

XE : ENGINEERING SCIENCES

Duration : Three Hours

Maximum Marks : 100

Read the following instructions carefully.

1. This question paper contains 40 pages including blank pages for rough work. Please check all pages and report discrepancy, if any.
2. Write your registration number, your name and name of the examination centre at the specified locations on the right half of the Optical Response Sheet (ORS).
3. Using HB pencil, darken the appropriate bubble under each digit of your registration number and the letters corresponding to your paper code.
4. All questions in this paper are of objective type.
5. Questions must be answered on the ORS by darkening the appropriate bubble (marked A, B, C, D) using HB pencil against the question number on the left hand side of the ORS. For each question darken the bubble of the correct answer. In case you wish to change an answer, erase the old answer completely. More than one answer bubbled against a question will be treated as an incorrect response.
6. There are a total of 65 questions carrying 100 marks.
7. This question paper contains eight sections as listed below. Sections GA and A are compulsory. Choose two more sections from the remaining sections B through G.

Section	Page No.	Section	Page No.
GA. General Aptitude	02	D. Solid Mechanics	18
A. Engineering Mathematics	04	E. Thermodynamics	23
B. Fluid Mechanics	07	F. Polymer Science and Engineering	28
C. Materials Science	14	G. Food Technology	31

Using HB pencil, mark the sections you have chosen by darkening the appropriate bubbles on the left hand side of the ORS provided. Make sure you have correctly bubbled the sections you have chosen. ORS will not be evaluated if this information is NOT marked.

8. There are 10 questions carrying 15 marks in General Aptitude (GA) section, which is compulsory. Questions Q.1 - Q.5 will carry 1-mark each, and questions Q.6 - Q.10 will carry 2-marks each.
9. There are 11 questions carrying 15 marks in XE Section A (Engineering Mathematics) paper, which is compulsory. Questions Q.1 - Q.7 will carry 1-mark each, and questions Q.8 - Q.11 will carry 2-marks each.
10. Each of the other XE section papers (Sections B through G) contains 22 questions carrying 35 marks. Questions Q.1 - Q.9 will carry 1-mark each. Questions Q.10 - Q.22 will carry 2-marks each containing 2 pairs of common data and 1 pair of linked questions. Questions Q.17 - Q.20 (2 pairs) are common data questions with 2-marks each, and questions Q.21 and Q.22 (1 pair) are linked answer questions with 2-marks each. The answer to the second question of the linked answer questions depends on the answer to the first question of the pair. If the first question in the linked pair is wrongly answered or is un-attempted, then the answer to the second question in the pair will not be evaluated.
11. Un-attempted questions will carry zero marks.
12. Wrong answers will carry **NEGATIVE** marks. In GA, for Q.1 - Q.5, $\frac{1}{2}$ mark will be deducted for each wrong answer and for Q.6 - Q.10, $\frac{2}{3}$ mark will be deducted for each wrong answer. In XE Section A, for Q.1 - Q.7, $\frac{1}{2}$ mark will be deducted for each wrong answer and for Q.8 - Q.11, $\frac{2}{3}$ mark will be deducted for each wrong answer. In all other XE section papers (Section B through G), for Q.1 - Q.9, $\frac{1}{2}$ mark will be deducted for each wrong answer and for Q.10 - Q.20, $\frac{2}{3}$ mark will be deducted for each wrong answer. The question pair (Q.21, Q.22) is questions with linked answers. There will be negative marks only for wrong answer to the first question of the linked answer question pair. For Q.21, $\frac{1}{2}$ mark will be deducted for wrong answer. There is no negative marking for Q.22.
13. Calculator (without data connectivity) is allowed in the examination hall.
14. Charts, graph sheets or tables are NOT allowed in the examination hall.
15. Rough work can be done on the question paper itself. Additionally, blank pages are provided at the end of the question paper for rough work.

SEAL

GA: General Aptitude (Compulsory)**Q.1 – Q.5 carry one mark each.**

- Q.1 *The question below consists of a pair of related words followed by four pairs of words. Select the pair that best expresses the relation in the original pair.*
Unemployed : Worker
- (A) fallow : land
(B) unaware : sleeper
(C) wit : jester
(D) renovated : house
- Q.2 *Choose the most appropriate word from the options given below to complete the following sentence:*
His rather casual remarks on politics _____ his lack of seriousness about the subject.
- (A) masked
(B) belied
(C) betrayed
(D) suppressed
- Q.3 *Which of the following options is the closest in meaning to the word below:*
Circuitous
- (A) cyclic
(B) indirect
(C) confusing
(D) crooked
- Q.4 25 persons are in a room. 15 of them play hockey, 17 of them play football and 10 of them play both hockey and football. Then the number of persons playing neither hockey nor football is:
- (A) 2 (B) 17 (C) 13 (D) 3
- Q.5 *Choose the most appropriate word from the options given below to complete the following sentence:*
If we manage to _____ our natural resources, we would leave a better planet for our children.
- (A) uphold
(B) restrain
(C) cherish
(D) conserve

Q.6 – Q.10 carry two marks each.

- Q.6 5 skilled workers can build a wall in 20 days; 8 semi-skilled workers can build a wall in 25 days; 10 unskilled workers can build a wall in 30 days. If a team has 2 skilled, 6 semi-skilled and 5 unskilled workers, how long will it take to build the wall?
- (A) 20 days (B) 18 days (C) 16 days (D) 15 days
- Q.7 Given digits 2, 2, 3, 3, 3, 4, 4, 4, 4 how many distinct 4 digit numbers greater than 3000 can be formed?
- (A) 50 (B) 51 (C) 52 (D) 54

- Q.8 If $137 + 276 = 435$ how much is $731 + 672$?
- (A) 534 (B) 1403 (C) 1623 (D) 1513
- Q.9 Hari (H), Gita (G), Irfan (I) and Saira (S) are siblings (i.e. brothers and sisters). All were born on 1st January. The age difference between any two successive siblings (that is born one after another) is less than 3 years. Given the following facts:
- Hari's age + Gita's age > Irfan's age + Saira's age.
 - The age difference between Gita and Saira is 1 year. However, Gita is not the oldest and Saira is not the youngest.
 - There are no twins.
- In what order were they born (oldest first)?
- (A) HSI G (B) SGHI (C) IGSH (D) IHSG
- Q.10 **Modern warfare has changed from large scale clashes of armies to suppression of civilian populations. Chemical agents that do their work silently appear to be suited to such warfare; and regrettably, there exist people in military establishments who think that chemical agents are useful tools for their cause.**
- Which of the following statements best sums up the meaning of the above passage:*
- (A) Modern warfare has resulted in civil strife.
(B) Chemical agents are useful in modern warfare.
(C) Use of chemical agents in warfare would be undesirable.
(D) People in military establishments like to use chemical agents in war.

END OF SECTION – GA

A : ENGINEERING MATHEMATICS (Compulsory)

Q.1 – Q.7 carry one mark each.

Q.1. If $P = \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$, then $P^8 - 2P^7 + 2P^6 - 4P^5 + 3P^4 - 6P^3 + 2P^2$ equals

- (A) P (B) $2P$ (C) $3P$ (D) $4P$

Q.2. Which one of the following matrices has the same eigen values as that of $\begin{pmatrix} 1 & 2 \\ 4 & 3 \end{pmatrix}$?

- (A) $\begin{pmatrix} 3 & 4 \\ 1 & 2 \end{pmatrix}$ (B) $\begin{pmatrix} 1 & 4 \\ 2 & 3 \end{pmatrix}$
 (C) $\begin{pmatrix} 4 & 2 \\ 1 & 3 \end{pmatrix}$ (D) $\begin{pmatrix} 2 & 4 \\ 1 & 3 \end{pmatrix}$

Q.3. The integral

$$\int_1^1 x^{-x} dx \text{ is}$$

- (A) an improper integral converging to -6 .
 (B) an improper integral converging to 0 .
 (C) not an improper integral but has value -6 .
 (D) a divergent improper integral.

Q.4. The residue of the function $f(z) = \frac{\sin^4 z}{(z + \pi/4)^3}$ at $z = -\pi/4$ is

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

Q.5. The variance of the number of heads resulting from ten independent tosses of a fair coin is

- (A) $\frac{5}{4}$ (B) $\frac{5}{2}$ (C) $\frac{3}{4}$ (D) $\frac{3}{2}$

Q.6. If the quadrature rule $\int_0^3 f(x) dx = \alpha f(1) + \beta f(3)$ is exact for all polynomials of degree 2 or less, then

- (A) $\alpha = \frac{3}{4}, \beta = \frac{3}{4}$ (B) $\alpha = \frac{3}{4}, \beta = \frac{9}{4}$
 (C) $\alpha = \frac{9}{4}, \beta = \frac{3}{4}$ (D) $\alpha = \frac{9}{4}, \beta = \frac{9}{4}$

- Q.7. Given that $\frac{dy}{dx} = 1 + y^2$, $y(0) = 0$, which one of the following is nearest to $y(0.4)$ computed by Euler's method with step size of 0.2 ?
- (A) 0.408 (B) 0.404 (C) 0.208 (D) 0.204

Q.8 – Q.11 carry two marks each.

- Q.8. Let

$$f(x) = \begin{cases} \frac{\sin x}{x} & \text{if } x \neq 0 \\ 1 & \text{if } x = 0. \end{cases}$$

Then

- (A) f is not continuous at $x=0$.
 (B) f is continuous at $x=0$ but not differentiable at $x=0$.
 (C) f is differentiable at $x=0$ and $f'(0) = 0$.
 (D) f is differentiable at $x=0$ and $f'(0) = 1$.
- Q.9. Let $u(x, y) = \tan\{xy(x+y)\}$. Then

- (A) $x \frac{\partial u}{\partial x} + y \frac{\partial u}{\partial y} = \frac{1}{3} xy(x+y) \sec^2\{xy(x+y)\}$.
 (B) $x \frac{\partial u}{\partial x} - y \frac{\partial u}{\partial y} = \frac{1}{3} xy(x+y) \sec^2\{xy(x+y)\}$.
 (C) $x \frac{\partial u}{\partial x} + y \frac{\partial u}{\partial y} = 3xy(x+y) \sec^2\{xy(x+y)\}$.
 (D) $x \frac{\partial u}{\partial x} - y \frac{\partial u}{\partial y} = 3xy(x+y) \sec^2\{xy(x+y)\}$.

