BARC PAPER PATTERN

Syllabus: Gate syllabus

Weightage Marks:

E. MEC---3 QUESTIONS

SOM--------13 Q

TOM--------10 Q

MD----------5 Q

FM,HM-----15 Q

TD----------12Q

HT----------10 Q

RAC----------3Q

IC.E--------2Q

PPE--------5 Q

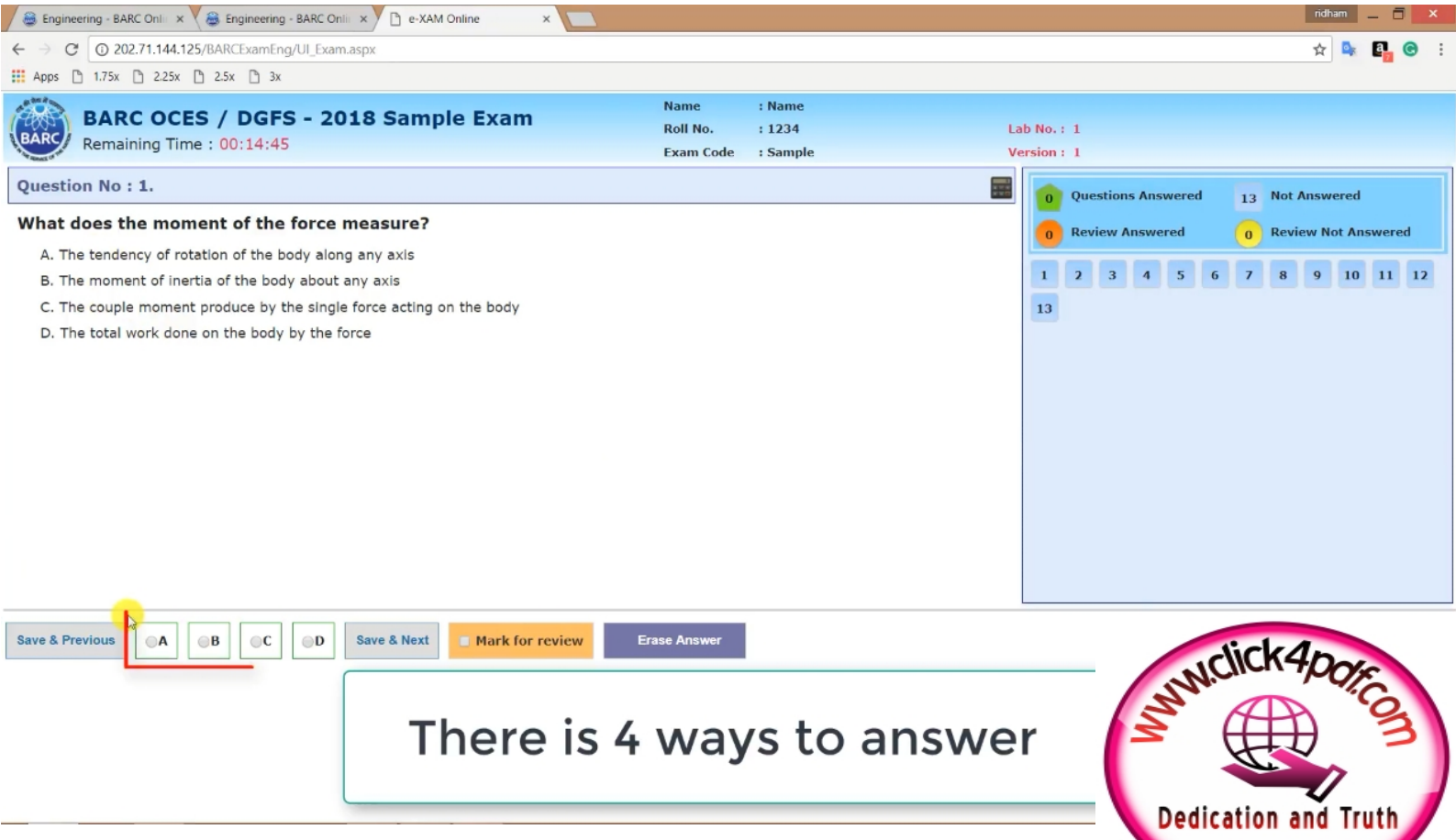
PRODUCTION---13 Q

IM OR------5 Q

MATHS------5Q

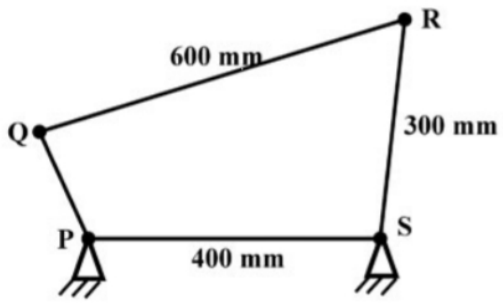
feedback

1. 50 Q → Easy to moderate [Numericals]
2. 20 Q → Theory [easy]
3. 10 Q → Moderate – hard
4. 15 Q → Hard [Dig based] Innovative.
5. 5 Q → MATHS [Easy]



There is 4 ways to answer

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. 42

A slot of 25 mm × 25 mm is to be milled in a workpiece of 300 mm length using a side and face milling cutter of diameter 100 mm, width 25 mm and having 20 teeth.

For a depth of cut 5 mm, feed per tooth 0.1 mm, cutting speed 35 m/min and approach and over travel distance of 5 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:

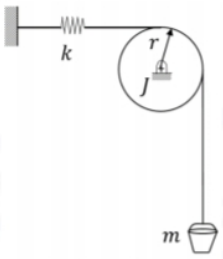
tolerance for hole = 0.002 mm,

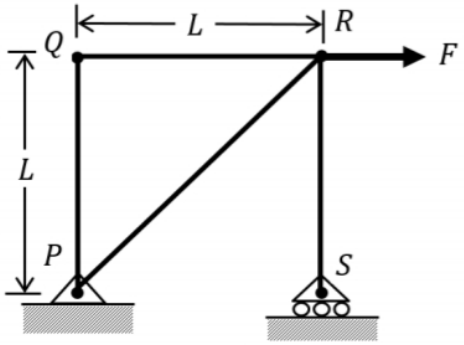
tolerance for shaft = 0.001 mm,

allowance = 0.003 mm,

basic size = 50 mm.

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

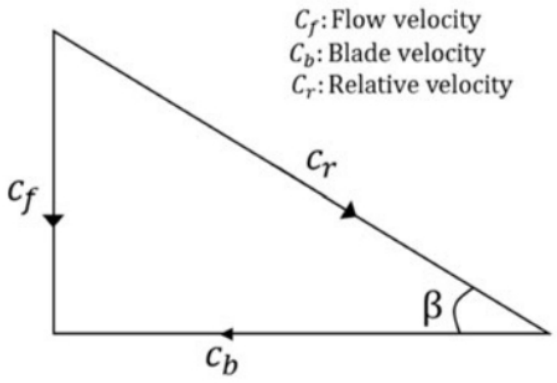
Q.34	**Consider the system shown in the figure. A rope goes over a pulley. A mass, m, is hanging from the rope. A spring of stiffness, k, is attached at one end of the rope. Assume rope is inextensible, massless and there is no slip between pulley and rope.**  **The pulley radius is r and its mass moment of inertia is J. Assume that the mass is vibrating harmonically about its static equilibrium position. The natural frequency of the system is**
(A)	$\sqrt{\frac{kr^2}{J-mr^2}}$
(B)	$\sqrt{\frac{kr^2}{J+mr^2}}$
(C)	$\sqrt{k/m}$
(D)	$\sqrt{\frac{kr^2}{J}}$

Q.14	**A plane truss *PQRS* (*PQ* = *RS*, and ∠*PQR* = 90°) is shown in the figure.**  **The forces in the members *PR* and *RS*, respectively, are _____**
(A)	$F\sqrt{2}$ (tensile) and F (tensile)
(B)	$F\sqrt{2}$ (tensile) and F (compressive)
(C)	F (compressive) and $F\sqrt{2}$ (compressive)
(D)	F (tensile) and $F\sqrt{2}$ (tensile)

Q.22	**A rigid tank of volume 50 m^3 contains a pure substance as a saturated liquid vapour mixture at 400 kPa. Of the total mass of the mixture, 20% mass is liquid and 80% mass is vapour. Properties at 400 kPa are: T_{sat} = 143.61 °C, v_f = 0.001084 m^3/kg, v_g = 0.46242 m^3/kg. The total mass of liquid vapour mixture in the tank is _____kg (*round off to the nearest integer*).**

Q.23	**An object is moving with a Mach number of 0.6 in an ideal gas environment, which is at a temperature of 350 K. The gas constant is 320 J/kg.K and ratio of specific heats is 1.3. The speed of object is _____m/s (*round off to the nearest integer*).**

Q.No. 54 For a Kaplan (axial flow) turbine, the outlet blade velocity diagram at a section is shown in figure.

