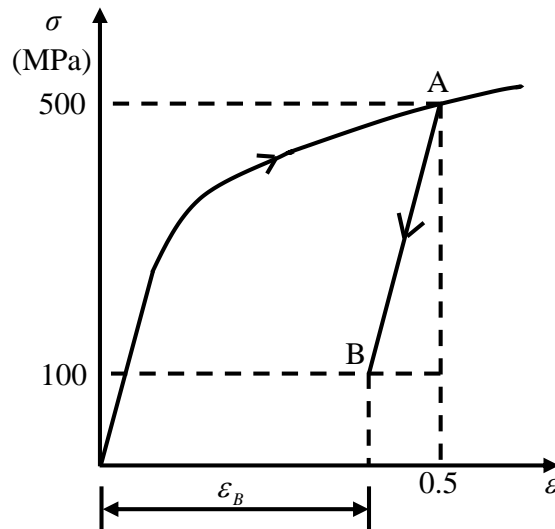
- Q.45 Steam flows through a nozzle at a mass flow rate of  $\dot{m} = 0.1 \text{ kg/s}$  with a heat loss of 5 kW. The enthalpies at inlet and exit are 2500 kJ/kg and 2350 kJ/kg, respectively. Assuming negligible velocity at inlet ( $C_1 \approx 0$ ), the velocity ( $C_2$ ) of steam (in m/s) at the nozzle exit is \_\_\_\_\_ (correct to two decimal places).



- Q.46 An engine working on air standard Otto cycle is supplied with air at 0.1 MPa and 35°C. The compression ratio is 8. The heat supplied is 500 kJ/kg. Property data for air:  $c_p = 1.005 \text{ kJ/kg K}$ ,  $c_v = 0.718 \text{ kJ/kg K}$ ,  $R = 0.287 \text{ kJ/kg K}$ . The maximum temperature (in K) of the cycle is \_\_\_\_\_ (correct to one decimal place).
- Q.47 A plane slab of thickness  $L$  and thermal conductivity  $k$  is heated with a fluid on one side (P), and the other side (Q) is maintained at a constant temperature,  $T_Q$  of 25°C, as shown in the figure. The fluid is at 45°C and the surface heat transfer coefficient,  $h$ , is 10 W/m<sup>2</sup>K. The steady state temperature,  $T_P$ , (in °C) of the side which is exposed to the fluid is \_\_\_\_\_ (correct to two decimal places).



- Q.48 The true stress ( $\sigma$ ) - true strain ( $\varepsilon$ ) diagram of a strain hardening material is shown in figure. First, there is loading up to point A, i.e., up to stress of 500 MPa and strain of 0.5. Then from point A, there is unloading up to point B, i.e., to stress of 100 MPa. Given that the Young's modulus  $E = 200$  GPa, the natural strain at point B ( $\varepsilon_B$ ) is \_\_\_\_\_ (correct to three decimal places).



- Q.49 An orthogonal cutting operation is being carried out in which uncut thickness is 0.010 mm, cutting speed is 130 m/min, rake angle is  $15^\circ$  and width of cut is 6 mm. It is observed that the chip thickness is 0.015 mm, the cutting force is 60 N and the thrust force is 25 N. The ratio of friction energy to total energy is \_\_\_\_\_ (correct to two decimal places).
- Q.50 A bar is compressed to half of its original length. The magnitude of true strain produced in the deformed bar is \_\_\_\_\_ (correct to two decimal places).

- Q.51 The minimum value of  $3x + 5y$  such that:

$$3x + 5y \leq 15$$

$$4x + 9y \leq 8$$

$$13x + 2y \leq 2$$

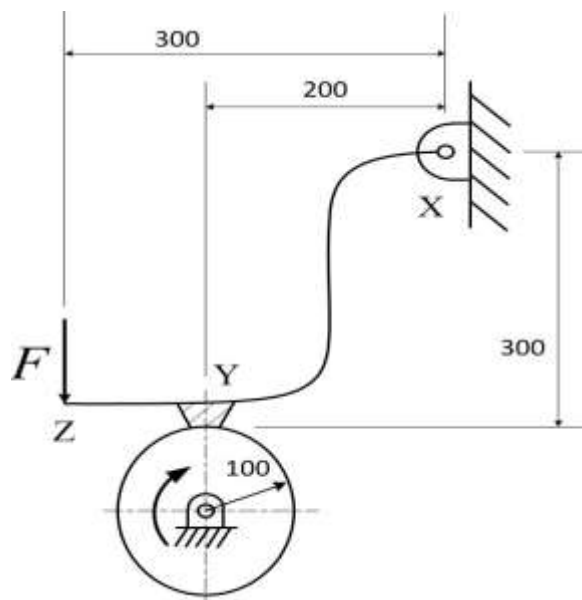
$$x \geq 0, y \geq 0$$

is \_\_\_\_\_.

- Q.52 Processing times (including setup times) and due dates for six jobs waiting to be processed at a work centre are given in the table. The average tardiness (in days) using shortest processing time rule is \_\_\_\_\_ (correct to two decimal places).

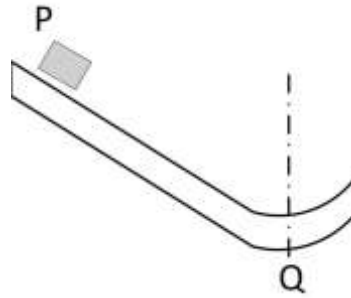
Job	Processing time (days)	Due date (days)
A	3	8
B	7	16
C	4	4
D	9	18
E	5	17
F	13	19

- Q.53 The schematic of an external drum rotating clockwise engaging with a short shoe is shown in the figure. The shoe is mounted at point Y on a rigid lever XYZ hinged at point X. A force  $F = 100\text{ N}$  is applied at the free end of the lever as shown. Given that the coefficient of friction between the shoe and the drum is 0.3, the braking torque (in Nm ) applied on the drum is \_\_\_\_\_ (correct to two decimal places).



(All dimensions are in mm)

- Q.54 Block P of mass 2 kg slides down the surface and has a speed 20 m/s at the lowest point, Q, where the local radius of curvature is 2 m as shown in the figure. Assuming  $g = 10 \text{ m/s}^2$ , the normal force (in N) at Q is \_\_\_\_\_ (correct to two decimal places).



- Q.55 An electrochemical machining (ECM) is to be used to cut a through hole into a 12 mm thick aluminum plate. The hole has a rectangular cross-section, 10 mm  $\times$  30 mm. The ECM operation will be accomplished in 2 minutes, with efficiency of 90%. Assuming specific removal rate for aluminum as  $3.44 \times 10^{-2} \text{ mm}^3/(\text{A s})$ , the current (in A) required is \_\_\_\_\_ (correct to two decimal places).