- Q.10. Which one of the following is a particular solution of the ordinary differential equation

$$x \frac{d^2 y}{dx^2} - \frac{dy}{dx} = 2x^2 f(x) ?$$

- (A) $x^2 \int x f(x) dx + \int x^3 f(x) dx$ (B) $x^2 \int f(x) dx + \int x^2 f(x) dx$
 (C) $x^2 \int x f(x) dx - \int x^3 f(x) dx$ (D) $x^2 \int f(x) dx - \int x^2 f(x) dx$

Q.11. Which one of the following is a possible solution to the partial differential equation

$$\frac{\partial^2 u}{\partial t^2} - \frac{\partial^2 u}{\partial x^2} = 0 \text{ with boundary conditions}$$

$$u(0,t)=0, \frac{\partial u(\pi,t)}{\partial x}=0, \text{ for } t \geq 0, \quad u(x,0)=0, \frac{\partial u(x,0)}{\partial t}=\pi, \text{ for } 0 \leq x \leq \pi ?$$

$$(A) \quad u(x,t) = \sum_{n=0}^{\infty} a_n \sin\left((n+\frac{1}{2})t\right) \sin\left((n+\frac{1}{2})x\right)$$

$$(B) \quad u(x,t) = \sum_{n=0}^{\infty} a_n \cos\left((n+\frac{1}{2})t\right) \sin\left((n+\frac{1}{2})x\right)$$

$$(C) \quad u(x,t) = \sum_{n=0}^{\infty} a_n \sin\left((n+\frac{1}{2})t\right) \cos\left((n+\frac{1}{2})x\right)$$

$$(D) \quad u(x,t) = \sum_{n=0}^{\infty} a_n \cos\left((n+\frac{1}{2})t\right) \cos\left((n+\frac{1}{2})x\right)$$

END OF SECTION - A

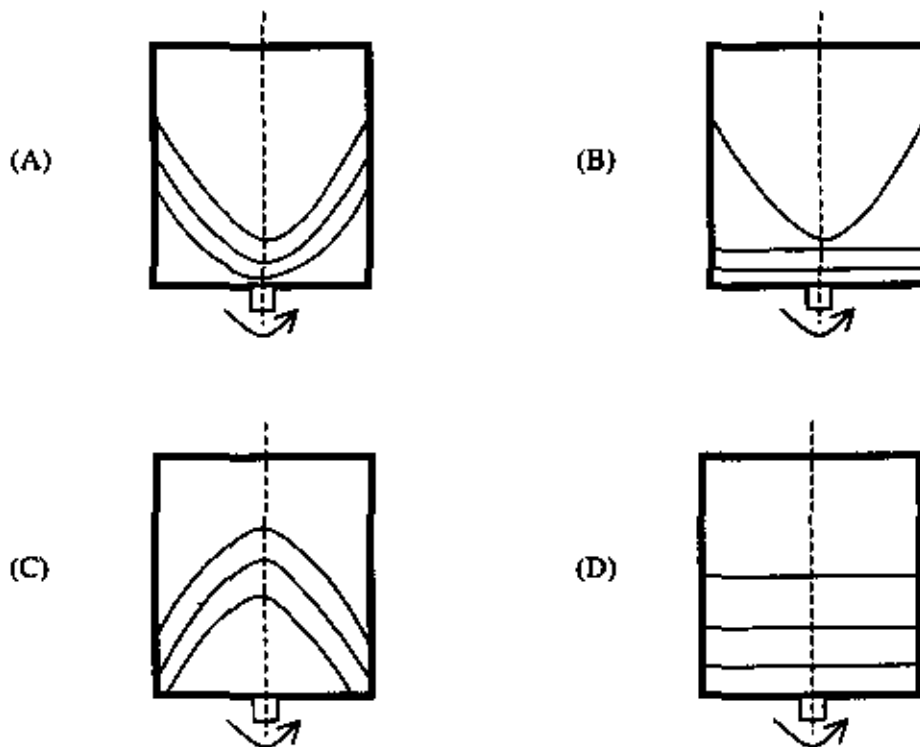
B : FLUID MECHANICS

Useful data

Acceleration due to gravity = 10 m/s^2
 Density of water = 1000 kg/m^3
 Density of mercury = 13570 kg/m^3

Q.1 – Q.9 carry one mark each.

- Q.1. A cylindrical container is filled with a liquid up to half of its height. The container is mounted on the centre of a turn-table and is held fixed using a spindle. The turn-table is now rotated about its central axis with a certain angular velocity. After some time interval, the fluid attains rigid body rotation. Which of the following profiles best represents the constant pressure surfaces in the container?



- Q.2. Match the items given in the following two columns using appropriate combinations:

Column 1

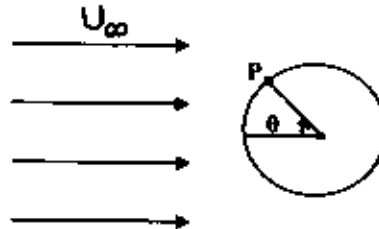
- P Ratio of inertial force to viscous force
 Q Ratio of momentum diffusivity to thermal diffusivity
 R Ratio of inertial force to compressibility force
 S Ratio of inertial force to gravity force

Column 2

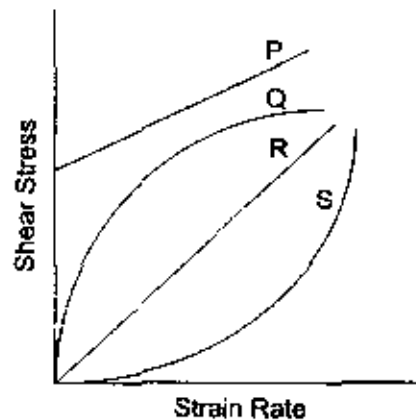
1. Reynolds number (Re)
 2. Froude number (Fr)
 3. Prandtl number (Pr)
 4. Mach number (Ma)

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

- Q.3. In the context of boundary layers, which one of the following statements is FALSE ?
- (A) It is a frictional layer, close to the body
 (B) It is a region where the fluid flow is irrotational
 (C) It is a region across which the pressure gradient is negligible
 (D) It is a diffusion layer of vorticity
- Q.4. Consider an ideal fluid flow past a circular cylinder shown in the figure below. The peripheral velocity at a point P on the surface of the cylinder is



- (A) 0 (B) U_∞ (C) $U_\infty \sin \theta$ (D) $2 U_\infty \sin \theta$
- Q.5. The Rheological diagram depicting the relation between shear stress and strain rate for different types of fluids is shown in the figure below.



- The most suitable relation for flow of tooth paste being squeezed out of the tube is given by the curve
- (A) P (B) Q (C) R (D) S
- Q.6. The diverging limb of a venturimeter is kept longer than the converging limb to
- (A) ensure that the flow remains laminar
 (B) avoid separation
 (C) ensure that the flow remains turbulent
 (D) avoid formation of boundary layer
- Q.7. The length scale of a model is kept as 1 : 64. The prototype fluid is water. Viscous and gravity forces are equally dominant in the prototype. The required kinematic viscosity (m^2/s) of the fluid used in the model is
- (A) 0.100E-07 (B) 0.195E-08
 (C) 0.156E-07 (D) 0.125E-07

Q.8. Let ϕ and ψ represent, respectively, the velocity potential and stream function of a flow field of an incompressible fluid. Which of the following statements are **TRUE**?

- P: ϕ exists for irrotational flows only
 Q: ψ exists for both irrotational and rotational flows
 R: ϕ exists for rotational flows only
 S: ψ exists for both rotational and irrotational flows

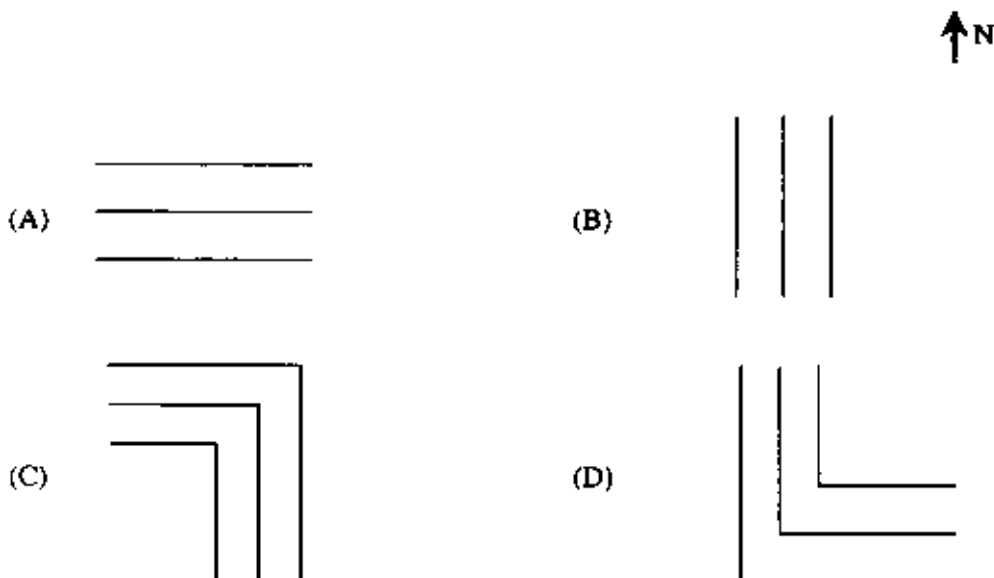
- (A) P, R (B) Q, S (C) Q, R (D) P, Q

Q.9. Two models M_1 and M_2 have equal volumes and are made of steel. Model M_1 is an aerofoil (a streamlined body) and model M_2 a sphere (a bluff body). Both models are dropped in two identical short jars filled with honey simultaneously. Which of the following statements is **TRUE**?

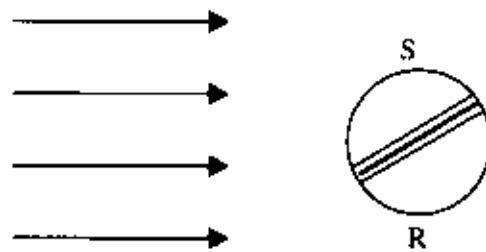
- (A) M_1 reaches the bottom earlier than M_2
 (B) M_2 reaches the bottom earlier than M_1
 (C) Both models reach the bottom at the same time
 (D) Both models float on the surface

Q.10 – Q.22 carry two marks each.

