Atmospheric and Oceanic Sciences (XE-H)

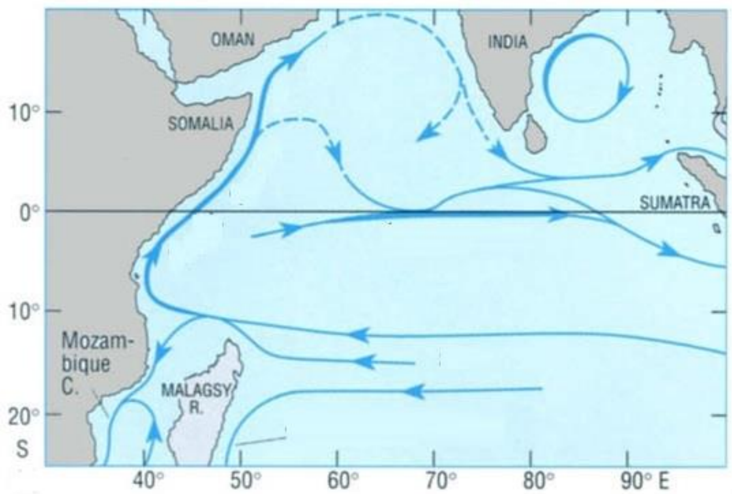
Q.1 – Q.5 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**Western Boundary Current in the ocean is primarily due to**
(A)	Ekman pumping.
(B)	rotation of the earth.
(C)	river water forcing.
(D)	ocean floor topography.

Q.2	**The relevant nondimensional number in deciding deepening of the thermocline driven by instability of ocean currents is**
(A)	Rossby number.
(B)	Reynolds number.
(C)	Richardson number.
(D)	Ekman number.

Q.3	**During July-August, the highest number of monsoon low pressure systems form over**
(A)	Arabian Sea.
(B)	Bay of Bengal.
(C)	South India.
(D)	Himalayan foothills.

Q.4	**CO_2 concentration in the Earth's atmosphere is increasing because 50% of the annual anthropogenic emissions are retained in the atmosphere. If nations agree to reduce annual CO_2 emissions by one Giga ton every year starting from 2021, then in which year will the CO_2 concentration in the atmosphere stop rising due to anthropogenic emissions?** **Take the anthropogenic CO_2 emissions in 2020 as 40 Giga tons.**
(A)	2020
(B)	2050
(C)	2060
(D)	2100

Q.5	**The figure shows a schematic of Indian Ocean surface circulation. This pattern is representative of the circulation in which month of the year?** 
(A)	January
(B)	July
(C)	May
(D)	November

Q. 6–Q. 7 Multiple Select Question (MSQ), Carry ONE mark each (no negative marks).

Q.6	**Over the open ocean, if the air sea temperature difference is zero, then which of the following statements is/are always true?**
(A)	Sensible heat flux is zero.
(B)	Latent heat flux is zero.
(C)	Momentum flux is zero.
(D)	Net energy flux is zero.

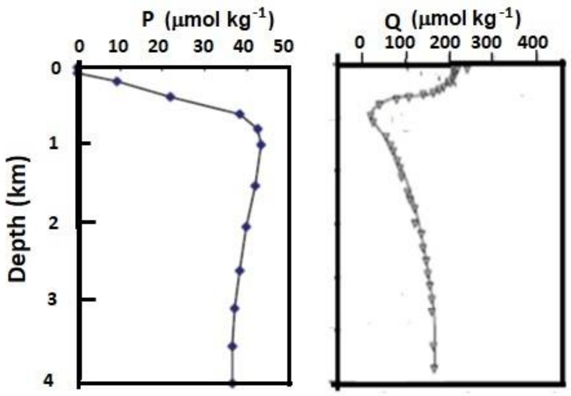
Q.7	**The psychrometric equation, which is useful in measuring humidity, is derived assuming the following process(es).**
(A)	Isobaric process
(B)	Isothermal process
(C)	Adiabatic process
(D)	Isentropic process

Q.8 – Q.9 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

Q.8	**The water vapour mixing ratio of an air parcel increases from 10 g kg^{-1} to 20 g kg^{-1} at a constant pressure of 1010 hPa and temperature of 300 K. The change in virtual temperature is _____ K (to one decimal place).**