**END OF THE QUESTION PAPER**

Q.No.	Type	Section	Key/Range	Marks
1	MCQ	GA	A	1
2	MCQ	GA	C	1
3	MCQ	GA	B	1
4	MCQ	GA	B	1
5	MCQ	GA	B	1
6	MCQ	GA	A	2
7	MCQ	GA	D	2
8	MCQ	GA	D	2
9	MCQ	GA	B	2
10	MCQ	GA	C	2
1	MCQ	ME	B	1
2	MCQ	ME	B	1
3	MCQ	ME	A	1
4	MCQ	ME	B	1
5	MCQ	ME	B	1
6	MCQ	ME	B	1
7	MCQ	ME	D	1
8	MCQ	ME	B	1
9	MCQ	ME	C	1
10	MCQ	ME	A	1
11	MCQ	ME	A	1
12	MCQ	ME	C	1
13	MCQ	ME	A	1

Q.No.	Type	Section	Key/Range	Marks
14	MCQ	ME	B	1
15	MCQ	ME	B	1
16	MCQ	ME	A	1
17	MCQ	ME	C	1
18	MCQ	ME	C	1
19	NAT	ME	1.00 to 1.20	1
20	NAT	ME	1 to 1	1
21	NAT	ME	8.00 to 8.50	1
22	NAT	ME	0.045 to 0.055	1
23	NAT	ME	0.20 to 0.22	1
24	NAT	ME	0.45 to 0.52	1
25	NAT	ME	57.000 to 58.000	1
26	MCQ	ME	B	2
27	MCQ	ME	C	2
28	MCQ	ME	C	2
29	MCQ	ME	C	2
30	MCQ	ME	C	2
31	MCQ	ME	C	2
32	MCQ	ME	A	2
33	MCQ	ME	B	2
34	MCQ	ME	B	2
35	MCQ	ME	D	2
36	NAT	ME	52.00 to 54.00	2

Q.No.	Type	Section	Key/Range	Marks
37	NAT	ME	2.55 to 2.65	2
38	NAT	ME	0.48 to 0.52	2
39	NAT	ME	29.8 to 30.1	2
40	NAT	ME	33.00 to 33.50	2
41	NAT	ME	1.00 to 1.20	2
42	NAT	ME	9.50 to 10.50	2
43	NAT	ME	10.6 to 10.8	2
44	NAT	ME	2.45 to 2.55	2
45	NAT	ME	445.00 to 450.00	2
46	NAT	ME	1402.0 to 1406.0	2
47	NAT	ME	33.50 to 34.30	2
48	NAT	ME	0.498 to 0.498	2
49	NAT	ME	0.39 to 0.49	2
50	NAT	ME	0.69 to 0.70	2
51	NAT	ME	0 to 0	2
52	NAT	ME	6.31 to 6.35	2
53	NAT	ME	8.00 to 9.00	2
54	NAT	ME	419.00 to 421.00	2
55	NAT	ME	968.80 to 969.20	2

**Q. 1 – Q. 5 carry one mark each.**

Q.1 “The dress \_\_\_\_\_ her so well that they all immediately \_\_\_\_\_ her on her appearance.”

The words that best fill the blanks in the above sentence are

- (A) complemented, complemented                      (B) complimented, complemented  
(C) complimented, complimented                      (D) complemented, complimented

Q.2 “The judge’s standing in the legal community, though shaken by false allegations of wrongdoing, remained \_\_\_\_\_.”

The word that best fills the blank in the above sentence is

- (A) undiminished      (B) damaged                      (C) illegal                      (D) uncertain

Q.3 Find the missing group of letters in the following series:  
BC, FGH, LMNO, \_\_\_\_\_

- (A) UVWXY                      (B) TUVWX                      (C) STUVW                      (D) RSTUV

Q.4 The perimeters of a circle, a square and an equilateral triangle are equal. Which one of the following statements is true?

- (A) The circle has the largest area.  
(B) The square has the largest area.  
(C) The equilateral triangle has the largest area.  
(D) All the three shapes have the same area.

Q.5 The value of the expression  $\frac{1}{1+\log_u vw} + \frac{1}{1+\log_v wu} + \frac{1}{1+\log_w uv}$  is \_\_\_\_\_.

- (A) -1                      (B) 0                      (C) 1                      (D) 3

**Q. 6 – Q. 10 carry two marks each.**

Q.6 Forty students watched films A, B and C over a week. Each student watched either only one film or all three. Thirteen students watched film A, sixteen students watched film B and nineteen students watched film C. How many students watched all three films?

- (A) 0                      (B) 2                      (C) 4                      (D) 8

Q.7 A wire would enclose an area of  $1936 \text{ m}^2$ , if it is bent into a square. The wire is cut into two pieces. The longer piece is thrice as long as the shorter piece. The long and the short pieces are bent into a square and a circle, respectively. Which of the following choices is closest to the sum of the areas enclosed by the two pieces in square meters?

- (A) 1096                      (B) 1111                      (C) 1243                      (D) 2486

Q.8 A contract is to be completed in 52 days and 125 identical robots were employed, each operational for 7 hours a day. After 39 days, five-seventh of the work was completed. How many additional robots would be required to complete the work on time, if each robot is now operational for 8 hours a day?

- (A) 50                      (B) 89                      (C) 146                      (D) 175

Q.9 A house has a number which needs to be identified. The following three statements are given that can help in identifying the house number.

- i. If the house number is a multiple of 3, then it is a number from 50 to 59.
- ii. If the house number is NOT a multiple of 4, then it is a number from 60 to 69.
- iii. If the house number is NOT a multiple of 6, then it is a number from 70 to 79.

What is the house number?

- (A) 54                      (B) 65                      (C) 66                      (D) 76

- Q.10 An unbiased coin is tossed six times in a row and four different such trials are conducted. One trial implies six tosses of the coin. If H stands for head and T stands for tail, the following are the observations from the four trials:  
(1) HTHTHT (2) TTHHHT (3) HTTHHT (4) HHHT\_\_ \_\_.

Which statement describing the last two coin tosses of the fourth trial has the highest probability of being correct?

- (A) Two T will occur.
- (B) One H and one T will occur.
- (C) Two H will occur.
- (D) One H will be followed by one T.

**END OF THE QUESTION PAPER**

**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

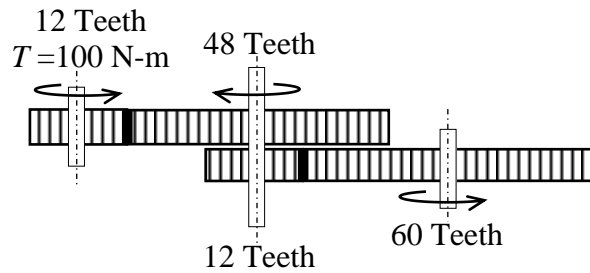
Q.4 If  $y$  is the solution of the differential equation  $y^3 \frac{dy}{dx} + x^3 = 0$ ,  $y(0) = 1$ , the value of  $y(-1)$  is

- (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

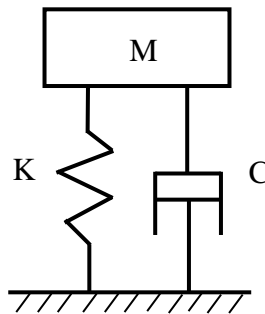
- (A)  $P = \frac{\pi^2 EI}{4L^2}$                       (B)  $P = \frac{\pi^2 EI}{L^2}$                       (C)  $P = \frac{3\pi^2 EI}{4L^2}$                       (D)  $P = \frac{4\pi^2 EI}{L^2}$

- 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  $1.45 \mu\text{m}$ . If the peak wavelength of emitted radiation changes to  $2.90 \mu\text{m}$ , 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 ( $\Delta s$ ) 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.

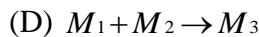
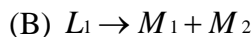
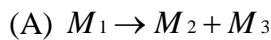
(A) The rotor blade is symmetric.

(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

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).