Q.10. The wind is blowing east - west at time $t < T$, and switches to south - north at $t = T$. At $t > T$, which of the following curves represent streaklines?

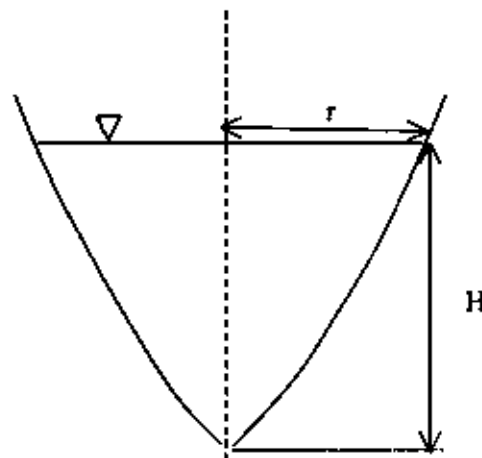


- Q.11. A cricket ball comprises of a seam running along its central section, which is essentially stitching of two hemi-spheres. The seam creates additional roughness. The bowler releases the ball with seam orientation as shown in the figure below.



This would result in an out swinger with side forces on the cricket ball. These side forces on the ball are attributed to

- (A) flow having a laminar boundary layer separation on both sides.
 - (B) flow having turbulent boundary layer separation on both sides.
 - (C) flow having a laminar boundary layer separation on the side "S" and a turbulent boundary layer separation on the side "R".
 - (D) flow having a laminar boundary layer separation on the side "R" and a turbulent boundary layer separation on the side "S".
- Q.12. Ancients have designed water clocks based upon the head of the water in a circular section container with a hole at the bottom as shown in the figure below. The radius (r) varies as a function of head (H) to maintain a constant rate of decline of H .



The relation between H and r is

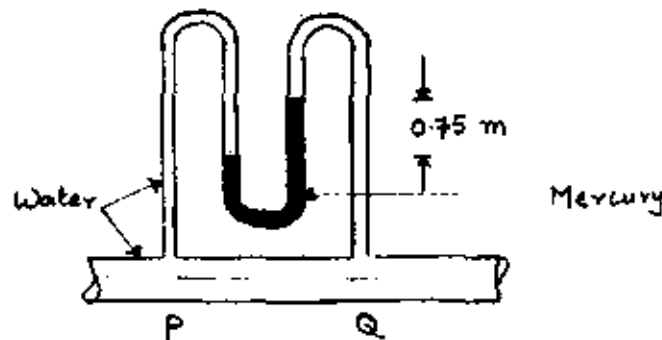
- (A) H is proportional to r
- (B) H is proportional to r^2
- (C) H is proportional to r^3
- (D) H is proportional to r^4

- Q.13. A 20 cm diameter pipe carries a water discharge of $\pi/100$ m³/s. The pipe is bent through an angle of 30° in the horizontal plane as shown in the figure below.

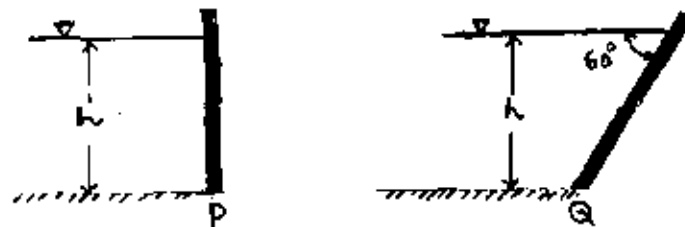


Neglecting friction, the components of the force (N) exerted by water on the bend in x - and y -directions, respectively, are

- (A) 4.21 and -15.71 (B) -4.21 and 15.71
 (C) 15.71 and -27.2 (D) 4.21 and 15.71
- Q.14. A differential U-tube manometer with mercury as the manometric fluid is used to measure the pressure difference between two sections P and Q in a horizontal pipe carrying water at steady state as shown in the figure below. If the difference in mercury levels in the two limbs of the manometer is 0.75 m, the difference in pressure (kPa) between sections P and Q is



- (A) 49.275 (B) 94.275 (C) 9.4275 (D) 492.75
- Q.15. Two walls are holding back water as shown in the figures below. The resisting moments per unit length of the walls at points P and Q are M_P and M_Q . Denoting the specific weight of water as γ , the difference in the moments ($M_Q - M_P$) is



- (A) $\frac{\sqrt{3}\gamma h^3}{2}$ (B) $\frac{2\gamma h^3}{\sqrt{3}}$ (C) $\frac{\gamma h^3}{18}$ (D) $\frac{\gamma h^3}{2}$

- Q.16. A 20 cm cubical box slides on oil (mass density = 800 kg/m^3), over a large plane surface with a steady state velocity of 0.4 m/s . The plane surface is inclined at an angle of 30° with the horizontal plane. The oil film between the block and the plane surface is 0.4 mm thick. The weight of the cubical box is 64 N . The kinematic viscosity of the oil is
- (A) $0.8 \text{ Pa}\cdot\text{s}$ (B) $0.001 \text{ m}^2/\text{s}$ (C) $1.6 \text{ Pa}\cdot\text{s}$ (D) $0.002 \text{ m}^2/\text{s}$

Common Data Questions

Common Data for Questions 17 and 18:

A 60% efficient pump is installed in a pipe of diameter 20 cm to lift water from a sump to an overhead tank at a discharge rate of $\pi/100 \text{ m}^3/\text{s}$. Free surface level in the overhead tank is 20 m higher than the free surface level in the sump. The all-inclusive head losses (not including the lift) in the suction and delivery sides of the pump are 2 times and 28 times the velocity head, respectively.

- Q.17. The power (W) supplied to the pump is
- (A) 10476.2 (B) 6285.7 (C) 6757.1 (D) 11261.9
- Q.18. The suction side of the pump is located $L \text{ m}$ above the free surface level in the sump. The minimum permissible pressure in the pipeline on the suction side of the pump is 8 m of water below atmospheric pressure. The maximum permissible value of L is
- (A) 20.00 (B) 8.00 (C) 7.85 (D) 5.00

Common Data for Questions 19 and 20:

The velocity field of a two-dimensional fluid flow is as follows:

$$u = U_0 \frac{x}{L}, \quad v = -U_0 \frac{y}{L}$$

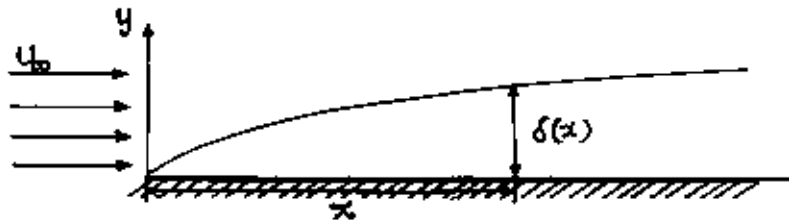
Where, U_0 and L are, respectively, the characteristic velocity and length.

- Q.19. If $L = 0.2 \text{ m}$ and the resultant of total accelerations in x - and y - directions at $(x = L, y = L)$ is 10 m/s^2 , the magnitude of U_0 (m/s) is
- (A) 1.414 (B) 2.38 (C) 1.19 (D) 11.90
- Q.20. The above fluid flow can be described as
- (A) rotational and compressible (B) irrotational and compressible
(C) rotational and incompressible (D) irrotational and incompressible

Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

The boundary layer formation over a flat plate is shown in the figure below. The variation of horizontal velocity (u) with y at any x along the plate in the boundary layer is approximated as: $u = P \sin(Qy) + R$



Q.21. The most acceptable boundary conditions are

- (A) at $y=0$, $u=0$; at $y=\delta$, $u=U_\infty$; at $y=0$, $\frac{du}{dy}=0$
- (B) at $y=0$, $u=U_\infty$; at $y=\delta$, $u=U_\infty$; at $y=0$, $\frac{du}{dy}=0$
- (C) at $y=0$, $u=0$; at $y=\delta$, $u=U_\infty$; at $y=\delta$, $\frac{du}{dy}=0$
- (D) at $y=0$, $u=U_\infty$; at $y=\delta$, $u=U_\infty$; at $y=\delta$, $\frac{du}{dy}=0$

Q.22. Expressions for P , Q and R are

- (A) $P=0$; $Q=0$; $R=0$
- (B) $P=U_\infty$; $Q=0$; $R=0$
- (C) $P=0$; $Q=\frac{\pi}{2\delta}$; $R=U_\infty$
- (D) $P=U_\infty$; $Q=\frac{\pi}{2\delta}$; $R=0$

END OF SECTION - B

C : MATERIALS SCIENCE

Useful Data

Avogadro's number	: $6.023 \times 10^{23} \text{ mol}^{-1}$
Boltzmann's constant (k_B)	: $1.38 \times 10^{-23} \text{ J K}^{-1}$
Electron charge (e)	: $1.602 \times 10^{-19} \text{ C}$
Gas Constant	: $8.314 \text{ J mol}^{-1} \text{ K}^{-1}$
Electron rest mass	: $9.1 \times 10^{-31} \text{ kg}$
Permittivity of vacuum (ϵ_0)	: $8.854 \times 10^{-12} \text{ F m}^{-1}$
Planck's constant (h)	: $6.626 \times 10^{-34} \text{ J s}^{-1}$
Bohr magneton (μ_B)	: $9.27 \times 10^{-24} \text{ Am}^2$
Free space permeability (μ_0)	: $4\pi \times 10^{-7} \text{ H m}^{-1}$
1 J = 6.242×10^{18} eV	
1 eV = 1.602×10^{-19} J	
1 cal = 4.2 J	

Q.1 – Q.9 carry one mark each.