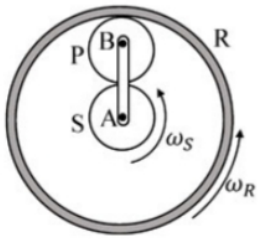


The diameter at this section is 3 m. The hub and tip diameters of the blade are 2 m and 4 m, respectively. The water volume flow rate is 100 m^3/s. The rotational speed of the turbine is 300 rpm. The blade outlet angle β is _____ degrees (*round off to one decimal place*).

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. 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 ω_S and ω_R, respectively, then the angular speed of the arm AB is

(A) $\frac{3}{4}\omega_R + \frac{1}{4}\omega_S$

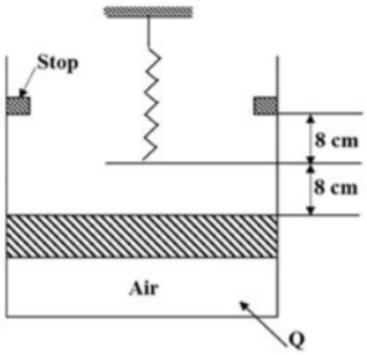
(B) $\frac{1}{4}\omega_R + \frac{3}{4}\omega_S$

(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.

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



The atmospheric pressure is 100 kPa and the initial pressure of air in the cylinder is 105 kPa. The area of piston is 300 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 N/mm. Considering the air inside the cylinder as the system, the work interaction is _____ J (*round off to the nearest integer*).

- **ESE 2019 Mains Test Series:** Test-3 (Similar Q. 1d(i))

End of Solution

Q.7 (c) A reaction steam turbine having diameter of 1400 mm is rotating at 3000 rpm. The turbine stages are designed in such a fashion that the enthalpy drop in both, rotor and stator, is same in each stage. If the speed ratio is 0.7 and angle at outlet is 20°, draw velocity triangles and determine degree of reaction, blade angle at inlet and diagram efficiency.

[20 Marks]

Solution:

Q.52 The thickness of a sheet is reduced by rolling (without any change in width) using 600 mm diameter rolls. Neglect elastic deflection of the rolls and assume that the coefficient of friction at the roll-workpiece interface is 0.05. The sheet enters the rotating rolls unaided. If the initial sheet thickness is 2 mm, the minimum possible final thickness that can be produced by this process in a single pass is _____ mm (round off to two decimal places).

Q.53 A through hole is drilled in an aluminum alloy plate of 15 mm thickness with a drill bit of diameter 10 mm, at a feed of 0.25 mm/rev and a spindle speed of 1200 rpm. If the specific energy required for cutting this material is 0.7 $N \cdot m/mm^3$, the power required for drilling is _____ W (round off to two decimal places).

Q.54 In an orthogonal machining with a single point cutting tool of rake angle 10°, the uncut chip

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

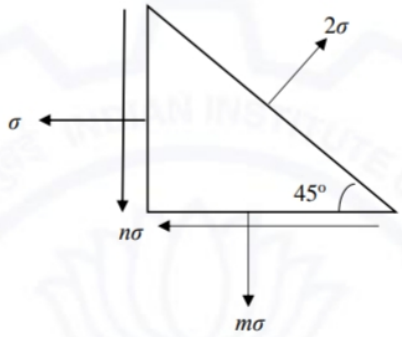
(D) 3

Q.6 (a) A centrifugal pump has an impeller diameter at outlet as 1 m and delivers 1.5 m^3/s of water against a head of 100 m. The impeller is running at 1000 rpm. The width of the impeller is 85 mm. If the manometric efficiency is 85%, determine the type of impeller (forward, radial or backward curved), and the blade angle at outlet. Draw velocity triangle at outlet.

[20 Marks]

Solution:

Q. 10–Q. 15 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

Q.10	**For the state of plane stress shown, the components of normal and shear stresses are given in terms of stress σ and unknown constants m and n. If the normal and shear components of stress on a 45o plane are 2σ and zero, the values of m and n would be:** 
(A)	$m = 1, n = 2$
(B)	$m = 2, n = 1$
(C)	$m = 1, n = 1$
(D)	$m = 2, n = 2$

Ans. (a)

End of Solution

Q.91 Consider the following statements:

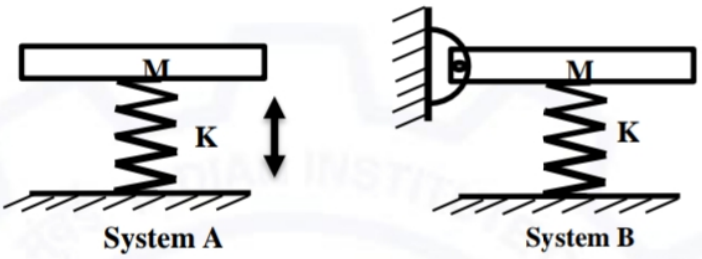
1. In spur gears, the contact occurs abruptly on a line parallel to the axis, and the disengagement too is abrupt.
2. In helical gears, both loading and unloading are gradual, and therefore, these happen more smoothly and less noisily.
3. When two gears mesh, any arbitrary shape of the tooth can be chosen for the profile of the teeth of any one of the two gears, and the profile for the other shall be obtained by applying the law of gearing.

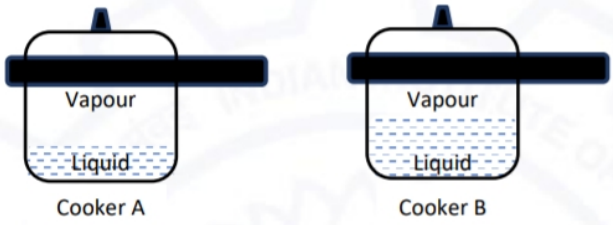
Which of the above statements are correct?

(a) 1 and 2 only
(b) 1 and 3 only
(c) 2 and 3 only
(d) 1, 2 and 3

Ans. (d)

End of Solution

Q.21	In System A, a rectangular block of mass M is centrally supported on a spring of stiffness K as shown. In the System B, the mass is hinged at one of its ends and is supported centrally by the spring. The ratio of natural frequency of System B to that of System A (rounded off to two decimal places) is _____ 

Q. 12	**Two identical pressure cookers, Cooker A and Cooker B, each having a total internal capacity of 6 litres are available. Cooker A is filled with 2 litres of liquid water at 110°C and Cooker B is filled with 4 litres of liquid water at 110°C. The remaining space in both the cookers is filled with saturated water vapour in equilibrium with the liquid water. If g represents the specific Gibbs free energy, and subscripts v and l represent the saturated vapour and the saturated liquid phases, respectively, which of the following expressions is correct?** 
(A)	$g_{v,A} > g_{l,B}$
(B)	$g_{v,A} < g_{l,B}$
(C)	$g_{v,A} = g_{l,B}$
(D)	$g_{l,B} = 2\, g_{l,A}$

Q.97 A solid rod of circular cross-section made of brittle material, when subjected to torsion, fails along a plane at 45° to the axis of the rod. Consider the following statements as pertaining thereto:

1. Distortion energy is maximum on this 45° plane.
2. Shear stress is maximum on this 45° plane.
3. Normal stress is maximum on this 45° plane.

Which of the above is/are correct?

(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

Ans. (c)

Brittle material shaft under pure torsion fail along a plane at 45° to the axis of the shaft because they are weak in tension and maximum tensile stress plane will be at angle of 45° to the cross-section of shaft or long axis of shaft [i.e. granular helicoidal feature occure.]