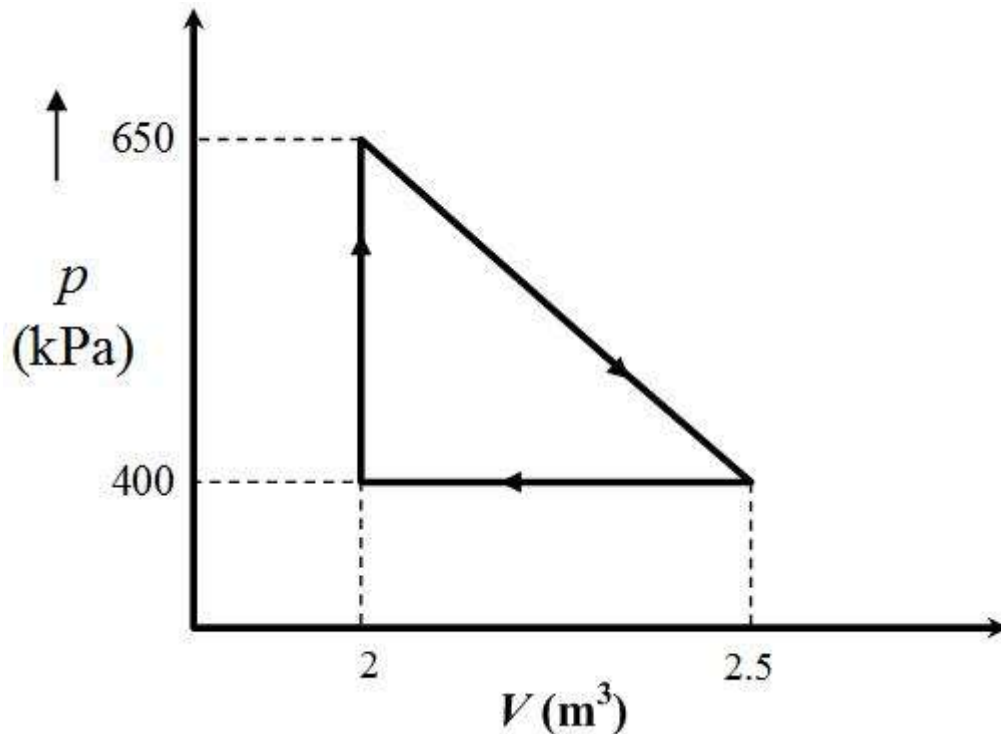
Q.20 A hollow circular shaft of inner radius 10 mm, outer radius 20 mm and length 1 m is to be used as a torsional spring. If the shear modulus of the material of the shaft is 150 GPa, the torsional stiffness of the shaft (in kN-m/rad) is \_\_\_\_\_ (correct to two decimal places).

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

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

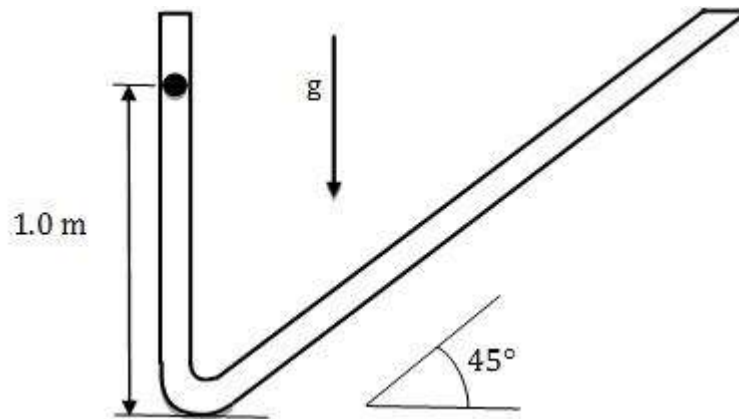
where  $\sigma_a$  is the stress amplitude in MPa and  $N$  is the failure life in cycles. The maximum allowable stress amplitude (in MPa) for a life of  $1 \times 10^5$  cycles under the same loading condition is \_\_\_\_\_ (correct to two decimal places).

- 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  $\delta_L$ . 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  $\delta_L$ ) 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).



**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,

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

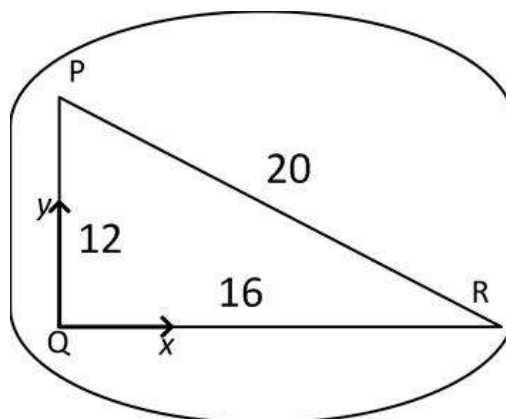
the value of  $A$  is

- (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

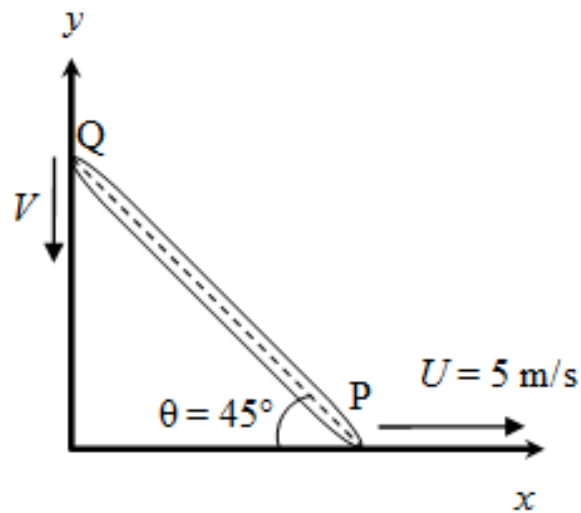
- (A)  $\vec{r}$                       (B)  $\frac{\vec{r}}{|\vec{r}|}$                       (C)  $\frac{\vec{r}}{\vec{r}\cdot\vec{r}}$                       (D)  $\frac{\vec{r}}{|\vec{r}|^3}$

- 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  $\text{m/s}^2$ ) of point R is



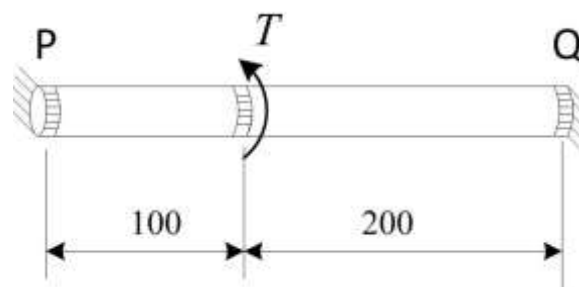
- (A)  $8\angle 233^\circ$                       (B)  $10\angle 225^\circ$                       (C)  $10\angle 217^\circ$                       (D)  $8\angle 217^\circ$

- 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



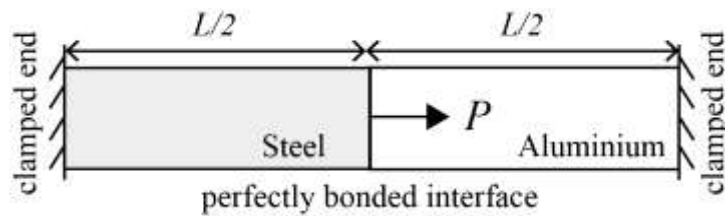
(All dimensions are in mm)

- (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  $\delta$  (radians) at constant angular velocity  $\omega$  (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

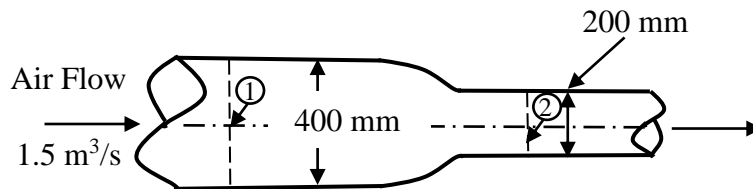
- (A)  $\frac{4h\omega}{\delta}$                       (B)  $h\omega$                       (C)  $\frac{2h\omega}{\delta}$                       (D)  $2h\omega$

Q.33 A bimetallic cylindrical bar of cross sectional area  $1 \text{ m}^2$  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  $1.2 \text{ kg/m}^3$  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

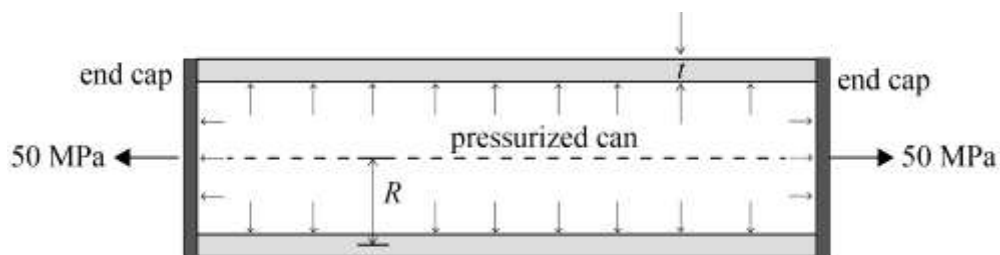
- (A) no solution
- (B) one solution
- (C) two solutions
- (D) more than two solutions

Q.36 Given the ordinary differential equation

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

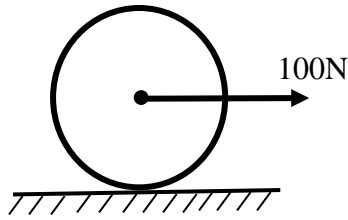
with  $y(0) = 0$  and  $\frac{dy}{dx}(0) = 1$ , the value of  $y(1)$  is \_\_\_\_\_ (correct to two decimal places).