- Q.1. The number of lattice points in an ideal Perovskite unit cell is
 (A) 1 (B) 2 (C) 4 (D) 5
- Q.2. A Frenkel defect is
 (A) a pair of cation and anion vacancy
 (B) a pair of cation interstitial and cation vacancy
 (C) a cation vacancy
 (D) an anion vacancy
- Q.3. The angle between the line vector of a screw dislocation and the Burgers vector is
 (A) 0 degree (B) 45 degrees (C) 60 degrees (D) 90 degrees
- Q.4. The addition of a network modifier to silica
 (A) produces vacancies
 (B) enhances the network structure
 (C) disrupts the network structure
 (D) increases the viscosity
- Q.5. The best semiconductor material for LED in the visible range is
 (A) Si (B) Ge (C) GaAs (D) $\text{GaAs}_{0.6}\text{P}_{0.4}$
- Q.6. A plain carbon steel sample is water-quenched from 900°C to room temperature. Its microstructure will consist of
 (A) pearlite (B) bainite (C) martensite (D) ferrite and pearlite

- Q.7. Graphite at zero Kelvin is a
 (A) good conductor (B) insulator (C) semiconductor (D) semi-metal
- Q.8. A high molecular weight polyethylene has an average molecular weight of 560,000g/mol. Its average degree of polymerization is
 (A) 15,000 (B) 18,660 (C) 19,310 (D) 20,000
- Q.9. In which region of the spectra crystal lattice absorption is very significant
 (A) ultraviolet (B) visible (C) microwave (D) infrared

Q.10 – Q.22 carry two marks each.

- Q.10. Match the properties in Column I with appropriate units in Column II

Column I

- P. viscosity
 Q. diffusivity
 R. charge mobility
 S. fracture toughness

Column II

1. m^2s^{-1}
 2. $Kg\ mm^{-2}$
 3. $Nm^{-2}s$
 4. $m^2\ V^{-1}s^{-1}$
 5. $MPa\ \sqrt{m}$

- (A) P-3, Q-4, R-1, S-2
 (C) P-5, Q-4, R-1, S-2

- (B) P-4, Q-1, R-2, S-5
 (D) P-3, Q-1, R-4, S-5

- Q.11. Match the terms in Column I with the details of phase transformations in Column II (\rightarrow indicates cooling)

Column I

- P. eutectic
 Q. monotectic
 R. eutectoid
 S. peritectic

Column II

1. $L + \alpha \rightarrow \beta$
 2. $\gamma \rightarrow \alpha + \beta$
 3. $L \rightarrow \alpha + \beta$
 4. $\alpha + \beta \rightarrow \gamma$
 5. $L1 \rightarrow \alpha + L2$

- (A) P-1, Q- 5, R- 4, S-3
 (C) P- 3, Q-5, R- 2, S-1

- (B) P- 3, Q- 4, R- 2, S-1
 (D) P- 5, Q- 2, R- 4, S-1

- Q.12. Match the following materials in Column I with appropriate preparation technique given in Column II

Column I

- P. single crystals of laser materials
 Q. highly dense fine grained ceramics
 R. nanocrystalline oxide powders
 S. metallic glasses

Column II

1. sol-gel
 2. melt spinning
 3. Bridgman-Stockbarger
 4. hot pressing
 5. Czochralski

- (A) P- 5, Q- 4, R- 1, S- 2
 (C) P- 2, Q- 1, R- 4, S- 5

- (B) P-3, Q- 5, R- 2, S- 1
 (D) P-5, Q- 2, R- 1, S- 4

Q.13. Match the statement given in **Column I** with the most suitable material given in **Column II**

<u>Column I</u>	<u>Column II</u>
P. biocompatible ceramic material	1. zinc
Q. magnetic material with very high B-H product	2. titanium
R. nonstick coating on aluminum	3. $\text{Nd}_2\text{Fe}_{14}\text{B}$
S. sacrificial coating on steel	4. $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$
	5. $\text{BaFe}_{12}\text{O}_{19}$
	6. polytetrafluoroethylene
	7. polyethylene terephthalate
(A) P-4, Q- 3, R- 7, S- 2	(B) P - 2, Q- 5, R- 6, S- 1
(C) P- 4, Q- 3, R- 6, S- 1	(D) P - 6, Q- 5, R- 7, S- 6

Q.14. A 99% pure copper wire has resistance of 0.1Ω at 0.1 K , and 20Ω at 300 K . For 100% pure, perfect copper wire of the same size, the estimated resistance at 0.1 K and 300 K is

- (A) ~ zero and 19.9Ω (B) ~ zero and 20.1Ω (C) 0.1 and 19.9Ω (D) 0.1 and 20.1Ω

Q.15. A 12.0 mm diameter aluminum alloy test bar is subjected to a load of 110 kN . If the diameter of the bar is 10.5 mm at this load, the true strain will be

- (A) 0.134 (B) 0.306 (C) 0.267 (D) 0.767

Q.16. If the effective magnetic moment of Fe^{3+} is equal to $5 \mu_B$, the magnetic moment in μ_B per formula of $\gamma\text{-Fe}_2\text{O}_3$ (which is inverse spinel with cation defects on the octahedral site) is

- (A) zero (B) 2.5 (C) 5 (D) 10

Common Data Questions

Common Data for Questions 17 and 18:

A unidirectional carbon fiber epoxy matrix composite contains 60 vol % carbon fibers. The density of carbon fiber is 1790 kg/m^3 and that of the epoxy matrix is 1200 kg/m^3 . The tensile moduli of the carbon fiber and the epoxy matrix are 340 GPa and 4.50 GPa respectively.

Q.17. The density of the composite in the units of kg/m^3 is

- (A) 1495 (B) 1554 (C) 1672 (D) 1790

Q.18. The tensile modulus of elasticity of the composite under iso-strain condition is

- (A) 5.5 GPa (B) 11.0 GPa (C) 102.9 GPa (D) 205.8 GPa

Common Data for questions 19 and 20:

For a type II superconductor (at 4 K), the lower critical field (B_{C1}) and thermodynamic critical field (B_C) are respectively 0.001 Tesla and 0.10 Tesla.

Q.19 The upper critical field (B_{C2}) in Tesla is

- (A) 0.10 (B) 0.33 (C) 1.00 (D) 10.00

Q.20 The maximum energy that can be stored per unit volume (Jm^{-3}) in the superconductor is

- (A) 3.979×10^3 (B) 50.00×10^3 (C) 7.96×10^3 (D) 1.326×10^3

Linked Answer Questions:**Statement for linked Answer Questions 21 and 22:**

For Cu metal, the conduction electron density, $n = 8.45 \times 10^{28} \text{ m}^{-3}$.

Q.21 The energy of the electrons at the Fermi level (E_F) is

- (A) 3.50 eV (B) 7.028 eV (C) 8.45 eV (D) 49.0 eV

Q.22 The density of states (DOS), for 1 cm^3 of Cu, at Fermi level per meV is

- (A) 1.20×10^{19} (B) 1.80×10^{19} (C) 1.20×10^{22} (D) 1.81×10^{22}

END OF SECTION – C

D : SOLID MECHANICS

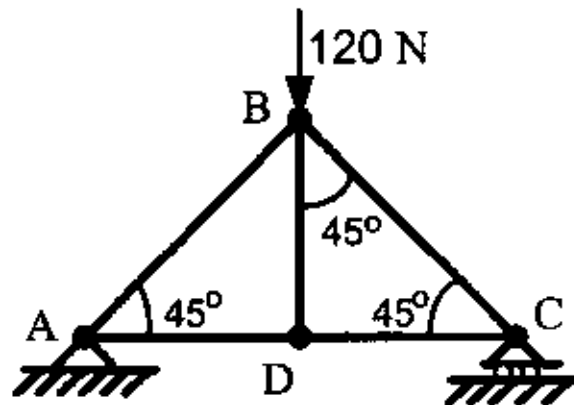
Q.1 – Q.9 carry one mark each.

Q.1. Three forces acting on a particle are given as

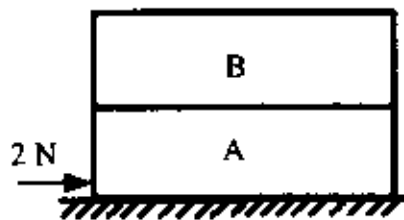
$$F_1 = (5\mathbf{i} + 6\mathbf{j})\text{N}, \quad F_2 = (-\mathbf{i} + 4\mathbf{k})\text{N} \quad \text{and} \quad F_3 = (\mathbf{i} + 6\mathbf{j} + 16\mathbf{k})\text{N},$$

where \mathbf{i} , \mathbf{j} , \mathbf{k} are the unit vectors along Cartesian coordinate axes. Which one of the following statements is true?

- (A) Forces are coplanar and the particle is in equilibrium
 - (B) Forces are coplanar but the particle is not in equilibrium
 - (C) Forces are not coplanar but the particle is in equilibrium
 - (D) Forces are not coplanar and the particle is not in equilibrium
- Q.2. A truss consisting of members AD, DC, AB, BD and BC is subjected to a vertical force of 120 N at joint B as shown in the figure. The members AD, DC and BD are each of 1 meter length. The magnitude of force in the member BD is



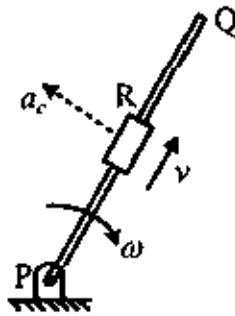
- (A) 0
 - (B) $20\sqrt{2}$ N
 - (C) 40 N
 - (D) 120 N
- Q.3. Two rigid bodies A and B are each weighing 30 N. Body A is kept on a floor and body B is kept on body A as shown in the figure. The coefficient of friction between two bodies, and between body A and the floor is 0.1. If a horizontal force of 2 N is applied on body A, the friction force at the interface of body A and body B will be



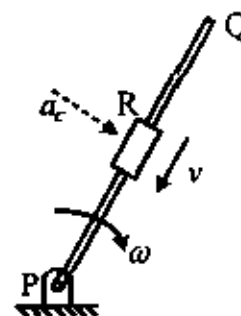
- (A) 0
- (B) 1 N
- (C) 2 N
- (D) 3 N

- Q.4. A rigid link PQ is rotating about a revolute joint at P with a uniform angular velocity ω . A slider R is sliding on the link with a relative velocity v . Which one of the following figures represents the correct direction of the Coriolis acceleration a_c ?