End of Solution

Q.98 A riveted joint may fail by

1. tearing of the plate at an edge
2. tearing of the plate across a row of rivets
3. shearing of rivets

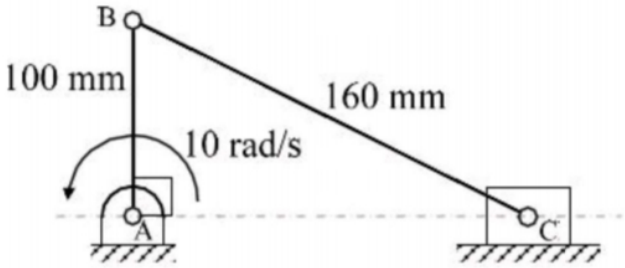
Which of the above are correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

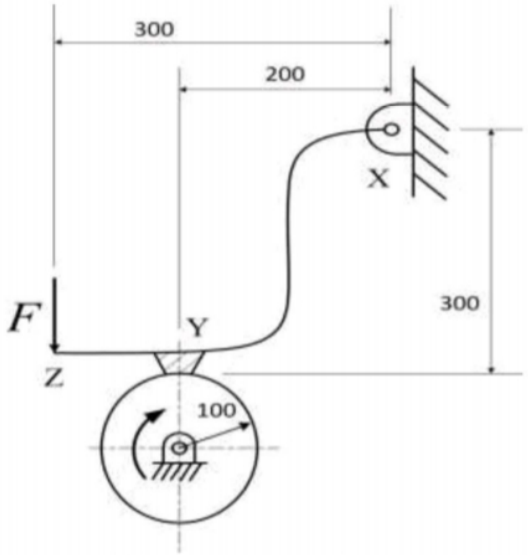
Ans. (d)

Question Number : 12 **Correct : 1 Wrong : 0**

In a slider-crank mechanism, the lengths of the crank and the connecting rod are 100 mm and 160 mm, respectively. The crank is rotating with an angular velocity of 10 radian/s counter-clockwise. The magnitude of linear velocity (in m/s) of the piston at the instant corresponding to the configuration shown in the figure is_____



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 $F = 100\ N$ 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)

(C) $Nu_q = Nu_T$ (D) $Nu_q = (Nu_T)$

Q.10 As per common design practice, the three types of hydraulic turbines, in descending order of flow rate, are

(A) Kaplan, Francis, Pelton

(B) Pelton, Francis, Kaplan

(C) Francis, Kaplan, Pelton

(D) Pelton, Kaplan, Francis

Q.11 A slender rod of length L, diameter d $(L >> d)$ and thermal conductivity k_1 is joined with another rod of identical dimensions but of thermal conductivity k_2 to form a composite

(A) $\frac{}{T}$ (B) $\frac{}{D}$ (C) $\frac{}{T}$ (D) $\frac{}{T}$

Q.8 Endurance limit of a beam subjected to pure bending decreases with

(A) decrease in the surface roughness and decrease in the size of the beam

(B) increase in the surface roughness and decrease in the size of the beam

(C) increase in the surface roughness and increase in the size of the beam

(D) decrease in the surface roughness and increase in the size of the beam

Q.9 A two-dimensional incompressible frictionless flow field is given by $\vec{u} = x\hat{i} - y\hat{j}$. If ρ is the density of the fluid, the expression for pressure gradient vector at any point in the flow field

Q.35 The activities of a project, their duration and the precedence relationships are given in the table. For example, in a precedence relationship "X < Y, Z" means that X is predecessor of activities Y and Z. The time to complete the activities along the critical path is _____ weeks.

Activity	Duration (Weeks)	Precedence Relationship
A	5	A < B, C, D
B	7	B < E, F, G
C	10	C < I
D	6	D < G
E	3	E < H
F	9	F < I
G	7	G < I
H	4	H < I
I	2	----

(A) 17

(B) 21

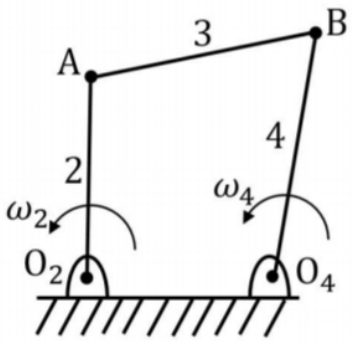
(C) 23

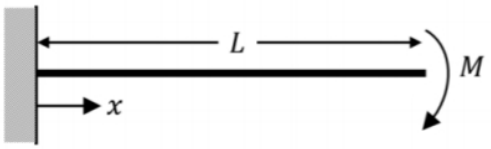
(D) 25

Q.39 A four bar mechanism is shown in the figure. The link numbers are mentioned near the links. Input link 2 is rotating anticlockwise with a constant angular speed ω_2. Length of different links are:

$$O_2O_4 = O_2A = L,$$
$$AB = O_4B = \sqrt{2}L.$$

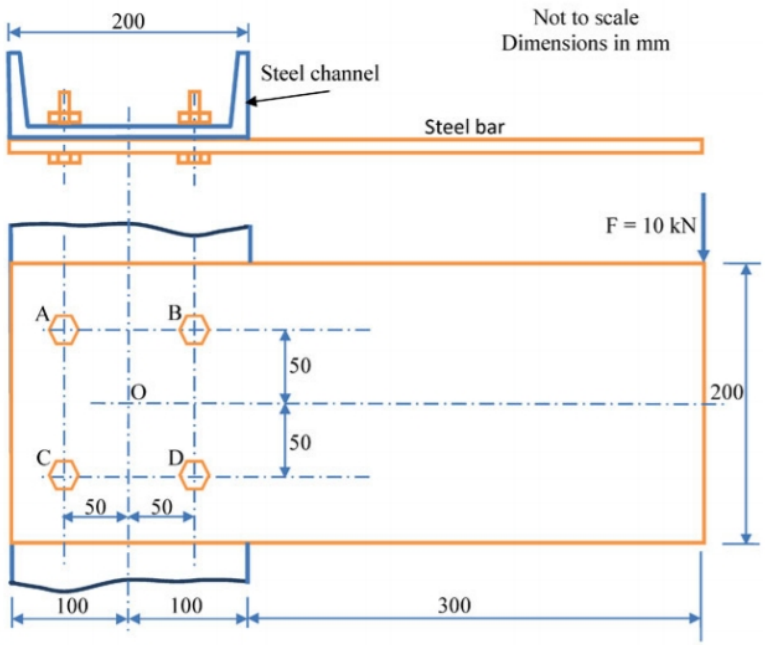
The magnitude of the angular speed of the output link 4 is ω_4 at the instant when link 2 makes an angle of 90° with O_2O_4 as shown. The ratio $\frac{\omega_4}{\omega_2}$ is _____ (round off to two decimal places).



Q.17	**A cantilever beam of length, L, and flexural rigidity, EI, is subjected to an end moment, M, as shown in the figure. The deflection of the beam at $x = \frac{L}{2}$ is** 
(A)	$\frac{ML^2}{2EI}$
(B)	$\frac{ML^2}{4EI}$
(C)	$\frac{ML^2}{8EI}$
(D)	$\frac{ML^2}{16EI}$

Q.49	**A vertical shaft Francis turbine rotates at 300 rpm. The available head at the inlet to the turbine is 200 m. The tip speed of the rotor is 40 m/s. Water leaves the runner of the turbine without whirl. Velocity at the exit of the draft tube is 3.5 m/s. The head losses in different components of the turbine are: (i) stator and guide vanes: 5.0 m, (ii) rotor: 10 m, and (iii) draft tube: 2 m. Flow rate through the turbine is 20 m^3/s. Take $g = 9.8$ m/s^2. The hydraulic efficiency of the turbine is _____ % (*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.



Question Number : 21 **Correct : 1 Wrong : -0.33**

In powder metallurgy, t' 'atomization' refers to a method of

(A) producing powde

(B) compaction of powders

(C) sintering of powder compacts

(D) blending of metal powders

Q.55 The annual demand of valves per year in a company is 10,000 units. The current order quantity is 400 valves per order. The holding cost is Rs. 24 per valve per year and the ordering cost is Rs. 400 per order. If the current order quantity is changed to Economic Order Quantity, then the saving in the total cost of inventory per year will be Rs. _____ (round off to two decimal places).

END OF THE QUESTION PAPER

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 $T_1 = 27°C$, to a final state of $p_2 = 3$ bar (absolute) and $T_2 = 127°C$. If the gas constant of air is 287 J/kg.K and the ratio of the specific heats $\gamma = 1.4$, then the change in the specific entropy (in 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. 31 The statement that best describes the function of a GO gauge in the context of Taylor's principle of gauging is

(A) GO gauge checks the Maximum Material Condition and is designed to check as many dimensions as possible

(B) GO gauge checks the Least Material Condition and is designed to check as many dimensions as possible

(C) GO gauge checks the Maximum Material Condition and is designed to check only one dimension

(D) GO gauge checks the Least Material Condition and is designed to check only one dimension

Q.No. 32

Q.No. 50 The spectral distribution of radiation from a black body at $T_1 = 3000$ K has a maximum at wavelength λ_{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 λ_{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°C and 70°C, respectively. The mass flow rate of the water is 720 kg/h. Disregard the thermal resistance of the tube wall. The internal heat transfer coefficient is 1697 W/m^2·K. Take specific heat C_p of water as 4.179 kJ/kg·K. The inner surface temperature at the exit section of the tube is _____ °C (*round off to one decimal place*).