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).

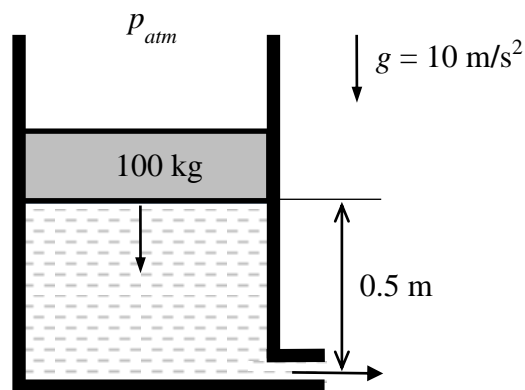


Q.38 A bar is subjected to a combination of a steady load of 60 kN and a load fluctuating between  $-10$  kN and 90 kN. The corrected endurance limit of the bar is 150 MPa, the yield strength of the material is 480 MPa and the ultimate strength of the material is 600 MPa. The bar cross-section is square 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).

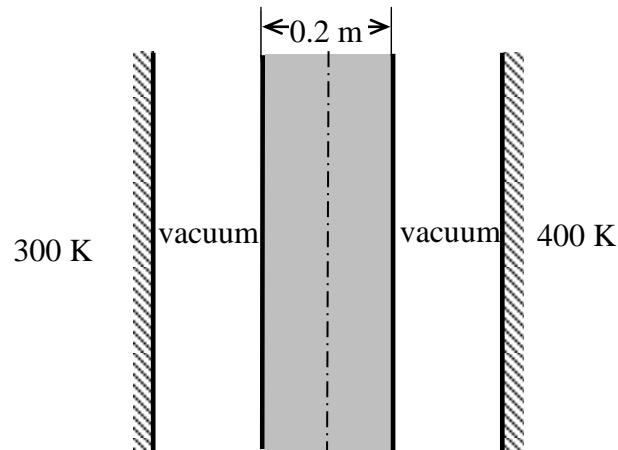
- Q.39 A force of 100 N is applied to the centre of a circular disc, of mass 10 kg and radius 1 m, resting on a floor as shown in the figure. If the disc rolls without slipping on the floor, the linear acceleration (in  $\text{m/s}^2$ ) of the centre of the disc is \_\_\_\_\_ (correct to two decimal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



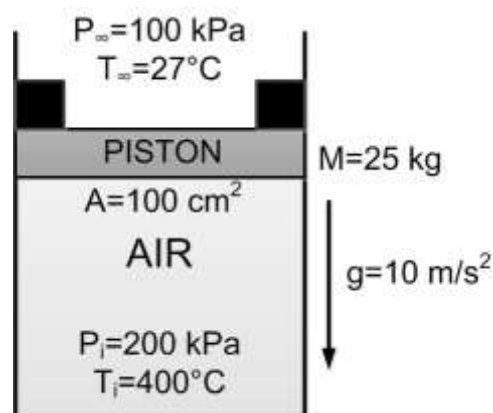
- Q.40 A frictionless circular piston of area  $10^{-2} \text{ m}^2$  and mass 100 kg sinks into a cylindrical container of the same area filled with water of density  $1000 \text{ kg/m}^3$  as shown in the figure. The container has a hole of area  $10^{-3} \text{ m}^2$  at the bottom that is open to 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  $\text{m/s}$ ) at the instant shown is \_\_\_\_\_ (correct to three decimal places).



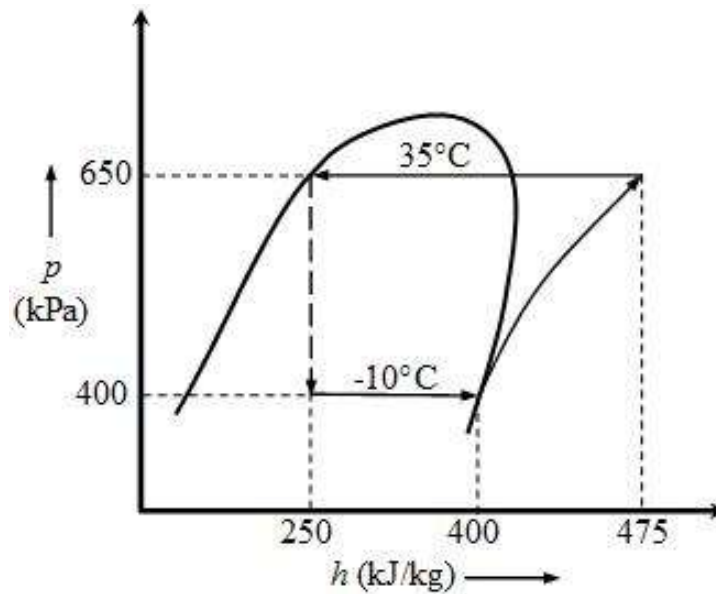
- Q.41 A 0.2 m thick infinite black plate having a thermal conductivity of 3.96 W/m-K is exposed to two infinite black surfaces at 300 K and 400 K as shown in the figure. At steady state, the surface temperature of the plate facing the cold side is 350 K. The value of Stefan-Boltzmann constant,  $\sigma$ , 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  $\text{W/m}^2$ ) 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  $400^\circ\text{C}$ , respectively. The ambient pressure  $P_\infty$  and temperature  $T_\infty$  are 100 kPa and  $27^\circ\text{C}$ , 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  $35^{\circ}\text{C}$  and an evaporating temperature of  $-10^{\circ}\text{C}$  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  $30^{\circ}\text{C}$  and 60% relative humidity. The saturation pressure of water at  $30^{\circ}\text{C}$  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  $10^3\text{ kg/m}^3$  and  $10\text{ m/s}^2$ , 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  $100 \text{ mm}^2$ . The cross-sectional area at the time of necking (in  $\text{mm}^2$ ) 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 ( $\alpha$ ) of the die is  $5^\circ$  and the coefficient of friction ( $\mu$ ) 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  $\sigma_f$ , (in MPa) is given as:

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

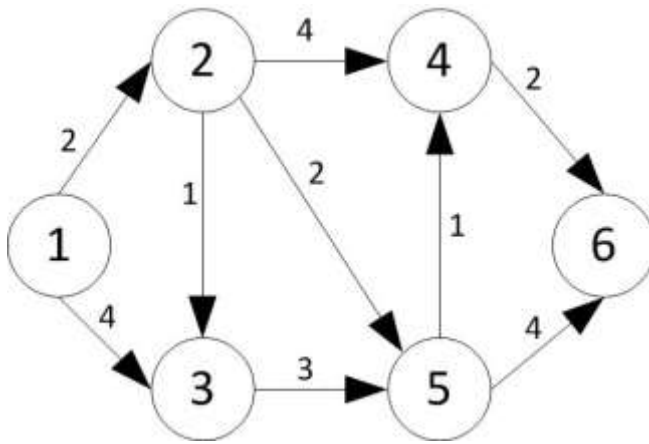
The drawing stress (in MPa) required to carry out this operation is \_\_\_\_\_ (correct to two decimal places).