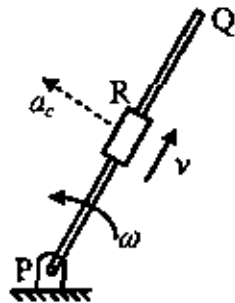
(A)



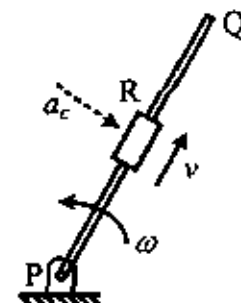
(B)



(C)



(D)



- Q.5. A bullet of mass m having a horizontal velocity of 500 m/s hits a stationary block of mass 6.15 kg. The block breaks into two parts viz. Q (mass of 3 kg) and R (mass of 3.15 kg), with the bullet embedded in R. The parts Q and R travel in the direction of initial velocity of the bullet. If the velocity of Q is 3 m/s and the velocity of R is 5 m/s, the mass of the bullet m is

(A) 5 kg

(B) 0.5 kg

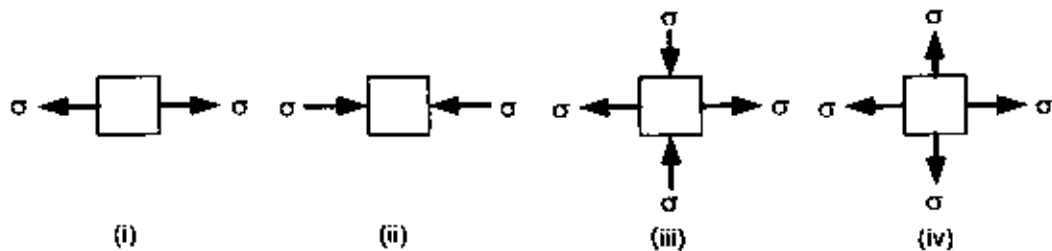
(C) 0.05 kg

(D) 0.005 kg

- Q.6. Two particles, P and Q , are initially at two ends of a circular arc which subtends an angle of 120° at the arc-center. The radius of the arc is r . The particles P and Q are moving along the arc towards each other with constant tangential velocities of v_P and v_Q respectively. The distance travelled by the particle P when it meets the particle Q is

(A) $\frac{2\pi r(v_P + v_Q)}{3 v_P}$ (B) $\frac{2\pi r(v_P + v_Q)}{3 v_Q}$ (C) $\frac{2\pi r v_P}{3(v_P + v_Q)}$ (D) $\frac{2\pi r v_Q}{3(v_P + v_Q)}$

- Q.7. Which one of the following plane states of stress corresponds to Mohr's circle of radius zero?



(A) (i)

(B) (ii)

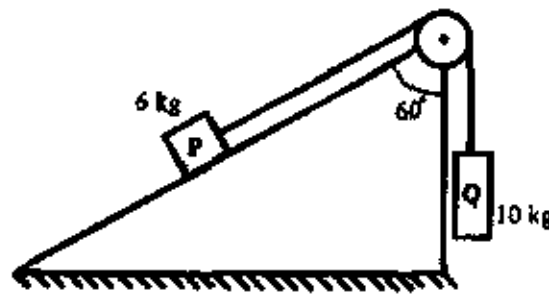
(C) (iii)

(D) (iv)

- Q.8. Maximum shear stress theory for material yielding is known as
 (A) Tresca's criterion (B) von-Mises criterion
 (C) Saint-Venant's theory (D) Rankine's theory
- Q.9. In a cantilever beam of length 2 m, the shear force in newton (N) along the length is given by $V(x) = 5x^2$, where x is the distance in meter measured from the fixed end. The magnitude of the load intensity at the mid-span of the beam is
 (A) 0 (B) 1 N/m (C) 5 N/m (D) 10 N/m

Q.10 – Q.22 carry two marks each.

- Q.10. Two blocks P and Q are connected by a string, which passes over a pulley as shown in the figure. The block P is sliding on an inclined surface. Ignoring the masses of the string and the pulley, the tension in the string is (use gravitational acceleration $g = 9.81 \text{ m/s}^2$ and neglect all friction)



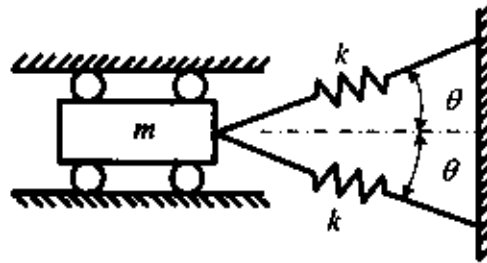
- (A) 55.2 N (B) 62.5 N (C) 74.3 N (D) 86.2 N
- Q.11. A hollow circular shaft of inside diameter 10 mm and outside diameter 20 mm is subjected to a pure symmetric-bending moment of 200 N-m. The magnitude of bending stress at a point in the plane of loading, which is at a distance of 5 mm from the neutral axis, is
 (A) 0 (B) 68.8 MPa (C) 135.8 MPa (D) 271.6 MPa
- Q.12. A stepped circular shaft made of steel is rigidly fixed at two supports A and C as shown in the figure. A torque of 680 N-m is applied on the shaft at point B. The diameter of portion AB is twice that of portion BC. The magnitudes of torque reactions at supports A and C respectively are



- (A) 640 N-m, 40 N-m (B) 40 N-m, 640 N-m
 (C) 340 N-m, 340 N-m (D) 544 N-m, 136 N-m
- Q.13. A thin-walled cylinder with open ends is subjected to uniform internal pressure p alone. The wall thickness is t , internal radius is r and the Young's modulus is E . The increase in radius of the cylinder due to the internal pressure is

- (A) zero (B) $\frac{pr^2}{2Er}$ (C) $\frac{pr^2}{Et}$ (D) $\frac{pr^2}{Et} + r$

- Q.14. A cylindrical steel bar of uniform cross-sectional area is subjected to an axial tensile force P and a torque T . Assuming linear elastic deformation of the bar, the internal strain energy stored in the bar is $(20P^2 + 8T^2) \times 10^{-6}$ N-m. The axial extension of the bar for $P = 10$ N and $T = 16$ N-m is
- (A) 256 μm (B) 400 μm (C) 2000 μm (D) 2048 μm
- Q.15. The buckling load of a slender column clamped at both the ends is 4000 N. The column is subjected to an axial compression. During the course of service, one of the ends gets detached from the clamp and becomes free end. The absolute percentage change in the buckling load due to the change in the end condition is
- (A) 50.00 (B) 75.00 (C) 83.25 (D) 93.75
- Q.16. A spring-mass system shown in the figure is vibrating with very small amplitude. The natural frequency of the system is

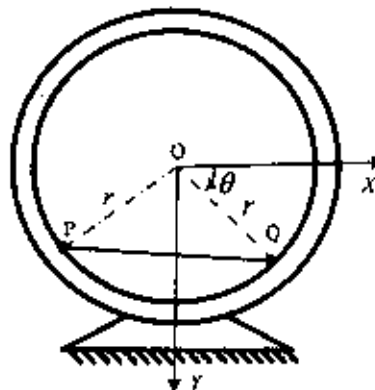


- (A) $\sqrt{\frac{k}{m}}$ (B) $\sqrt{\frac{2k}{m}}$ (C) $\sqrt{\frac{2k \cos \theta}{m}}$ (D) $\sqrt{\frac{2k \cos^2 \theta}{m}}$

Common Data Questions

Common Data for Questions 17 and 18:

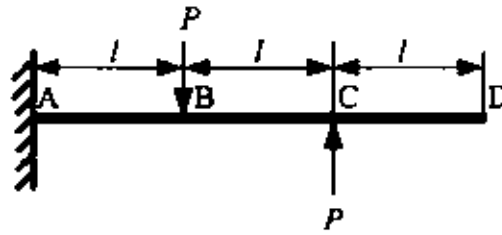
Two particles P and Q are connected by a rigid link of negligible mass. The length of the link PQ is $\sqrt{2}r$. The inner radius of the ring is r and its centre is at O as shown in the figure. The particles are allowed to slide freely with negligible friction on the inner surface of a vertical circular ring. The angle θ , between OQ and horizontal X-axis, is measured from X-axis in the clockwise sense. Gravitational acceleration is g .



- Q.17. Mass of the particles P and Q are m and $2m$, respectively. The link PQ is released from $\theta = 0^\circ$. When the link occupies the horizontal position, the magnitude of velocity of particle P is
- (A) $0.865\sqrt{gr}$ (B) $1.865\sqrt{gr}$ (C) $0.086\sqrt{gr}$ (D) $2.865\sqrt{gr}$
- Q.18. If both the particles P and Q are of the mass m and the link PQ is released from $\theta = 0^\circ$, the maximum possible value of θ during the oscillation of the link is
- (A) 45° (B) 90° (C) 135° (D) 180°

Common Data for Questions 19 and 20:

A cantilever beam of length $3l$ is subjected to two forces each of magnitude P as shown in the figure. The flexural rigidity of the beam is EI . Assume linear elastic material and small deflections.



Q.19. Which one of the following statements is true?

- (A) The magnitude of the bending moment in portion AB is zero
 (B) The magnitude of the bending moment in portion AB is Pl
 (C) The magnitude of the bending moment in portion AB is $2Pl$
 (D) The magnitude of the bending moment in portion AB varies linearly from 0 to Pl

Q.20. The deflection due to bending at point B is

- (A) $\frac{Pl^3}{3EI}$ ↓ (downward) (B) $\frac{Pl^3}{2EI}$ ↑ (upward)
 (C) $\frac{Pl^3}{6EI}$ ↓ (downward) (D) $\frac{Pl^3}{6EI}$ ↑ (upward)

Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

A steel bar of rectangular cross-section is heated uniformly and the rise in the temperature is ΔT . The Young's modulus is E , the Poisson's ratio is ν and the coefficient of thermal expansion is α . The bar is completely restrained in the axial direction and lateral directions.

Q.21. The thermal stress developed in the bar along the axial direction is

- (A) $-\frac{E\alpha\Delta T}{1+2\nu}$ (B) $-E\alpha\Delta T$ (C) $-\frac{E\alpha\Delta T}{1-2\nu}$ (D) $-\frac{E\alpha\Delta T\nu}{1-2\nu}$

Q.22. Assume that the bar is allowed to deform freely in the lateral directions, while keeping the axial direction restrained. The percentage change in the magnitude of axial thermal stress for $\nu = 0.25$ is

- (A) 0 (B) 25 (C) 50 (D) 100

END OF SECTION - D

E : THERMODYNAMICS

Q.1 – Q.9 carry one mark each.

- Q.1. Match the items in **Group I** for their correctness with the corresponding appropriate terms given in **Groups II and III**.