End of Solution

22. Consider the following statements:
For the laminar condensation on a vertical plate, the Nusselt theory says that
1. inertia force in the film is negligible compared to viscosity and weight.
2. heat flow is mainly by conduction through the liquid film, convection in liquid film as well as in vapour is neglected.
3. velocity of vapour is very high.

Which of the above statements are correct?

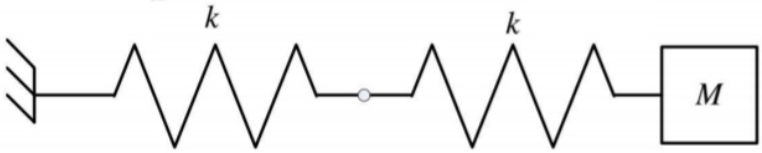
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

Ans. (b)

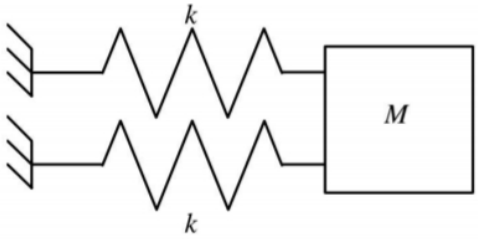
Momentum and energy transfers by advection in the condensate film are assumed to be negligible.

End of Solution

Q.6 The natural frequencies corresponding to the spring-mass systems I and II are ω_I and ω_{II}, respectively. The ratio $\frac{\omega_I}{\omega_{II}}$ is



SYSTEM I

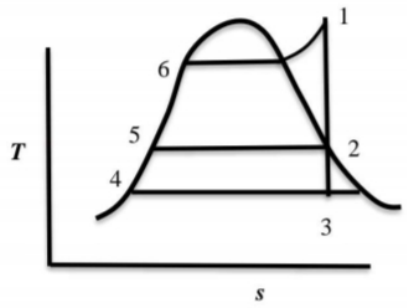


SYSTEM II

(A) $\frac{1}{4}$ (B) $\frac{1}{2}$ (C) 2 (D) 4

Q.49 A steam power cycle with regeneration as shown below on the *T-s* diagram employs a single open feedwater heater for efficiency improvement. The fluids mix with each other in an open feedwater heater. The turbine is isentropic and the input (bleed) to the feedwater heater from the turbine is at state 2 as shown in the figure. Process 3-4 occurs in the condenser. The pump work is negligible. The input to the boiler is at state 5. The following information is available from the steam tables:

State	1	2	3	4	5	6
Enthalpy (kJ/kg)	3350	2800	2300	175	700	1000



The mass flow rate of steam bled from the turbine as a percentage of the total mass flow rate at the inlet to the turbine at state 1 is _____

Q.23	**A rigid insulated tank is initially evacuated. It is connected through a valve to a supply line that carries air at a constant pressure and temperature of 250 kPa and 400 K respectively. Now the valve is opened and air is allowed to flow into the tank until the pressure inside the tank reaches to 250 kPa at which point the valve is closed. Assume that the air behaves as a perfect gas with constant properties ($c_p = 1.005$ kJ/kg.K, $c_v = 0.718$ kJ/kg.K, $R = 0.287$ kJ/kg.K). Final temperature of the air inside the tank is _____ K (*round off to one decimal place*).**

Q.48	**A single jet Pelton wheel operates at 300 rpm. The mean diameter of the wheel is 2 m. Operating head and dimensions of jet are such that water comes out of the jet with a velocity of 40 m/s and flow rate of 5 m^3/s. The jet is deflected by the bucket at an angle of 165°. Neglecting all losses, the power developed by the Pelton wheel is _____ MW (*round off to two decimal places*).**

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

$$\sin\alpha = \frac{}{(D_1 - D_2)}$$

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

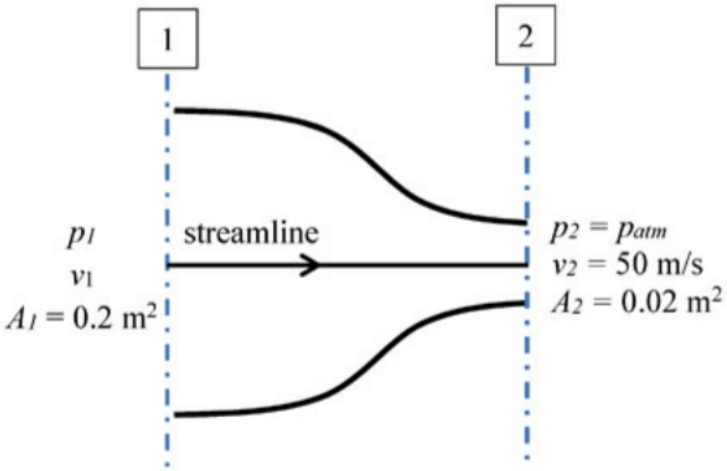
(A) 0.10

(B) 0.40

(C) 0.50

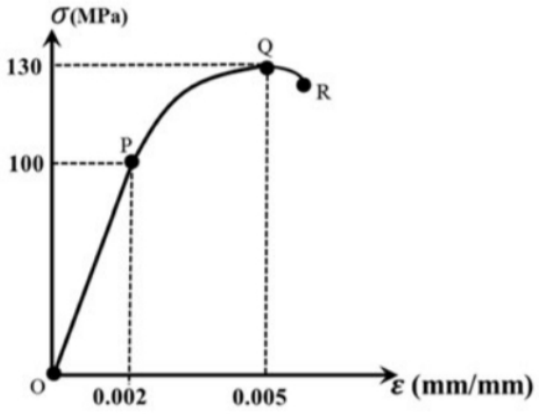
(D) 1.00

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 kg/m^3. The pressure difference, $(p_1 - p_{atm})$ is_____ kPa (*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.21 The state of stress at a point in a component is represented by a Mohr's circle of radius 100 MPa centered at 200 MPa on the normal stress axis. On a plane passing through the same point, the normal stress is 260 MPa. The magnitude of the shear stress on the same plane at the same point is _____ MPa.

Q.22 A wire of circular cross-section of diameter 1.0 mm is bent into a circular arc of radius 1.0 m by application of pure bending moments at its ends. The Young's modulus of the material of the wire is 100 GPa. The maximum tensile stress developed in the wire is _____ MPa.

Q.53	**A cantilever beam with a uniform flexural rigidity ($EI = 200 \times 10^6$ N.m^2) is loaded with a concentrated force at its free end. The area of the bending moment diagram corresponding to the full length of the beam is 10000 N.m^2. The magnitude of the slope of the beam at its free end is _____ micro radian (*round off to the nearest integer*).**

Q.54	**The torque provided by an engine is given by $T(\theta) = 12000 + 2500 \sin(2\theta)$ N.m, where θ is the angle turned by the crank from inner dead center. The mean speed of the engine is 200 rpm and it drives a machine that provides a constant resisting torque. If variation of the speed from the mean speed is not to exceed ±0.5%, the minimum mass moment of inertia of the flywheel should be _____ kg.m^2 (*round off to the nearest integer*).**

(D)	$n = 0$

Q.2	**Which one of the following options is TRUE?**
(A)	Pathlines and streaklines are the same in an unsteady flow, **and** streamlines are tangential to the local fluid velocity at a point.
(B)	Streamlines are perpendicular to the local fluid velocity at a point, **and** streamlines and streaklines are the same in a steady flow.
(C)	Pathlines and streaklines are the same in an unsteady flow, **and** streamlines and streaklines are the same in a steady flow.
(D)	Streamlines are tangential to the local fluid velocity at a point, **and** streamlines and streaklines are the same in a steady flow.

Q.44	**A shell and tube heat exchanger is used as a steam condenser. Coolant water enters the tube at 300 K at a rate of 100 kg/s. The overall heat transfer coefficient is 1500 W/m².K, and total heat transfer area is 400 m². Steam condenses at a saturation temperature of 350 K. Assume that the specific heat of coolant water is 4000 J/kg.K. The temperature of the coolant water coming out of the condenser is _____ K (*round off to the nearest integer*).**

Q.45	**Ambient air flows over a heated slab having flat, top surface at $y = 0$. The local temperature (in Kelvin) profile within the thermal boundary layer is given by $T(y) = 300 + 200\exp(-5y)$, where y is the distance measured from the slab surface in meter. If the thermal conductivity of air is 1.0 W/m.K and that of the slab is 100 W/m.K, then the magnitude of temperature**

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^3 and 400 J/kg.K, respectively. If the bead is considered as lumped system, the convective heat transfer coefficient (in W/m^2.K) between the metal bead and the fluid stream is

(A) 283.3

(B) 299.8

(C) 149.9

(D) 449.7

Q.No. 42 A mould cavity of 1200 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 cm^2. Consider acceleration due to gravity as 9.81 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° - 9° - 7° - 8° - 15° - 30° - 0.05 inch (Coordinate system, ASA)

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*).