Q.48 Following data correspond to an orthogonal turning of a 100 mm diameter rod on a lathe. Rake angle:  $+15^\circ$ ; 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  $80 \text{ mm} \times 120 \text{ mm} \times 20 \text{ mm}$ , 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).

- Q.51 The arc lengths of a directed graph of a project are as shown in the figure. The shortest path length from node 1 to node 6 is \_\_\_\_\_.



- Q.52 A circular hole of 25 mm diameter and depth of 20 mm is machined by EDM process. The material removal rate (in  $\text{mm}^3/\text{min}$ ) is expressed as
- $$4 \times 10^4 IT^{-1.23},$$
- where  $I = 300$  A and the melting point of the material,  $T = 1600^\circ\text{C}$ . The time (in minutes) for machining this hole is \_\_\_\_\_ (correct to two decimal places)

- Q.53 A welding operation is being performed with voltage = 30 V and current = 100 A. The cross-sectional area of the weld bead is  $20 \text{ mm}^2$ . The work-piece and filler are of titanium for which the specific energy of melting is  $14 \text{ J/mm}^3$ . Assuming a thermal efficiency of the welding process 70%, the welding speed (in  $\text{mm/s}$ ) is \_\_\_\_\_ (correct to two decimal places).
- Q.54 Steam in the condenser of a thermal power plant is to be condensed at a temperature of  $30^\circ\text{C}$  with cooling water which enters the tubes of the condenser at  $14^\circ\text{C}$  and exits at  $22^\circ\text{C}$ . The total surface area of the tubes is  $50 \text{ m}^2$ , and the overall heat transfer coefficient is  $2000 \text{ W/m}^2 \text{ K}$ . The heat transfer (in MW) to the condenser is \_\_\_\_\_ (correct to two decimal places).
- Q.55 A vehicle powered by a spark ignition engine follows air standard Otto cycle ( $\gamma=1.4$ ). The engine generates 70 kW while consuming 10.3 kg/hr of fuel. The calorific value of fuel is 44,000 kJ/kg. The compression ratio is \_\_\_\_\_ (correct to two decimal places).

**END OF THE QUESTION PAPER**

Q.No.	Type	Section	Key/Range	Marks
1	MCQ	GA	D	1
2	MCQ	GA	A	1
3	MCQ	GA	B	1
4	MCQ	GA	A	1
5	MCQ	GA	C	1
6	MCQ	GA	C	2
7	MCQ	GA	C	2
8	MCQ	GA	Marks to All	2
9	MCQ	GA	D	2
10	MCQ	GA	B	2
1	MCQ	ME	C	1
2	MCQ	ME	C	1
3	MCQ	ME	B	1
4	MCQ	ME	C	1
5	MCQ	ME	B	1
6	MCQ	ME	D	1
7	MCQ	ME	C	1
8	MCQ	ME	C	1
9	MCQ	ME	B	1
10	MCQ	ME	A	1
11	MCQ	ME	D	1
12	MCQ	ME	A (or) D	1
13	MCQ	ME	B	1

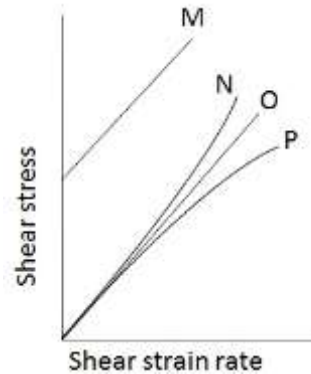
Q.No.	Type	Section	Key/Range	Marks
14	MCQ	ME	C	1
15	MCQ	ME	C	1
16	MCQ	ME	B	1
17	MCQ	ME	D	1
18	MCQ	ME	C	1
19	NAT	ME	0.25 to 0.25	1
20	NAT	ME	35.24 to 35.44	1
21	NAT	ME	190.00 to 200.00	1
22	NAT	ME	41.30 to 41.50	1
23	NAT	ME	62.00 to 63.00	1
24	NAT	ME	0.36 to 0.40	1
25	NAT	ME	Marks to All	1
26	MCQ	ME	A	2
27	MCQ	ME	A	2
28	MCQ	ME	C	2
29	MCQ	ME	D	2
30	MCQ	ME	A	2
31	MCQ	ME	C	2
32	MCQ	ME	C	2
33	MCQ	ME	D	2
34	MCQ	ME	A	2
35	MCQ	ME	B	2
36	NAT	ME	1.45 to 1.48	2

Q.No.	Type	Section	Key/Range	Marks
37	NAT	ME	4.80 to 5.20	2
38	NAT	ME	31.60 to 31.65	2
39	NAT	ME	6.60 to 6.70	2
40	NAT	ME	1.400 to 1.500	2
41	NAT	ME	385.00 to 395.00	2
42	NAT	ME	145.00 to 150.00	2
43	NAT	ME	9.50 to 10.50	2
44	NAT	ME	16.00 to 16.50	2
45	NAT	ME	28.85 to 29.25	2
46	NAT	ME	65.00 to 70.00	2
47	NAT	ME	315.00 to 317.00	2
48	NAT	ME	22.00 to 24.00	2
49	NAT	ME	252.00 to 254.00	2
50	NAT	ME	42.00 to 52.00	2
51	NAT	ME	7 to 7 (or) 11 to 11	2
52	NAT	ME	7.00 to 7.30	2
53	NAT	ME	7.49 to 7.51	2
54	NAT	ME	1.14 to 1.16	2
55	NAT	ME	7.40 to 7.80	2

**XE (B): Q. 1 – Q. 9 carry one mark each & Q. 10 – Q. 22 carry two marks each.**

Q.1 Rheological diagram of different types of fluids is shown in figure. Column I represents the nature of the fluid and column II represents the curve showing the variation of shear stress against shear strain rate.

Column I	Column II
(i) Newtonian	M
(ii) Shear thinning	N
(iii) Shear thickening	O
(iv) Bingham plastic	P



The most appropriate match between columns I and II is,

- (A) (i) – O; (ii) – N ; (iii) – P; (iv) – M  
 (B) (i) – O; (ii) – P ; (iii) – N; (iv) – M  
 (C) (i) – P; (ii) – O ; (iii) – M; (iv) – N  
 (D) (i) – P; (ii) – O ; (iii) – N; (iv) – M

Q.2 In a two-dimensional, incompressible and irrotational flow, stream function ( $\psi = \psi(x, y)$ ) and velocity potential ( $\phi = \phi(x, y)$ ) exist. The velocities in  $x$  and  $y$  directions are non-zero.