<u>GROUP I</u>	<u>GROUP II</u>	<u>GROUP III</u>	
P: Pressure	1: Path dependent quantity	X: Intensive property	
Q: Heat	2: Path independent quantity	Y: Extensive property	
(A) P,1,X	(B) P,2,X	(C) Q,1,X	(D) Q,2,Y

- Q.2. An object of mass ' m ' in a wooden box having mass ' M ' falls through a height ' h ' under the influence of gravity in vacuum. The work done by the object on the box is

(A) 0 (B) mgh (C) Mgh (D) $(m+M)gh$

- Q.3. An ideal gas is known to obey following relationships: $u = 200 + 0.718T$ and $Pv = 0.287(T + 273)$, where u is specific internal energy (kJ/kg), T is temperature ($^{\circ}\text{C}$), P is pressure (kPa) and v is specific volume (m^3/kg). Specific heat (in kJ/kg-K) at constant pressure is

(A) 0.287 (B) 0.431 (C) 0.718 (D) 1.005

- Q.4. A heat pump, which operates in a cycle, extracts heat energy from the cold reservoir and supplies the same amount of energy to the hot reservoir. Which of the following statements holds for this process?

(A) This process violates both the first and the second law
 (B) This process violates the first law but not the second law
 (C) This process violates the second law but not the first law
 (D) This process does not violate both first and second law

- Q.5. An insulated rigid container having 1 m^3 volume has two compartments having equal volume separated by a thin membrane. Half of the container is filled with helium ($R = 2.08 \text{ kJ/kg-K}$, $C_p = 5.19 \text{ kJ/kg-K}$ and $C_v = 3.11 \text{ kJ/kg-K}$), while the remaining half is empty. Suddenly the membrane ruptures and helium fills the whole volume of the container. Temperature and pressure of helium before rupture are 500°C and 0.1 MPa respectively. The change in the entropy of helium is

(A) 0.019 kJ/K (B) 0.045 kJ/K (C) 0.112 kJ/K (D) 0.675 kJ/K

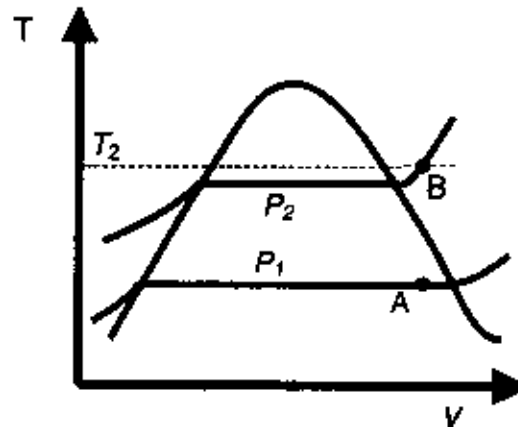
- Q.6. 1 kg of methane is enclosed in a cylinder having volume 6.4 litres and is maintained at a temperature of 13°C and pressure of 18.56 MPa . If molecular weight of methane is 16 kg/kmol (for methane, critical pressure = 4.64 MPa , critical temperature is 191.1 K ; universal gas constant is 8.314 kJ/kmol-K), compressibility factor, Z , is

(A) 0.375 (B) 0.8 (C) 1.25 (D) 2.66

- Q.7. $\left(\frac{\partial P}{\partial T}\right)_s$ is equal to

(A) $\left(\frac{\partial S}{\partial V}\right)_p$ (B) $-\left(\frac{\partial S}{\partial V}\right)_p$ (C) $\left(\frac{\partial S}{\partial V}\right)_T$ (D) $-\left(\frac{\partial S}{\partial V}\right)_T$

- Q.8. A rigid spherical vessel contains 1 kg of wet steam of quality x at pressure P_1 . This is shown by point A on the $T-v$ diagram. Heat is transferred to the vessel to form superheated steam at pressure P_2 and temperature T_2 as shown by point B.



Specific enthalpy and specific internal energy corresponding to the saturated water and saturated vapour at pressures P_1 and P_2 as well as at points A and B are given by

Property	Saturated liquid		Saturated vapour		Point A	Point B
	Pressure P_1	Pressure P_2	Pressure P_1	Pressure P_2		
Specific Enthalpy (kJ/kg)	h_{f1}	h_{f2}	h_{g1}	h_{g2}	h_A	h_B
Specific internal energy (kJ/kg)	u_{f1}	u_{f2}	u_{g1}	u_{g2}	u_A	u_B

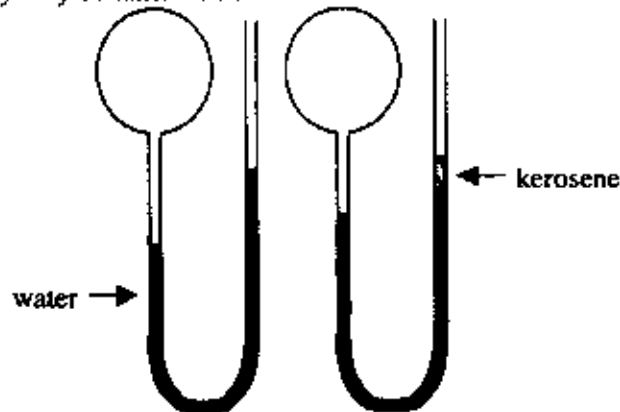
Heat transferred to the steam is

- (A) $h_B - h_A$ (B) $h_B - h_{f1}$ (C) $u_B - u_A$ (D) $u_B - u_{f1}$
- Q.9. Determine the correctness or otherwise of the following Assertion [a] and the Reason [r]
Assertion: Carnot cycle is not used in vapour power cycles.
Reason: Pumping of a two phase mixture is difficult
- (A) Both [a] and [r] are true and [r] is a reason for [a]
 (B) Both [a] and [r] are true but [r] is NOT a reason for [a]
 (C) [a] is true but [r] is false
 (D) Both [a] and [r] are false

Q.10 – Q.22 carry two marks each.

- Q.10. A slab of mass 2000 kg and volume 0.2 m^3 is raised slowly in the vertical direction by a massless rope through a height of 2 m from the bottom of a fresh-water lake. Depth of water in the lake is 10 m. If the density of fresh water is 1000 kg/m^3 and acceleration due to gravity is 10 m/s^2 , work done by water on the block is
- (A) - 40 kJ (B) 0 kJ (C) 4 kJ (D) + 40 kJ

- Q.11. A bulb is connected to a U-tube with long vertical column as shown in the figure below. Cross-sectional area of both sides of the U-tube is 3 cm^2 . Water is poured in the right side open column of the U-tube such that the trapped air in the left column and the bulb above water has a volume of 1000 cc and a pressure of 105 kPa . Ambient pressure is 100 kPa . Density of water is 1000 kg/m^3 . Acceleration due to gravity may be taken as 10 m/s^2 .



When 90 cc of kerosene oil (specific gravity = 0.7) is poured on the right side of the U-tube, water level in the left column rises by 10 cm . The pressure in the bulb becomes

- (A) 105.1 kPa (B) 108.3 kPa (C) 112.4 kPa (D) 119.7 kPa
- Q.12.
- Air ($R = 287 \text{ J/kg-K}$, $C_p = 1005 \text{ J/kg-K}$ and $\gamma = 1.4$) flows sequentially through a compressor, a heater and a turbine as shown in the figure. Volume flow rate of air coming out from the compressor is $2.33 \text{ m}^3/\text{s}$ when pressure and temperature are 276 kPa and $43 \text{ }^\circ\text{C}$ respectively. Air is then heated at same pressure to $430 \text{ }^\circ\text{C}$ in a heater. From heater, air flows through a turbine which produces 1860 kW of power. Heat loss from turbine to the surrounding is 90 kW . Air temperature at the turbine exit is
- (A) $156.4 \text{ }^\circ\text{C}$ (B) $181.6 \text{ }^\circ\text{C}$ (C) $223.7 \text{ }^\circ\text{C}$ (D) $678.4 \text{ }^\circ\text{C}$
- Q.13. Availability per unit mass associated with air ($R = 287 \text{ J/kg-K}$, $C_p = 1005 \text{ J/kg-K}$ and $\gamma = 1.4$) flowing from a reservoir at 10 atm and $25 \text{ }^\circ\text{C}$ when atmosphere is at 1 atm and $25 \text{ }^\circ\text{C}$ is (Neglect changes in the potential and the kinetic energies)
- (A) 98.4 kJ/kg (B) 196.9 kJ/kg (C) 492.3 kJ/kg (D) 689.14 kJ/kg
- Q.14. In an air standard Diesel cycle, compression ratio is 14 . At the beginning of compression of air ($R = 287 \text{ J/kg-K}$, $C_p = 1005 \text{ J/kg-K}$ and $\gamma = 1.4$) the temperature is $27 \text{ }^\circ\text{C}$ and the pressure is 1 bar . If the specific volume after heat addition is two times the specific volume after compression, heat added (in kJ per kg of air) at constant pressure is
- (A) 555.5 (B) 622.7 (C) 767.8 (D) 866.4
- Q.15. A mixture of Freon and air is supplied for cleaning a chamber. The mixture contains 70% by volume of air and 30% by volume of Freon. Specific heat ratios for Freon and air are 1.1 and 1.4 respectively. Molecular mass of Freon is 200 g/mole and that of air is 30 g/mole . Temperature of gas is 300 K . If, universal gas constant is 8.314 J/mole-K , specific heat ratio of the mixture is
- (A) 1.16 (B) 1.21 (C) 1.25 (D) 1.31

- Q.16. Air-water vapour mixture having 100% relative humidity at 50°C is heated isobarically to 100°C in a closed system. If saturation pressure at 50°C is 12.352 kPa and at 100°C is 101.42 kPa, final relative humidity is
- (A) 0% (B) 8.2% (C) 12.2% (D) 100%

Common Data Questions

Common Data for Questions 17 and 18:

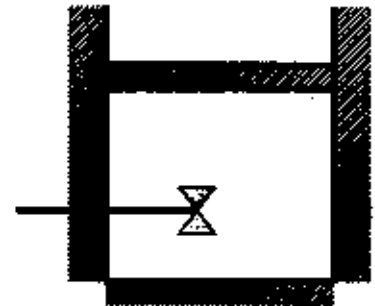
Saturated vapour enters a turbine at a pressure of 2 bar and leaves the turbine at a pressure of 0.1 bar and a quality of 0.9. After condensation, saturated water at 0.1 bar is pumped into the boiler where it receives heat at a constant pressure of 2 bar. The pumping process can be considered to be isentropic. Use the data given in the following table to answer Q17 and Q18.