$\left(\frac{\quad}{F_{c1}}\right) \times 100$, 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

Q.47 Water flowing at the rate of 1 kg/s through a system is heated using an electric heater such that the specific enthalpy of the water increases by 2.50 kJ/kg and the specific entropy increases by 0.007 kJ/kg·K. The power input to the electric heater is 2.50 kW. There is no other work or heat interaction between the system and the surroundings. Assuming an ambient temperature of 300 K, the irreversibility rate of the system is _____ kW (round off to two decimal places).

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) $k/2$

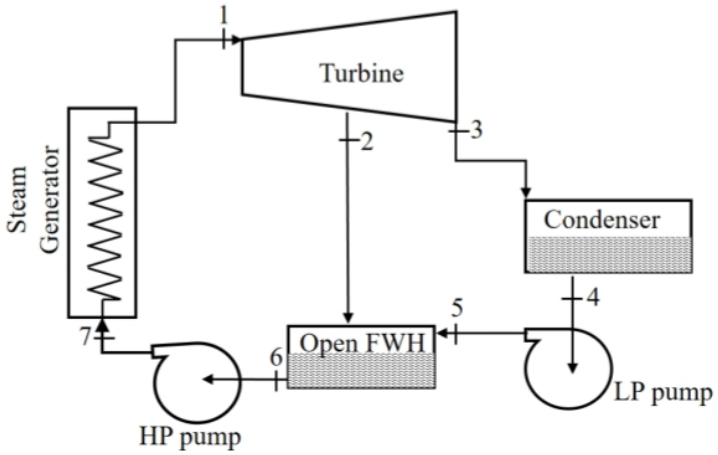
(B) k

(C) $8k$

(D) $16k$

Q.No. 32

Q.47 **Consider the open feed water heater (FWH) shown in the figure given below:**



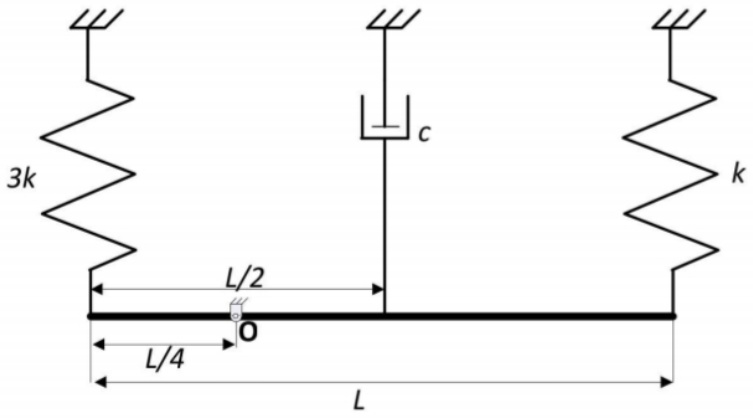
Specific enthalpy of steam at location 2 is 2624 kJ/kg, specific enthalpy of water at location 5 is 226.7 kJ/kg and specific enthalpy of saturated water at location 6 is 708.6 kJ/kg. If the mass flow rate of water entering the open feed water heater (at location 5) is 100 kg/s then the mass flow rate of steam at location 2 will be _____ kg/s (*round off to one decimal place*).

by this process in a single pass is _____ mm (round off to two decimal places).

Q.53 A through hole is drilled in an aluminum alloy plate of 15 mm thickness with a drill bit of diameter 10 mm, at a feed of 0.25 mm/rev and a spindle speed of 1200 rpm. If the specific energy required for cutting this material is 0.7 $N \cdot m/mm^3$, the power required for drilling is _____ W (round off to two decimal places).

Q.54 In an orthogonal machining with a single point cutting tool of rake angle 10°, the uncut chip thickness and the chip thickness are 0.125 mm and 0.22 mm, respectively. Using Merchant's first solution for the condition of minimum cutting force, the coefficient of friction at the chip-tool interface is _____ (round off to two decimal places).

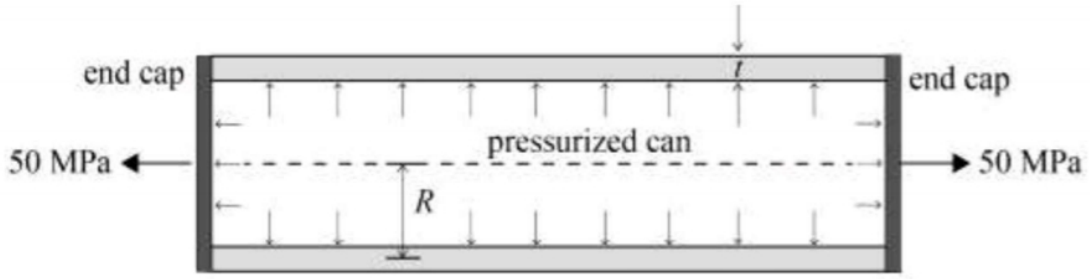
Q.32 A slender uniform rigid bar of mass m is hinged at O and supported by two springs, with stiffnesses $3k$ and k, and a damper with damping coefficient c, as shown in the figure. For the system to be critically damped, the ratio $c/\sqrt{km}$ should be



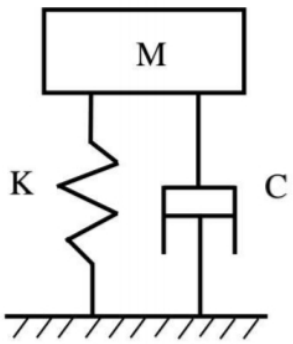
(A) 2 (B) 4 (C) $2\sqrt{7}$ (D) $4\sqrt{7}$

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.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.16 Consider the following statements:

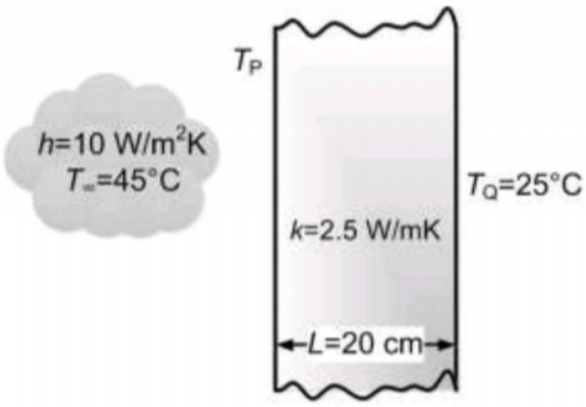
1. The entropy of a pure crystalline substance at absolute zero temperature is zero.
2. The efficiency of a reversible heat engine is independent of the nature of the working substance and depends only on the temperature of the reservoirs between which it operates.
3. Carnot's theorem states that of all heat engines operating between a given constant temperature source and a given constant temperature sink, none has a higher efficiency than a reversible engine

Which of the above statement are correct?

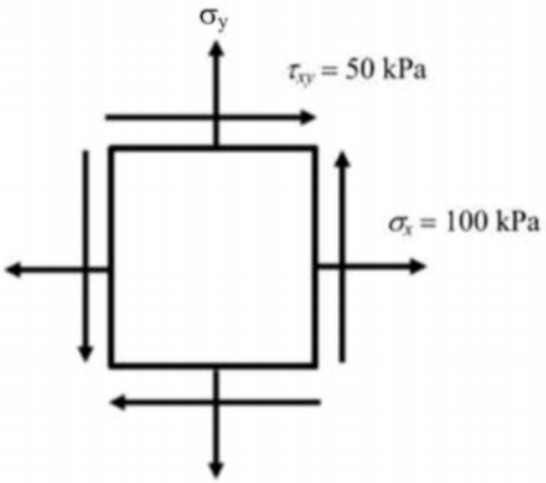
(a) 1 and 2 only
(b) 1 and 3 only
(c) 2 and 3 only
(d) 1, 2 and 3

Ans. (d)

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 $10\,W/m^2K$. The steady state temperature, T_P, (in °C) of the side which is exposed to the fluid is _____ (correct to two decimal places).