The product of  $\left. \frac{dy}{dx} \right|_{\phi=\text{constant}}$  and  $\left. \frac{dy}{dx} \right|_{\psi=\text{constant}}$ , is

- (A)  $-1$                       (B)  $0$                       (C)  $1$                       (D)  $\infty$

Q.3 The inviscid flow past a rotating circular cylinder can be generated by the superposition of

- (A) uniform flow, source and vortex                      (B) uniform flow, doublet  
 (C) uniform flow, sink and vortex                      (D) uniform flow, doublet and vortex

Q.4 The velocity field and the surface normal vector are given by,  $\vec{V} = u\hat{i} + v\hat{j} + w\hat{k}$  and  $\vec{n} = n_1\hat{i} + n_2\hat{j} + n_3\hat{k}$ , respectively. If Euler equations are to be solved, the boundary condition that must be satisfied at the wall is,

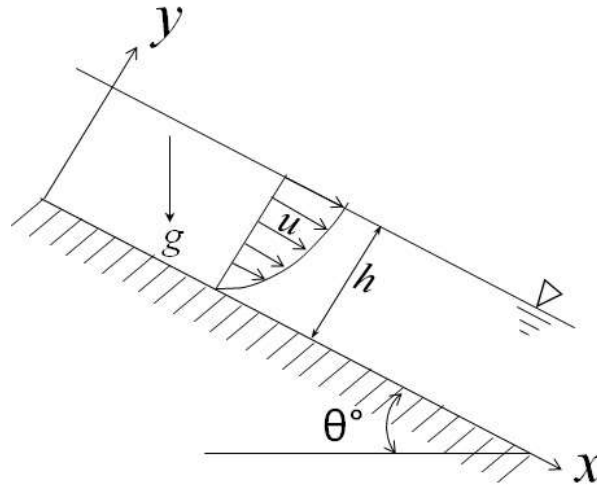
- (A)  $\vec{V} \cdot \vec{n} = 0$                       (B)  $\vec{V} = 0$                       (C)  $\nabla \cdot \vec{V} = 0$                       (D)  $\vec{V} \times \vec{n} = 0$

Q.5 The influence of Froude number is most significant in

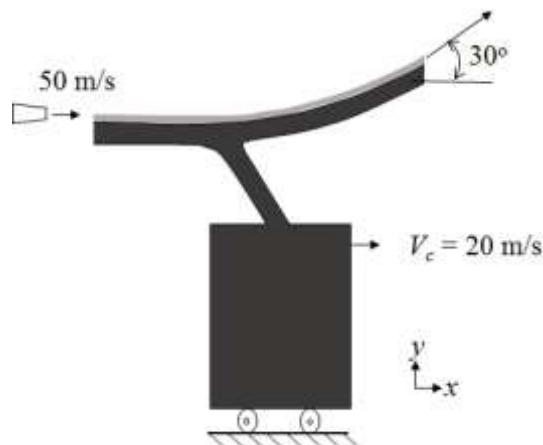
- (A) capillary flows                      (B) creeping flows  
 (C) free surface flows                      (D) compressible flows

- Q.6 If the stream function ( $\psi(x, y)$ ) for a two-dimensional incompressible flow field is given as  $2y(x^2 - y^2)$ , the corresponding velocity field is
- (A)  $\vec{V} = 2(x^2 - 3y^2)\hat{i} + 4xy\hat{j}$   
(B)  $\vec{V} = 2(x^2 - 3y^2)\hat{i} - 4xy\hat{j}$   
(C)  $\vec{V} = 2(x^2y)\hat{i} - 4xy\hat{j}$   
(D)  $\vec{V} = 2(x^2y)\hat{i} + 4xy\hat{j}$
- Q.7 Water is flowing in two different tubes of diameters  $D$  and  $2D$ , with the same velocity. The ratio of laminar friction factors for the larger diameter tube to the smaller diameter tube is
- (A) 0.5                      (B) 1.0                      (C) 2.0                      (D) 4.0
- Q.8 If the velocity field is  $\vec{V} = xy^2\hat{i} + 4xy\hat{j}$  m/s, vorticity of the fluid element in the field at  $(x=1, y=2)$  in  $s^{-1}$  is \_\_\_\_\_.
- Q.9 A pitot-static tube is used to measure air velocity in a duct by neglecting losses. The density of air is  $1.2 \text{ kg/m}^3$ . If the difference between the total and static pressures is 1 kPa, the velocity of air at the measuring location, in m/s, is \_\_\_\_\_.
- Q.10 A parallelepiped of  $(2 \text{ m} \times 2 \text{ m})$  square cross-section and 10 m in length, is partially floating in water upto a depth of 1.2 m, with its longest side being horizontal. The specific gravity of the block is
- (A) 0.8                      (B) 0.6                      (C) 0.5                      (D) 0.4
- Q.11 The velocity field in a two-dimensional, unsteady flow is given by  $\vec{V}(x, y, t) = 2xy^2\hat{i} + 3xyt\hat{j}$  m/s. The magnitude of acceleration of a fluid particle located at  $x = 1 \text{ m}$ ,  $y = 1 \text{ m}$  at the time  $t = 1 \text{ s}$ , in  $\text{m/s}^2$ , is
- (A) 16.0                      (B) 18.1                      (C) 24.1                      (D) 34.1
- Q.12 In a two-dimensional, incompressible and irrotational flow, fluid velocity ( $v$ ) in the  $y$ -direction is given by  $v = 2x - 5y$ . The velocity ( $u$ ) in the  $x$ -direction is
- (A)  $u = 2x - 5y$       (B)  $u = 2x + 5y$       (C)  $u = 5x + 2y$       (D)  $u = 5x - 2y$

- Q.13 A two-dimensional laminar viscous liquid film of constant thickness ( $h$ ) steadily flows down an incline as shown in figure. Acceleration due to gravity is  $g$ . If the velocity profile in the liquid film is given as,  $u = ky(2h - y)$ ;  $v = 0$ , the value of constant  $k$  is



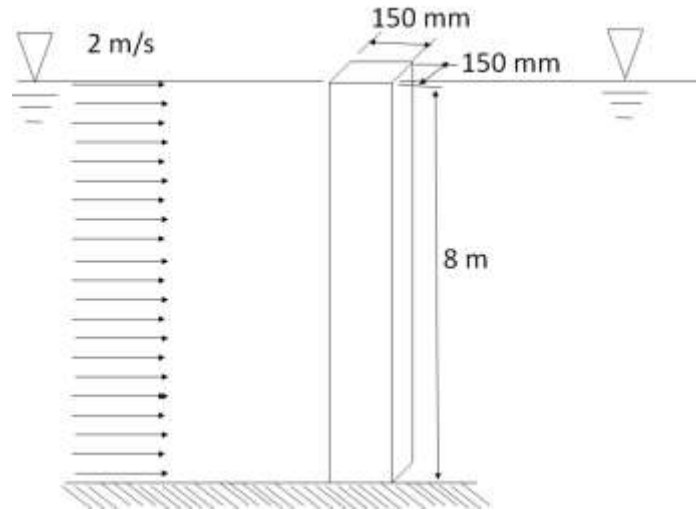
- (A)  $\frac{\rho g \sin \theta}{2\mu}$  (B)  $\frac{\rho g \cos \theta}{2\mu}$   
 (C)  $\rho g \sin \theta$  (D)  $\rho g \cos \theta$
- Q.14 A water jet of 100 mm diameter issuing out of a nozzle at a speed of 50 m/s strikes a vane and flows along it as shown in figure. The vane is attached to a cart which is moving at a constant speed of 20 m/s on a frictionless track. The jet is deflected at an angle of  $30^\circ$ . Take the density of water as  $1000 \text{ kg/m}^3$ . Neglecting the friction between the vane and the fluid, the magnitude of the force exerted by water on the cart in the  $x$ -direction, in N, is \_\_\_\_\_.



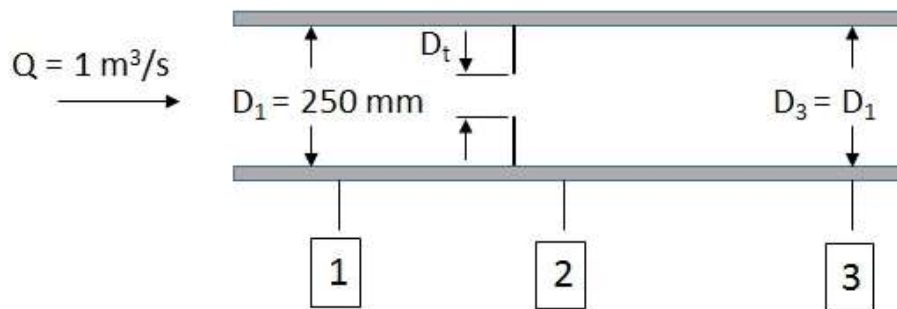
- Q.15 Capillary waves are generated in the sea. The speed of propagation ( $C$ ) of these waves is known to be a function of density ( $\rho$ ), wave length ( $\lambda$ ), and surface tension ( $\sigma$ ). Assume,  $\rho$  and  $\lambda$  to be constant. If the surface tension is doubled, in the functional form of the relevant non-dimensional group, the percentage increase in propagation speed ( $C$ ) is \_\_\_\_\_.