Pressure (bar)	Saturation temperature (°C)	Specific volume (m ³ /kg)		Specific enthalpy (kJ/kg)		Specific entropy (kJ/kg-K)	
		v_f	v_g	h_f	h_g	s_f	s_g
2	120.23	0.001061	0.8857	504.68	2706.6	1.530	7.1271
0.1	45.81	0.001010	14.674	191.81	2584.6	0.6492	8.1501

- Q.17. Work done by the turbine is
- (A) 276.5 kJ/kg (B) 303.9 kJ/kg (C) 335.8 kJ/kg (D) 361.3 kJ/kg
- Q.18. Heat addition in the boiler is
- (A) 2000.9 kJ/kg (B) 2514.6 kJ/kg (C) 3028.2 kJ/kg (D) 3554.5 kJ/kg

Common Data for Questions 19 and 20:

An insulated piston-cylinder assembly having a paddle wheel, as shown in the adjacent figure, contains air ($R = 287 \text{ J/kg-K}$, and $C_p = 718 \text{ J/kg-K}$) of mass 4 kg. Both piston and paddle wheel can be considered as insulated and massless. Temperature and pressure of air inside the cylinder are 300 K and 100 kPa respectively. Ambient pressure is 100 kPa.

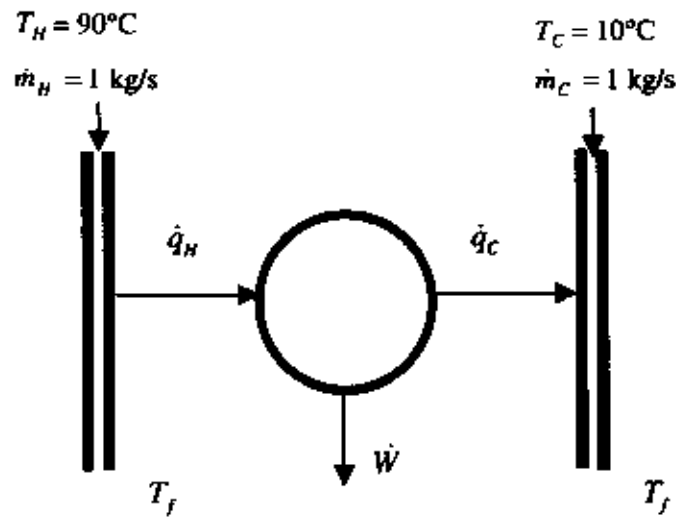


- Q.19. If the piston is locked in the fixed position and the paddle wheel delivers 75 kJ of work, final air temperature is
- (A) 300 K (B) 318.7 K (C) 320.6 K (D) 326.1 K
- Q.20. If the piston is free to slide without any friction when the paddle wheel delivers 75 kJ of work, final temperature of air in the cylinder is
- (A) 305.2 K (B) 309.3 K (C) 312.6 K (D) 318.7 K

Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

In a process industry, two different streams of water (to be considered incompressible) are available at 10°C and 90°C as shown in the figure. Mass flow rates of both the streams are 1 kg/s . Rather than wasting these resources, it is desired to connect a reversible Carnot engine that will continuously extract heat from the hot stream and supply part of it to the cold stream such that the exit temperature of both the streams T_f is identical. Heat capacity of water is $4.18\text{ kJ/kg}\cdot\text{K}$.



Q.21. Value of T_f is

- (A) 30°C (B) 42.5°C (C) 47.5°C (D) 50°C

Q.22. Work output \dot{W} is:

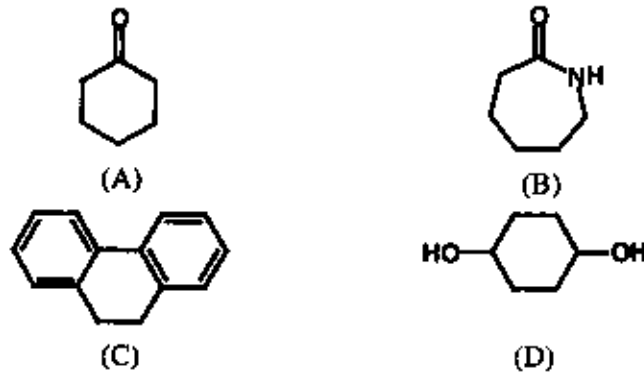
- (A) 20.8 kW (B) 42.5 kW (C) 63 kW (D) 167 kW

END OF SECTION – E

F : POLYMER SCIENCE AND ENGINEERING

Q.1 – Q.9 carry one mark each.

Q.1. Which one of the following molecules undergoes ring opening polymerization?



Q.2. Out of the following polymers, which one shows the highest melting temperature?

- | | |
|----------------------------------|-----------------------------------|
| (A) Poly(ethylene terephthalate) | (B) Poly(propylene terephthalate) |
| (C) Poly(butylene terephthalate) | (D) Poly(hexylene terephthalate) |

Q.3. Which one of the following reagents is used to prevent coagulation of natural rubber latex?

- | | |
|----------------------|---------------------|
| (A) Ammonia | (B) Acetic acid |
| (C) Toluyl mercaptan | (D) Sodium chloride |

Q.4. From the following four groups of polymers, identify the group in which all four polymers are semicrystalline

- | | |
|------------------------------|-----------------------------|
| (A) HDPE, PP, PS, UF | (B) PET, PVC, PF, ABS |
| (C) Nylon 6, EPDM, PMMA, SBR | (D) Nylon 66, PP, HDPE, PET |

Q.5. If η represents viscosity of polymer solution and η_0 represents viscosity of pure solvent, then the specific viscosity (η_{sp}) of the polymer solution is expressed as

- | | | | |
|---------------------------|-------------------------------|-------------------------------|---------------------------|
| (A) $\frac{\eta}{\eta_0}$ | (B) $\frac{\eta}{\eta_0} - 1$ | (C) $\frac{\eta_0}{\eta} - 1$ | (D) $\frac{\eta_0}{\eta}$ |
|---------------------------|-------------------------------|-------------------------------|---------------------------|

Q.6. A polymer blend is developed by mixing

- | | |
|------------------------------------|--------------------------------|
| (A) A polymer and a monomer | (B) A polymer and a stabilizer |
| (C) A polymer with another polymer | (D) A polymer and a filler |

Q.7. In shear deformation of a polymer melt, the unit of shear rate is

- | | | | |
|-------------------|-------------------|-----------------|----------------|
| (A) m^3sec^{-1} | (B) m^2sec^{-1} | (C) $msec^{-1}$ | (D) sec^{-1} |
|-------------------|-------------------|-----------------|----------------|

Q.8. A rubber compound is made by mixing functional additives with the rubber using

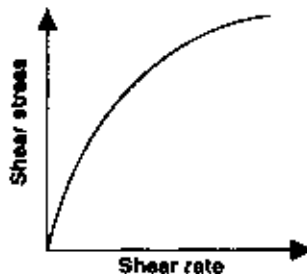
- | | |
|-------------------------|---------------------------------|
| (A) Two-roll mill | (B) Compression molding machine |
| (C) Three-roll calender | (D) Thermoforming machine |

Q.9. The group of polymers consisting of LDPE, PP, PS and PVC is best categorized as

- | | |
|--------------------------|----------------------------|
| (A) Engineering polymers | (B) Biodegradable polymers |
| (C) Commodity polymers | (D) Natural polymers |

Q.10 – Q.22 carry two marks each.

- Q.10. A small molecule is eliminated as a byproduct during the synthesis of
 (A) Polycaprolactone (B) Poly(ethylene terephthalate)
 (C) Styrene butadiene copolymer (D) Polytetrafluoroethylene
- Q.11. For free radical copolymerization of monomers M_1 and M_2 , if the reactivity ratios r_1 and r_2 are both found to be zero, then the resulting copolymer is
 (A) Random (B) Branched
 (C) Block (D) Alternating
- Q.12. Pair each item in **Column I** with the appropriate one in **Column II**
- | <u>Column I</u> | <u>Column II</u> |
|--------------------------|----------------------|
| P. Shampoo bottles | 1. Injection molding |
| Q. Overhead tank | 2. Extrusion |
| R. Helmet | 3. Blow molding |
| S. Insulation for cables | 4. Rotomolding |
- (A) P-1; Q-2; R-4; S-3 (B) P-2; Q-1; R-3; S-4
 (C) P-3; Q-4; R-1; S-2 (D) P-4; Q-3; R-2; S-1
- Q.13. Toughness of a plastic material can be judged from the area under the stress-strain curve obtained from tensile test. The plastic having the highest toughness exhibits
 (A) High tensile strength and low elongation (B) Low tensile strength and high elongation
 (C) High tensile strength and high elongation (D) Low tensile strength and low elongation
- Q.14. Match the following additives for plastics with their respective functions
- | <u>Additives</u> | <u>Functions</u> |
|----------------------|-------------------|
| P. Iron oxide | 1. Blowing agent |
| Q. Azodicarbonamide | 2. Coloring agent |
| R. Phenyl salicylate | 3. Filler |
| S. Calcium carbonate | 4. UV stabilizer |
- (A) P-1; Q-2; R-3; S-4 (B) P-2; Q-1; R-4; S-3
 (C) P-3; Q-4; R-1; S-2 (D) P-4; Q-3; R-2; S-1
- Q.15. The volume fraction of epoxy resin in a glass fibre/epoxy composite is 0.48. The densities of glass fibre and composite are 2540 kg/m^3 and 1950 kg/m^3 , respectively. The weight fraction of the fibre in the composite is
 (A) 0.68 (B) 0.52 (C) 0.48 (D) 0.32
- Q.16. The change of shear stress with shear rate of a polymer melt as shown in the figure below indicates



- (A) Viscosity increase with increase in shear rate
 (B) Viscosity decrease with increase in shear rate
 (C) Viscosity remaining independent of shear rate
 (D) Viscosity oscillation with increase in shear rate

Common Data Questions

Common Data for Questions 17 and 18:

For polyesterification of $\text{HO}-(\text{CH}_2)_4-\text{COOH}$, the number average degree of polymerization, \overline{X}_n , is related to the stoichiometric imbalance r between the functional groups and the extent of polymerization p by the equation

$$\overline{X}_n = \frac{1+r}{1+r-2rp}$$

Q.17. For 100% polyesterification, the \overline{X}_n will be

- (A) 100 (B) 1000 (C) 10000 (D) ∞

Q.18. The percentage conversion of functional groups required to obtain the polyester with a molecular weight of 24000 g/mol will be

- (A) 99 (B) 96 (C) 93 (D) 90

Common Data for Questions 19 and 20:

The glass transition temperatures of PVC, plasticized PVC and nitrile rubber are 81 °C, -3 °C and -50 °C, respectively. For making a plastic raincoat, 40 mass percent of polymeric plasticizer is added to PVC.