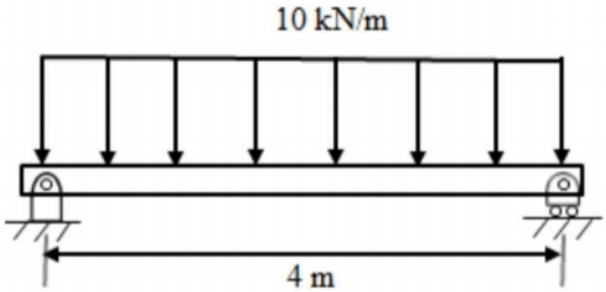


Q.29 The state of stress at a point, for a body in plane stress, is shown in the figure below. If the minimum principal stress is 10 kPa, then the normal stress σ_y (in kPa) is

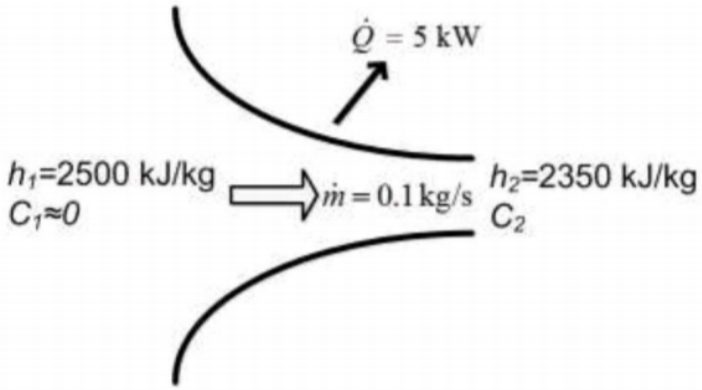


(A) 9.45 (B) 18.88 (C) 37.78 (D) 75.50

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.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 2500kJ/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).



Question Number : 15 **Correct : 1 Wrong : -0.33**

If a mass of moist air contained in a closed metallic vessel is heated, then its

(A) relative humidity decreases

(B) relative humidity increases

(C) specific humidity increases

(D) specific humidity decreases

Question Number : 16 **Correct : 1 Wrong : -0.33**

For the stability of a floating body the

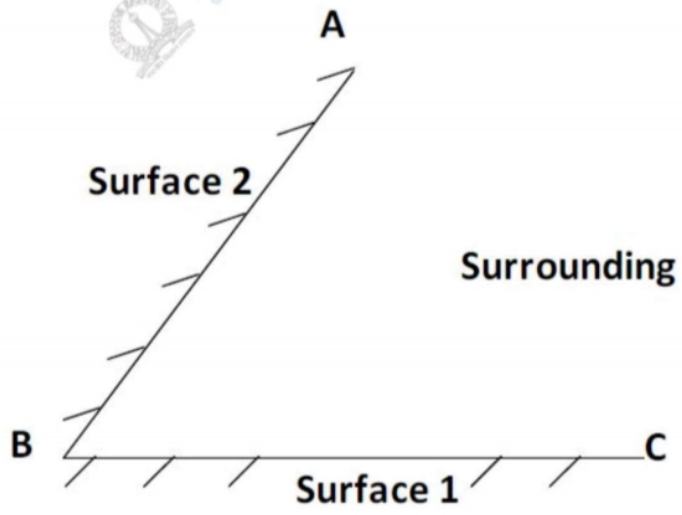
(A) centre of buoyancy must coincide with the centre of gravity
(B) centre of buoyancy must be above the centre of gravity
(C) centre of gravity must be above the centre of buoyancy
(D) metacentre must be above the centre of gravity

Question Number : 10 **Correct : 1 Wrong : 0**

A steel bar is held by two fixed supports as shown in the figure and is subjected to an increase of temperature ΔT=100 °C. If the coefficient of thermal expansion and Young's modulus of elasticity of steel are 11×10^{-6} /°C and 200 GPa, respectively, the magnitude of thermal stress (in MPa) induced in the bar is _____

Question Number : 37 **Correct : 2 Wrong : 0**

Two black surfaces, AB and BC, of lengths 5 m and 6 m, respectively, are oriented as shown. Both surfaces extend infinitely into the third dimension. Given that view factor $F_{12} = 0.5$, $T_1 = 800\text{K}$, $T_2 = 600\text{K}$, $T_{\text{surrounding}} = 300\text{K}$ and Stefan Boltzmann constant, $\sigma = 5.67 \times 10^{-8}\text{W/(m}^2\text{K}^4\text{)}$, the heat transfer rate from Surface 2 to the surrounding environment is _____kW.



Q.55	**A 3.5 mm thick sheet is rolled using a two high rolling mill to reduce the thickness under plane strain condition. Both rolls have a diameter of 500 mm and are rotating at 200 RPM. The coefficient of friction at the sheet and roll interface is 0.08, and the elastic deflection of the rolls is negligible. If the mean flow strength of the sheet material is 400 MPa, then the minimum possible thickness (in mm) of sheet that can be produced in a single pass is _____.** **[*round off to 2 decimal places*]**

END OF THE QUESTION PAPER

Q.43	**A wire of 5 mm diameter is drawn into a wire of 4 mm diameter through a conical die at a constant pulling speed of 5 m/s. Neglecting the coefficient of friction and redundant work, the drawing stress (σ_d) in MPa for the above process is given by $\sigma_d = \bar{\sigma} \ln\left[\frac{1}{1-r}\right]$, where $\bar{\sigma}$ is the mean flow strength of wire material in MPa, and r is the ratio of decrease in area of cross-section to initial area of cross-section of the wire. If the mean flow strength of wire material is 600 MPa, then the power required in kW in the above wire drawing process is _____.** [*round off to 2 decimal places*]

Q.44	**In an arc welding process, the DC power source characteristic is linear with an open circuit voltage of 60 V and short circuit current of 600 A. The heat required for melting a metal during the welding is 10 J/mm^3, and the heat transfer and melting efficiencies are 80% and 25%, respectively. If the weld cross-sectional area of 20 mm^2 is made using the maximum arc power, then the required welding speed in mm/s is _____. [*round off to one decimal place*]**

Q.32 **A company manufactures two products P and Q with unit profit of 4 and 5, respectively. The production requires manpower and two kinds of raw materials R1 and R2. The following table summarizes the requirement and availability of resources.**

Resource	Resource usage per unit of production		Amount of resource available
	P	Q	
manpower	1	1	10
R1	1	2	18
R2	2	1	18

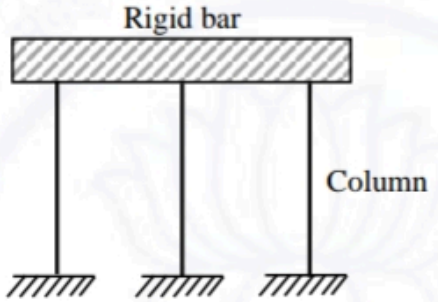
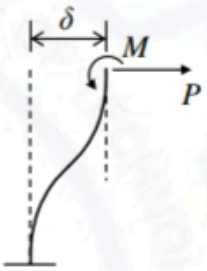
The maximum profit the company can make is

(A) 45

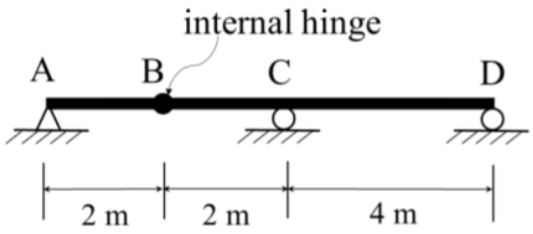
(B) 48

(C) 42

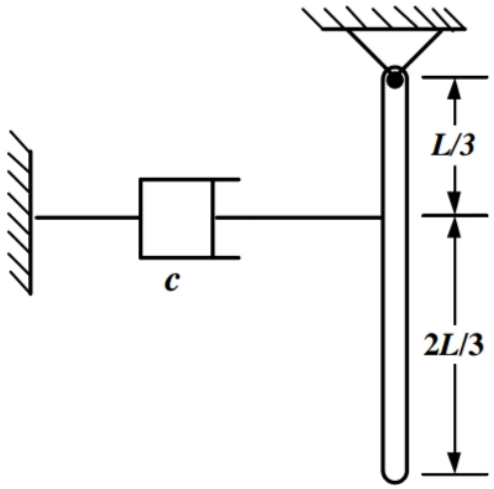
(D) 54

Q.7	**A single story building model is shown in the figure. The rigid bar of mass 'm' is supported by three massless elastic columns whose ends are fixed against rotation. For each of the columns, the applied lateral force (P) and corresponding moment (M) are also shown in the figure. The lateral deflection (δ) of the bar is given by $\delta = \frac{PL^3}{12EI}$, where L is the effective length of the column, E is the Young's modulus of elasticity and I is the area moment of inertia of the column cross-section with respect to its neutral axis.**  Building model  Lateral deflection profile of any column **For the lateral deflection profile of the columns as shown in the figure, the natural frequency of the system for horizontal oscillation is**
(A)	$6\sqrt{\frac{EI}{mL^3}}$ rad/s
(B)	$\frac{1}{L}\sqrt{\frac{2EI}{m}}$ rad/s
(C)	$2\sqrt{\frac{6EI}{mL^3}}$ rad/s
(D)	$\frac{2}{L}\sqrt{\frac{EI}{m}}$ rad/s