- Q.16 Consider a fully developed, two-dimensional and steady flow of a viscous fluid between two fixed parallel plates separated by a distance of 30 mm. The dynamic viscosity of the fluid is 0.01 kg/m-s and the pressure drop per unit length is 300 Pa/m. The fluid velocity at a distance of 10 mm from the bottom plate, in m/s, is \_\_\_\_\_.
- Q.17 A 2.6 gram smooth table-tennis (ping-pong) ball has a diameter of 38 mm. Density ( $\rho$ ) of air is 1.2 kg/m<sup>3</sup>. Neglect the effect of gravity. Take coefficient of drag as 0.5. If the ball is struck with an initial velocity of 30 m/s, the initial deceleration, in m/s<sup>2</sup>, is \_\_\_\_\_.
- Q.18 On a flat plate, transition from laminar to turbulent boundary layer occurred at a critical Reynolds number ( $Re_{cr}$ ). The empirical relations for the laminar and turbulent boundary layer thickness are given by  $\frac{\delta_{lam}}{x} = 5.48 Re_x^{-0.5}$  and  $\frac{\delta_{turb}}{x} = 0.37 Re_x^{-0.2}$ , respectively. The ratio of laminar to turbulent boundary layer thickness, at the location of transition, is 0.3. The value of  $Re_{cr}$  is \_\_\_\_\_.
- Q.19 In a capillary tube of radius  $R = 0.25$  mm, a fully developed laminar velocity profile is defined as,  $u = \frac{R^2}{4\mu} \left( -\frac{dp}{dx} \right) \left( 1 - \frac{r^2}{R^2} \right)$ . In this expression,  $-\frac{dp}{dx} = 1$  MPa/m,  $\mu$  is the dynamic viscosity of the fluid, and  $r$  is the radial position from the centerline of the tube. If the flow rate through the tube is 1000 mm<sup>3</sup>/s, the viscosity of the fluid, in Pa-s, is \_\_\_\_\_.
- Q.20 The skin friction coefficient for a turbulent pipe flow is defined as,  $C_f = \frac{\tau_w}{1/2 \rho V^2}$ , where  $\tau_w$  is the wall shear stress and  $V$  is the average flow velocity. The value of  $C_f$  is empirically given by the relation:  $C_f = 0.065 \left( \frac{2}{Re} \right)^{0.25}$ , where  $Re$  is the Reynolds number. If the average flow velocity is 10 m/s, diameter of the pipe is 250 mm, kinematic viscosity of the fluid is  $0.25 \times 10^{-6}$  m<sup>2</sup>/s, and density of the fluid is 700 kg/m<sup>3</sup>, the skin friction drag induced by the flow over 1 m length of the pipe, in N, is \_\_\_\_\_.

- Q.21 A (150 mm × 150 mm) square pillar is located in a river with water flowing at a velocity of 2 m/s, as shown in figure. The height of the pillar in water is 8 m. Take density of water as 1000 kg/m<sup>3</sup> and kinematic viscosity as  $1 \times 10^{-6}$  m<sup>2</sup>/s. The coefficient of drag of the pillar is 2.0. The drag force exerted by water on the pillar in N is \_\_\_\_\_.



- Q.22 An orifice plate is used to measure flow rate of air (density = 1.23 kg/m<sup>3</sup>) in a duct of 250 mm diameter as shown in figure. The volume flow rate is 1 m<sup>3</sup>/s. Flow at sections 1 and 3 is uniform and section 2 is located at vena contracta. The diameter ratio,  $D_v/D_1$ , is 0.66. The flow area at vena contracta,  $A_2 = 0.65A_t$ , where  $A_t$  is area of the orifice. The pressure difference between locations 2 and 3 in N/m<sup>2</sup> is \_\_\_\_\_.



**END OF THE QUESTION PAPER**

**XE (E): Q. 1 – Q. 9 carry one mark each & Q. 10 – Q. 22 carry two marks each.**

**Notation used:**

$P$  : pressure,  $V$  : volume,  $T$  : temperature,  $s$  : specific entropy,  $h$  : specific enthalpy,  $C_p$  : molar heat capacity at constant pressure,  $C_v$  : molar heat capacity at constant volume,  $R$  : universal gas constant

- Q.1 When a fixed mass of air-water vapour mixture is heated at constant pressure,
- (A) both relative and specific humidity decrease.  
 (B) relative humidity decreases, but specific humidity remains unchanged.  
 (C) specific humidity decreases, but relative humidity remains unchanged.  
 (D) both relative and specific humidity increase.
- Q.2 For a reversible isothermal expansion of one mole of an ideal gas from state 1 to state 2, the magnitude of work done is
- (A)  $RT \ln\left(\frac{P_1}{P_2}\right)$  (B)  $P_2V_2 - P_1V_1$   
 (C)  $R \ln\left(\frac{V_1}{V_2}\right)$  (D) 0
- Q.3 The statement which is NOT a consequence of the first law of thermodynamics is
- (A) Heat is a path function  
 (B) Energy is a property of a system  
 (C) Energy of an isolated system is not conserved  
 (D) A perpetual motion machine of the first kind is not possible
- Q.4 For a refrigerator absorbing heat  $Q_L$  from a cold region and rejecting heat  $Q_H$  to a hot region, the coefficient of performance is written as
- (A)  $\frac{Q_L}{Q_H - Q_L}$  (B)  $\frac{Q_H}{Q_H - Q_L}$   
 (C)  $\frac{Q_H - Q_L}{Q_L}$  (D)  $\frac{Q_L}{Q_H}$
- Q.5 The value of the compressibility factor at the critical point evaluated using the van der Waals equation of state is
- (A)  $\frac{2}{7}$  (B)  $\frac{5}{8}$  (C)  $\frac{3}{8}$  (D)  $\frac{1}{7}$

- Q.6 The vapour pressure of a liquid at 8 °C is 2.7 kPa. Its enthalpy of vaporization is constant and equal to 42700 kJ/kmol. Take  $R = 8.314$  kJ/kmol.K. The temperature (in °C) at a vapour pressure of 13.5 kPa is  
(A) 58.7 (B) 51.4 (C) 44.3 (D) 35.2
- Q.7 One kmol of an ideal gas ( $C_p = 21$  kJ/kmol.K) undergoes a constant pressure process from 300 K to 500 K. The molar entropy of the gas at 300 K is 150 kJ/kmol.K. The molar entropy (in kJ/kmol.K) at 500 K (up to 1 decimal place) is \_\_\_\_\_.
- Q.8 A spring, having a spring constant of 350 kN/m, is initially compressed by 0.4 cm. The work required (in J) to compress it by another 0.6 cm (up to 1 decimal place) is \_\_\_\_\_.
- Q.9 An ideal gas has a molar mass of 40 kg/kmol. Take  $R = 8.314$  kJ/kmol.K. At a pressure of 2 bar and a temperature of 300 K, the volume (in m<sup>3</sup>) of 1 kg of this gas (up to 2 decimal places) is \_\_\_\_\_.
- Q.10 Consider the following statements for an ideal gas undergoing a reversible non-flow process:
- P. If the process is adiabatic, the change in enthalpy of the gas is necessarily zero.
  - Q. If the process is adiabatic, the change in entropy of the gas is necessarily zero.
  - R. If the process is isothermal, the change in enthalpy of the gas is necessarily zero.
  - S. If the process is isothermal, the change in entropy of the gas is necessarily zero.
- Which one of the following options is valid?
- (A) Only P is correct
  - (B) Only S is correct
  - (C) Only Q and R are correct
  - (D) Only P and S are correct
- Q.11 An ideal Otto cycle (O) and an ideal diesel cycle (D) have the same maximum temperature and reject equal amount of heat. Also, the working fluid enters at the same state before compression. One of the following statements always true about their efficiencies ( $\eta$ ) is
- (A)  $\eta_O > \eta_D$
  - (B)  $\eta_O = \eta_D$
  - (C)  $\eta_O < \eta_D$
  - (D)  $\eta_O = 1 - \eta_D$
- Q.12 A reversible engine receives 75 kJ/s of energy from a reservoir at 750 K and does 12 kJ/s of work. The heat is rejected to two reservoirs at 650 K and 550 K. The rate of heat rejection (in kJ/s) to the reservoir at 650 K is
- (A) 11
  - (B) 31
  - (C) 41
  - (D) 52