Q.19. The glass transition temperature of the polymeric plasticizer will be

- (A) -84 °C (B) -74 °C (C) 74 °C (D) 84 °C

Q.20. If the polymeric plasticizer is replaced by nitrile rubber to make the same raincoat, the mass percent of rubber to be blended with PVC is

- (A) 40 (B) 47 (C) 53 (D) 60

Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

A polydisperse polymer consists of the following three different fractions

	Fraction I	Fraction II	Fraction III
Mass of polymer (%)	30	20	50
Molecular weight (g/mol)	30,000	80,000	150,000

Q.21. The number average molecular weight, \overline{M}_n (g/mol) of the polymer is

- (A) 1.02×10^5 (B) 0.99×10^5
 (C) 0.63×10^5 (D) 0.55×10^5

Q.22. The polydispersity index of the polymer is

- (A) 2.59 (B) 1.87 (C) 1.72 (D) 1.59

END OF SECTION - F

- Q.6. Which two of the following statements are NOT the objectives of homogenization of milk?
- Counteracting segregation for the most part of creaming thus avoiding sedimentation or phase separation
 - Arresting rancidity of fat globules in milk
 - Increasing fluidity of milk by lowering viscosity
 - Improving the colour of the milk (more whitish)
 - Improving milk stability by preventing partial coalescence of fat globules

(A) i and ii (B) ii and iii (C) iii and iv (D) iv and v

- Q.7. Shelf-life of fish can be extended by chilling as it

(A) reduces chemical activity of food constituents and increases biochemical activity
 (B) reduces water activity and increases biochemical reaction rate
 (C) reduces chemical and biochemical reactions in fish cells
 (D) destroys pathogenic microbes

- Q.8. Major spoilage organisms of poultry meat at low temperatures are

(A) *Candida* and *Staphylococcus* (B) *Torula* and *Clostridium*
 (C) *Pseudomonas* and *Acinetobacter* (D) *Flavobacteria* and *Lactobacillus*

- Q.9. The appropriate explanation for spoilage of egg, stored at low temperature, might be due to:

(A) Shell of egg is porous and only fungal hyphae can enter and contaminate the egg liquid
 (B) Shells are non-porous and the spoilage is mainly attributed to chemical decomposition
 (C) Shell of egg is porous and microorganisms contaminating the shell penetrate it and cause the spoilage
 (D) Eggs are contaminated before they are laid by hen

Q.10 – Q.22 carry two marks each.

- Q.10. Two faces of a metal plate having thermal conductivity $17 \text{ W m}^{-1} \text{ K}^{-1}$ and thickness 10 mm are maintained at 80°C and 100°C . If the thickness of the plate is increased by 20% and the temperature of the hotter face is increased to 120°C , then the percent increase in heat flux under steady state heat transfer is

(A) 20.67 (B) 40.00 (C) 59.99 (D) 66.67

- Q.11. Match the items in Group I with the most appropriate items in Group II

<u>Group I</u>	<u>Group II</u>
P. Freeze concentration	1. Triple point of water
Q. Reverse osmosis	2. Heat transfer by conduction
R. Drum drying	3. Eutectic point
S. Freeze drying	4. Radiation heat transfer
	5. Concentration polarization

(A) P-4, Q-5, R-2, S-1

(B) P-3, Q-2, R-5, S-1

(C) P-3, Q-5, R-2, S-1

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

- Q.12. Match the following items in Group I and Group II in relation to nutritional requirement of human body

Group I

- P. Calcium and Phosphorus
 Q. Vitamin D
 R. Manganese and Chromium
 S. Vitamin K

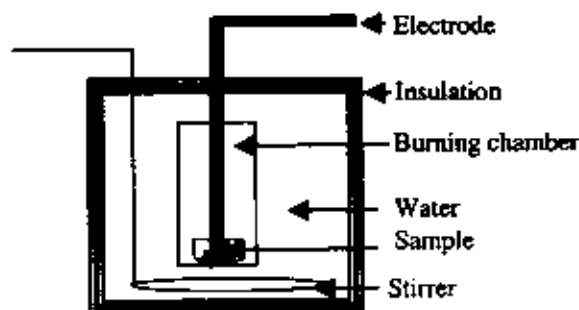
Group II

1. Elements not needed in diet
2. Promotes absorption of iron
3. Elements that are required in small quantities
4. Promotes the absorption of Calcium
5. Essential for normal clotting of blood
6. Elements that are required in large quantities

- (A) P-6, Q-2, R-1, S-5
 (C) P-6, Q-4, R-3, S-5

- (B) P-5, Q-2, R-6, S-4
 (D) P-2, Q-5, R-1, S-4

- Q.13. 9.5 g of corn flakes containing 5% moisture (wet basis) is oxidized completely to CO_2 and H_2O by ignition in a Bomb Calorimeter (as shown in the figure). The combustion increases the temperature of 2500 g of water from 15°C to 27°C . Assume that the heat capacity and latent heat of vaporization of water are $4.187 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and 2257 kJ kg^{-1} , respectively. Neglect any sensible heat gain by water vapour. The calorific value of the flake is



- (A) 18.28 kJ g^{-1} (4.37 kcal g^{-1})
 (C) 14.04 kJ g^{-1} (3.36 kcal g^{-1})

- (B) 9.79 kJ g^{-1} (2.34 kcal g^{-1})
 (D) 22.43 kJ g^{-1} (5.36 kcal g^{-1})

- Q.14. Match the following items in Group I and Group II in relation to permitted food additives/preservatives in India

Group I

- P. Jelly
 Q. Edible oil
 R. Meat flavour enhancer
 S. Bread

Group II

1. Calcium propionate
2. Monosodium glutamate
3. Sodium benzoate
4. Butylated hydroxylated anisole
5. Tricalcium silicate

- (A) P-3, Q-4, R-2, S-1
 (C) P-1, Q-3, R-4, S-5

- (B) P-5, Q-3, R-2, S-4
 (D) P-2, Q-3, R-1, S-5

- Q.15. Preparation of sweet coated breakfast cereals like corn flakes includes several major processing steps, like

- P: Soaking in water followed by steaming of corn grits
 Q: Coating of sugar followed by drying of flakes
 R: Breaking the whole corn into large grits
 S: Flaking of cooked grits
 T: Packaging of finished product
 U: Toasting of flakes
 V: Cleaning of whole corn

The correct sequence for the preparation of sugar coated corn flake is

- (A) $V \rightarrow U \rightarrow Q \rightarrow P \rightarrow S \rightarrow R \rightarrow T$
 (B) $V \rightarrow R \rightarrow S \rightarrow P \rightarrow U \rightarrow Q \rightarrow T$
 (C) $V \rightarrow U \rightarrow P \rightarrow Q \rightarrow S \rightarrow R \rightarrow T$
 (D) $V \rightarrow R \rightarrow P \rightarrow S \rightarrow U \rightarrow Q \rightarrow T$

- Q.16. A bacterial strain isolated from meat is inoculated in a growth medium at a cell density of 2×10^5 cells/ml. Then, 0.2 ml of the culture broth is withdrawn immediately and mixed with 0.8 ml of sterile saline. This sample is diluted by mixing 0.1 ml of it with 99.9 ml sterile water. Then 0.1 ml of this diluted solution is spread on appropriate nutrient agar plate. The number of colonies expected on the agar plate is
- (A) 4 (B) 40 (C) 400 (D) 4000

Common Data Questions

Common Data for Questions 17 and 18:

Water at 20°C is pumped from a base tank to an elevated tank, 15 m above the base tank. Water flows at a rate of $5.0 \times 10^{-3} \text{ m}^3 \text{ s}^{-1}$ through a pipe having internal diameter of 0.1023 m. Frictional energy loss in the pipe is 6.837 J kg^{-1} . The pump has an efficiency of 65%. Density and viscosity of water are 998.2 kg m^{-3} and $1.005 \times 10^{-3} \text{ Pa s}$, respectively.

- Q.17. Reynolds number for water flowing through the pipe is
 (A) 5.286×10^4 (B) 6.180×10^4
 (C) 2.285×10^4 (D) 1.252×10^5
- Q.18. Power needed for pumping water in kW is
 (A) 1.182 (B) 3.334 (C) 0.985 (D) 2.226

Common Data for Questions 19 and 20:

True density and bulk density of rice grain are 1230 kg m^{-3} and 740 kg m^{-3} , respectively, and that of wheat grain are 1360 kg m^{-3} and 650 kg m^{-3} , respectively.

- Q.19. The void fractions of a bed of rice and that of wheat are respectively,
 (A) 0.331 and 0.546 (B) 0.662 and 0.261 (C) 0.398 and 0.480 (D) 0.398 and 0.522
- Q.20. Assume the bulk volume for the mixture of two grains follows additive rule. If the bulk density of a *mixture* of rice and wheat is 700 kg m^{-3} , weight percentage of wheat in the mixture is nearly
 (A) 41 (B) 50 (C) 24 (D) 36

Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

D_0 value of a bacterium is determined by using two thin walled glass capillary tubes filled with same bacterial suspension in distilled water. The sealed capillaries are dipped in an oil bath maintained at 121°C and kept for 60 s and 135 s, respectively. These capillaries are cooled immediately in ice water. Number of survivals remained in the respective tubes are 2000 and 300.

- Q.21. D_0 value (in minutes) of the bacterium is
 (A) 1.32 (B) 0.52 (C) 1.52 (D) 2.52
- Q.22. The processing time (in minutes) to kill 99.999% of the bacteria in any food at 121°C will be
 (A) 7.60 (B) 6.60 (C) 12.62 (D) 2.60

END OF THE QUESTION PAPER

Space for Rough Work

Space for Rough Work

Space for Rough Work

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