Q.36 A long uniformly distributed load of 10 *kN/m* and a concentrated load of 60 *kN* are moving together on the beam ABCD shown in the figure (*not drawn to scale*). The relative positions of the two loads are not fixed. The maximum shear force (in *kN, round off to the nearest integer*) caused at the internal hinge B due to the two loads is _____



Q.21 The uniform pendulum rod, having mass 10 kg and length $L = 5$ m, is attached to a viscous damper having damping coefficient c. Use acceleration due to gravity $g = 10$ m/s^2. The least value of c (in N-s/m) such that small motions of the pendulum rod decay without oscillations is _____



Q.8 Match the component with the corresponding manufacturing process in the table below.

Component		Manufacturing process	
P	**Aluminum alloy piston for IC engine**	**1**	**Blow molding**
Q	**Low carbon steel oil pan**	**2**	**Powder metallurgy**
R	**Tungsten carbide cutting tool insert**	**3**	**Sand casting**
S	**Plastic bottle**	**4**	**Deep drawing**

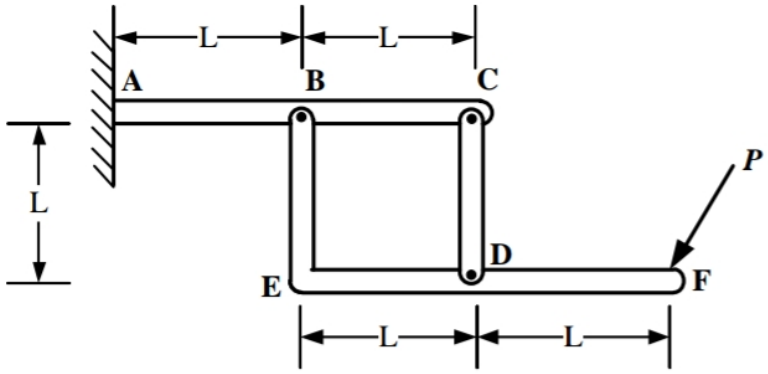
(A) P-3, Q-2, R-1, S-4

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

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

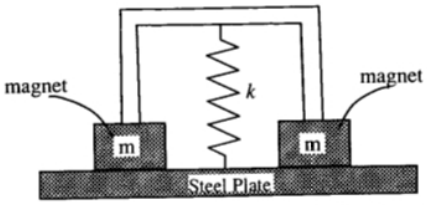
(D) P-1, Q-3, R-2, S-4

Q.3 The frame comprises members ABC, CD, and BEDF. This frame is fixed at A, and the connections between the three members are pins. Load *P* is applied at F. Which of the following statements is TRUE?

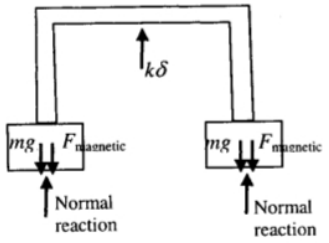


(A) ABC and CD are two-force members
(B) CD is the only two-force member
(C) BEDF and CD are two-force members
(D) ABC is the only two-force member

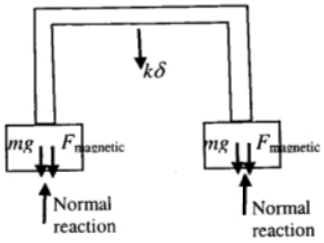
Q.9 A non-magnetic light rigid frame with two magnets attached to its legs rests on a mild steel plate as shown. A spring, compressed by an amount δ from its unstretched length, connects the steel plate to the center of the frame as shown. Which of the figures below represents the **CORRECT** free-body diagram?



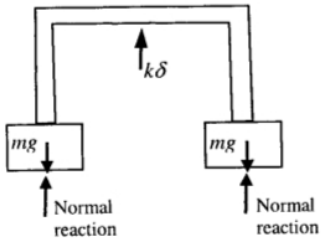
(A)



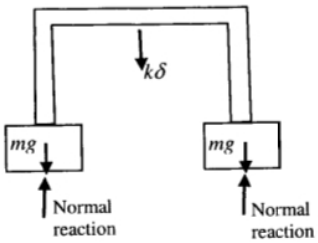
(B)



(C)

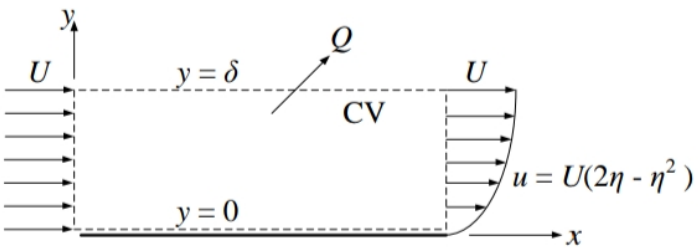


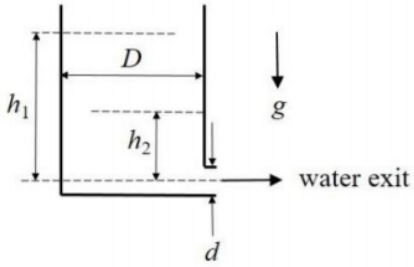
(D)

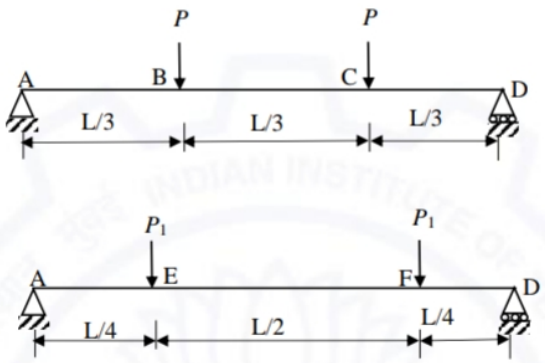


Q.3	**Two air streams of mass flow rates $\dot{m}_1$ and $\dot{m}_2$ enter a mixing chamber and exit after perfect mixing. The corresponding temperatures of the inlet streams are T_1 and T_2, respectively. Heat loss rate from the mixing chamber to the surrounding is $\dot{Q}$. Assume that the process is steady, specific heat capacity is constant, and air behaves as an ideal gas. Identify the correct expression for the final exit temperature T_3 after mixing. The mass specific heat capacities of the gas at constant volume and constant pressure are c_v and c_p, respectively. Neglect the bulk kinetic and potential energies of the streams.**
(A)	$T_3 = \dfrac{\dot{m}_1 T_1 + \dot{m}_2 T_2}{\dot{m}_1 + \dot{m}_2} - \dfrac{\dot{Q}}{c_v(\dot{m}_1 + \dot{m}_2)}$
(B)	$T_3 = \dfrac{\dot{m}_1 T_1 + \dot{m}_2 T_2}{\dot{m}_1 + \dot{m}_2} + \dfrac{\dot{Q}}{c_p(\dot{m}_1 + \dot{m}_2)}$
(C)	$T_3 = \dfrac{\dot{m}_1 T_1 + \dot{m}_2 T_2}{\dot{m}_1 + \dot{m}_2} - \dfrac{\dot{Q}}{c_p(\dot{m}_1 + \dot{m}_2)}$
(D)	$T_3 = \dfrac{\dot{m}_1 T_1 + \dot{m}_2 T_2}{\dot{m}_1 + \dot{m}_2} + \dfrac{\dot{Q}}{c_v(\dot{m}_1 + \dot{m}_2)}$