Q.13 A gas obeys the following equation of state:

$$P(\bar{v} - b) = RT + \frac{aP^2}{T},$$

where  $\bar{v}$  is molar volume, and  $a, b$  are constants with values  $a = 10^{-5} \text{ J.K/Pa}^2.\text{kmol}$  and  $b = 8 \times 10^{-2} \text{ m}^3/\text{kmol}$ . Take  $C_p = 30 \text{ kJ/kmol.K}$ . At 10 bar and 500 K, the value of the Joule-Thomson coefficient (in K/Pa) is

- (A)  $-2 \times 10^{-6}$       (B)  $-4 \times 10^{-6}$       (C)  $2 \times 10^{-6}$       (D)  $4 \times 10^{-6}$

Q.14 In an ideal Rankine cycle, steam enters the turbine at 10 MPa and 500 °C ( $h = 3375.1 \text{ kJ/kg}$ ,  $s = 6.5995 \text{ kJ/kg.K}$ ). It is cooled in the condenser at a pressure of 10 kPa. At 10 kPa,  $h_f = 191.81 \text{ kJ/kg}$ ,  $s_f = 0.6492 \text{ kJ/kg.K}$ ,  $h_g = 2583.9 \text{ kJ/kg}$  and  $s_g = 8.1488 \text{ kJ/kg.K}$ . The heat rejected in the condenser (in kJ/kg) is

- (A) 1898      (B) 3796      (C) 949      (D) 2847

Q.15 Methane has compressibility factor value of 0.9 at reduced pressure of 1.0 and reduced temperature of 1.5. For propane, the critical temperature and pressure are 369.8 K and 42.48 bar, respectively. Take  $R = 8.314 \text{ kJ/kmol.K}$ . Applying the principle of corresponding states, the molar volume of propane (in  $\text{m}^3/\text{kmol}$ ) at the same reduced pressure and temperature is

- (A) 0.355      (B) 0.526      (C) 0.791      (D) 0.977

Q.16 A rigid insulated vessel is divided into two compartments by a partition. One compartment contains 12 kg of oxygen at 200 kPa and 280 K. The other compartment contains 26 kg of carbon dioxide at 400 kPa and 360 K. The specific heats at constant volume in kJ/kg.K for oxygen and carbon dioxide are 0.662 and 0.653, respectively. The partition is removed and the gases are allowed to mix. Considering both gases are ideal, the final temperature (in K) of the mixture (up to 1 decimal place) is \_\_\_\_\_.

Q.17 Moist air having 60% relative humidity, enters a steady-flow air-conditioning unit at 102 kPa and 30 °C. The volume flow rate of the moist air entering the unit is  $0.1 \text{ m}^3/\text{s}$ . The moist air leaves the unit at 95 kPa and 15 °C with a relative humidity of 100%. Liquid condensate leaves the unit at 15 °C.

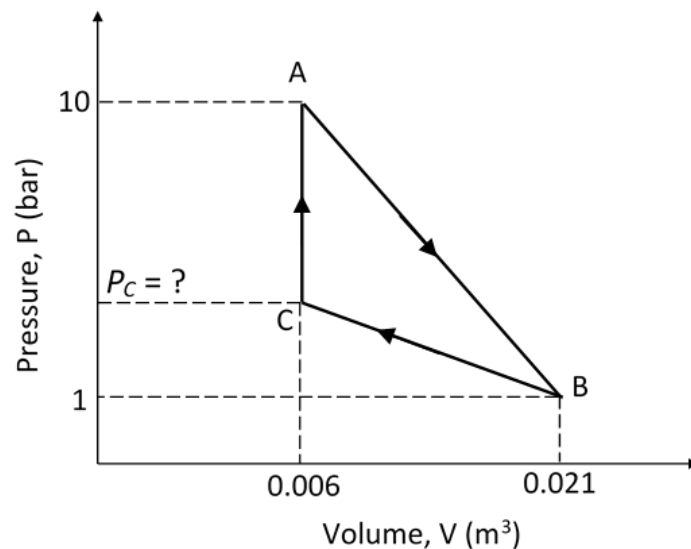
For water: at 15 °C,  $h_f = 62.982 \text{ kJ/kg}$ ,  $h_g = 2528.3 \text{ kJ/kg}$ ,  $P_{sat} = 1.7057 \text{ kPa}$ .

at 30 °C,  $h_f = 125.74 \text{ kJ/kg}$ ,  $h_g = 2555.6 \text{ kJ/kg}$ ,  $P_{sat} = 4.2469 \text{ kPa}$ .

For air, specific heat at constant pressure is  $1.004 \text{ kJ/kg.K}$  and the specific gas constant is  $0.287 \text{ kJ/kg.K}$ .

Neglecting heat leakage to the surrounding, the magnitude of heat extracted (in kW) from the air stream (up to 2 decimal places) is \_\_\_\_\_.

- Q.18 Air at 150 kPa and 323 K is filled in a rigid vessel of  $0.05 \text{ m}^3$  capacity. For air, assumed as an ideal gas, specific heat at constant volume is  $0.7163 \text{ kJ/kg.K}$  and the specific gas constant is  $0.287 \text{ kJ/kg.K}$ . Neglect kinetic and potential energy changes. If 30 kJ of heat is added, the final temperature (in K) of air (up to 1 decimal place) is \_\_\_\_\_.
- Q.19 Superheated steam at 2 bar and  $300^\circ\text{C}$ , with an enthalpy of  $3072.1 \text{ kJ/kg}$ , enters a horizontal adiabatic nozzle with negligible velocity and leaves at 0.2 bar as saturated vapour with an enthalpy of  $2609.9 \text{ kJ/kg}$ . Assuming steady flow and neglecting the potential energy changes, the exit velocity (in m/s) of the steam (up to 1 decimal place) is \_\_\_\_\_.
- Q.20 A given mass of a simple compressible substance undergoes a reversible cycle, as shown in the P-V diagram. The magnitude of the net work done during the cycle is 3 kJ. The pressure (in bar) at point C (up to 1 decimal place) is \_\_\_\_\_.



- Q.21 One kmol of an ideal gas at 300 K and 10 bar is reversibly heated in a constant volume process to 500 K. It is then reversibly and isothermally expanded to 2 bar. Take  $C_v = 20.8 \text{ kJ/kmol.K}$  and  $R = 8.314 \text{ kJ/kmol.K}$ . The total heat supplied (in kJ) to the gas (up to 1 decimal place) is \_\_\_\_\_.
- Q.22 A rigid container is completely filled with a liquid having a constant isothermal compressibility of  $1.09 \times 10^{-4} \text{ bar}^{-1}$  and a constant coefficient of volume expansion of  $1.12 \times 10^{-3} \text{ K}^{-1}$ . The liquid is initially at 300 K and 1 bar. Heat is supplied to the liquid to raise its temperature to 350 K. Assuming that no phase change occurs, the final pressure (in bar) of the liquid (up to 1 decimal place) is \_\_\_\_\_.

END OF THE QUESTION PAPER