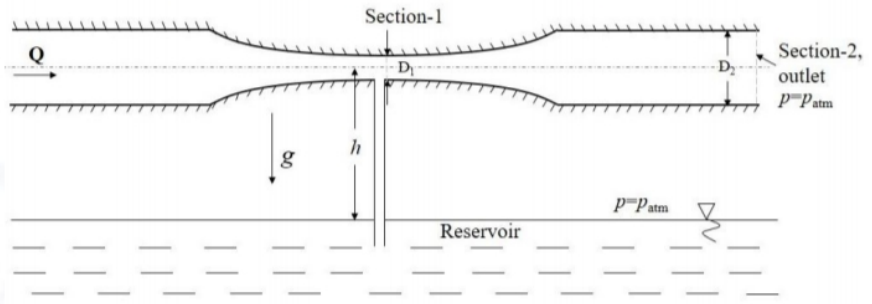
Q.21 An incompressible fluid flows past a flat plate as shown in the figure below with a uniform inlet velocity profile $u = U$ and a parabolic exit velocity profile $u = U(2\eta - \eta^2)$, where u is the component of velocity parallel to the wall, y is the normal distance from the plate and $\eta = y/\delta$. If the volume flow rate across the top surface of the control volume (CV) is $Q = pU\delta$ per unit width (perpendicular to the x-y plane) of the plate, the value of p (rounded off to 2 decimal places) is _____



Q. 20	**Water discharges from a cylindrical tank through an orifice, as shown in the figure. The flow is considered frictionless. Initially, the water level in the tank was $h_1 = 2$ m. The diameter of the tank is $D = 1$ m, while the diameter of the jet is $d = 10$ cm, and the acceleration due to gravity is $g = 10$ m/s^2. The time taken (in seconds, up to one decimal place) for the water level in the tank to come down to $h_2 = 1$ m is _____.** 

Q.7	**A simply supported beam of length L is loaded by two symmetrically applied point loads P at L/3 from each support. Both the loads are then shifted to new points which are at a distance L/4 from each support. The bending moments at the mid-section of the beam in both the cases are same. The magnitude of P1 in terms of P is** 
(A)	$P/4$
(B)	$8P/3$
(C)	$4P/3$
(D)	$P/3$

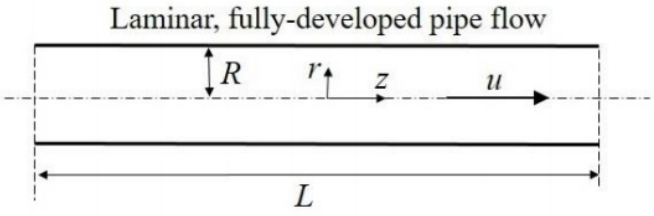
Q. 22	**Water is flowing with a flow rate Q in a horizontal circular pipe. Due to the low pressure created at the venturi section (Section-1 in the figure), water from a reservoir is drawn upward using a connecting pipe as shown in the figure. Take acceleration due to gravity $g = 10$ m/s^2. The flow rate $Q = 0.1$ m^3/s, $D_1 = 8$ cm, and $D_2 = 20$ cm. The maximum height (h, in meters, up to one decimal place) of the venturi from the reservoir just sufficient to raise the liquid upto Section-1 is _____.**



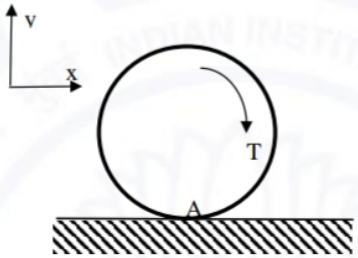
Q. 13 – Q. 22 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

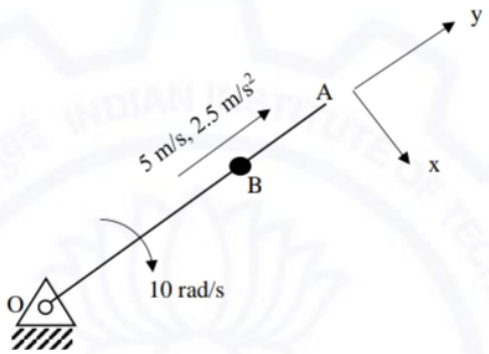
Q. 13

In a laminar, incompressible, fully-developed pipe flow of a Newtonian fluid, as shown in the figure, the velocity profile over a cross-section is given by $u = U\left(1 - \frac{r^2}{R^2}\right)$, where U is a constant. The pipe length is L and the fluid viscosity is μ. The power P required to sustain the flow is expressed as $P = c\mu LU^2$, where c is a dimensionless constant. The value of the constant c (up to one decimal place) is _____.

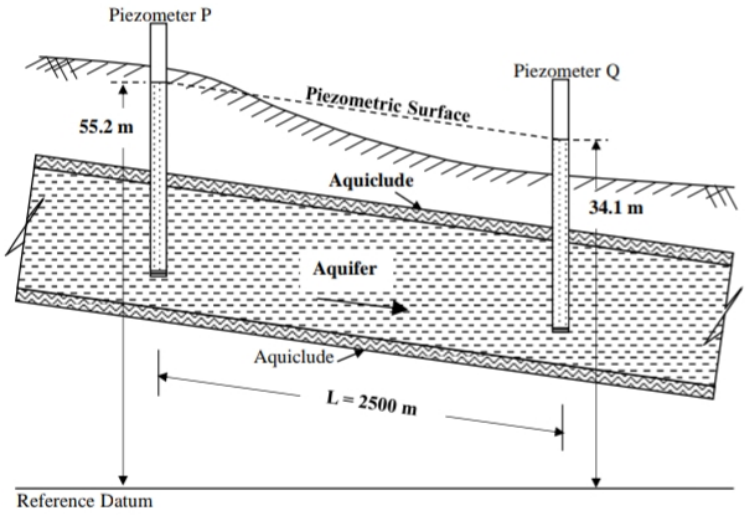


Q. 16 – Q. 22 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

Q.16	**A rigid circular disc of radius 0.2 m and mass 10 kg rolls without slip on the ground at A. The coefficient of static friction μ between ground and disc is 0.7. A torque T of 9 Nm acts on the disc as shown. Given acceleration due to gravity g = 10 m/s^2 . The friction force (in N) acting on the disc (in integer) is _____** 

Q.2	**A rigid rod OA rotates clockwise at an angular velocity of 10 rad/s. A bead B (OB = 1 m) translates outward on the rod at a speed of 5 m/s and acceleration 2.5 m/s2 (both quantities with respect to the rod). The Coriolis component of acceleration is** 
(A)	2.5 m/s2 in +x direction
(B)	100 m/s2 in +x direction
(C)	100 m/s2 in –y direction
(D)	25 m/s2 in + y direction

Q.47 A confined aquifer of 15 *m* constant thickness is sandwiched between two aquicludes as shown in the figure (not drawn to scale).



The heads indicated by two piezometers P and Q are 55.2 *m* and 34.1 *m*, respectively. The aquifer has a hydraulic conductivity of 80 *m/day* and its effective porosity is 0.25. If the distance between the piezometers is 2500 *m*, the time taken by the water to travel through the aquifer from piezometer location P to Q (in *days, round off to 1 decimal place*) is _____

Ans. (c)

End of Solution

Q.137 **Statement (I) :** Non-viscous flow between two plates held parallel with a very small spacing between them is an example of irrotational flow.
Statement (II) : forced vortex implies irrotational flow.

Ans. (c)

End of Solution

Q.138 **Statement (I) :** The air-fuel ratio employed in a gas turbine is around 60 : 1.
Statement (II) : A lean mixture of 60 : 1 in a gas turbine is mainly used for complete combustion.

Ans. (a)

End of Solution

Q.139 **Statement (I) :** the condenser in a steam power plant is always filled with a mixture of water, steam and air.
Statement (II) : Slightly wet steam enters the condenser wherein the pressure is below the atmospheric conditions, causing some leakage of air through the glands and also the release of some air dissolved in the boiler feedwater.

Ans. (a)

Q.3 The differential equation $\frac{dy}{dx}+4y=5$ is valid in the domain $0\le x\le 1$ with $y(0)=2.25$. The solution of the differential equation is

(A) $y=e^{-4x}+5$

(B) $y=e^{-4x}+1.25$

(C) $y=e^{4x}+5$

(D) $y=e^{4x}+1.25$

Q. 1 – Q. 25 carry one mark each.

Q.1 Consider the matrix

$$P = \begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$

The number of distinct eigenvalues of P is

(A) 0 (B) 1 (C) 2 (D) 3

Q.19	Value of $(1+i)^8$, where $i=\sqrt{-1}$, is equal to
(A)	4
(B)	16
(C)	$4i$
(D)	$16i$

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

Q.No. 37

Q.No. 2 The value of

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

(A) c

(B) $c + 1$

(C) $\dfrac{c}{c+1}$

(D) $\dfrac{c+1}{c}$