Q.9	**The Ekman layer thickness, if turbulent diffusivity is 0.01 m^2 s^{-1}, is _____ m. Take Coriolis parameter to be 10^{-4} s^{-1}. Calculate to the nearest integer.**

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

Q. 10	**The figure shows vertical variation of two chemicals P and Q measured in the Pacific Ocean. Identify the correct combination showing (P, Q) pair from the list below.** 
(A)	Oxygen, Nitrate
(B)	Oxygen, Neon
(C)	Nitrate, Oxygen
(D)	Neon, Nitrate

Q. 11 –Q. 15 Multiple Select Question (MSQ), Carry TWO marks each (no negative marks).

Q. 11	**Consider tropical high-level clouds and low-level stratus clouds with bases at 12 km and 1 km above the surface of the Earth, respectively. Which of the following statement(s) is/are correct?**
(A)	High clouds are composed of ice crystals.
(B)	High clouds have a larger albedo than low clouds.
(C)	High clouds have a net warming effect on climate.
(D)	Low clouds have a net warming effect on climate.

Q. 12	**Which of the following statement(s) is/are correct in the context of Sverdrup transport?**
(A)	Sverdrup transport is always in the meridional direction.
(B)	Sverdrup transport is always orthogonal to the wind direction.
(C)	Sverdrup transport depends on the variation of the Coriolis parameter.
(D)	Sverdrup transport is only due to ageostrophic currents.

Q.13	**Which of the following statement(s) is/are true with regard to the Hadley circulation?**
(A)	The ascending branch is narrower than its descending branch.
(B)	Thunderstorms are more frequent in the subsiding region of the Hadley cell than in its ascending region.
(C)	The lower level winds between the ascending and descending branches of the Hadley cell are north-westerly.
(D)	Latent heat is transported from the subsiding to the ascending region of the Hadley cell.

Q.14	**Which of the following statement(s) is/are true about the ocean circulation?**
(A)	Large-scale ocean surface currents are driven by winds.
(B)	Cold, dense and salty water forms in the North Atlantic Ocean.
(C)	Upwelling currents bring warm nutrient deficient water to the surface of the ocean.
(D)	Thermohaline circulation does not transport energy in the meridional direction.

Q. 15	**Coral reefs are found primarily in tropical and subtropical shallow seawaters. Which of the following statement(s) is/are correct?**
(A)	Corals require plenty of sunlight for photosynthesis and sunlight is abundant in the tropical and subtropical latitudes.
(B)	Corals grow optimally in seawater unsaturated in carbonate, which is found only in the tropical and subtropical oceans.
(C)	Corals grow optimally in fresh low-salinity water.
(D)	Corals grow optimally in water temperatures between 23^{o}C and 29^{o}C.

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

Q. 16	**In an incompressible fluid, the horizontal divergence is $-0.01\ s^{-1}$. Then, the vertical velocity at 50 m above a flat surface is ____ $m\ s^{-1}$. Round off to one decimal place.**

Q. 17	**In an atmosphere, temperature (T) decreases linearly with height above the ground (z), i.e., $T(z) = T_o - \gamma z$, where γ is a constant. Surface pressure is 900 hPa. If the atmosphere is at rest, then the value of z at which the pressure decreases to half of that at the surface is _____ m (round off to the nearest integer).** **Take acceleration due to gravity $g = 10\ m\ s^{-2}$, gas constant $R = 300\ J\ kg^{-1}\ K^{-1}$, $T_o = 300$ K and $\gamma = 1/30\ K\ m^{-1}$, and the atmosphere behaves as an ideal gas.**

Q. 18	**In a local Cartesian system, a zonal jet has a form $u(y) = u_o (1 - y^2/L^2)$, for $-L \le y \le L$. Here, y is the meridional distance measured from the axis of the jet and is positive northward. The vertical component of vorticity of this flow at y=L/2 is _____ s^{-1}. Round off to 3 decimal places.** **Take $u_o = 50\ m\ s^{-1}$ and L = 5 km.**

Q.19	**An eastward flow with a speed of 10 $m\ s^{-1}$ goes from station M to station N, which are separated by a distance of 1 km. The temperature at station N is always higher than that at station M by 10 K. The absolute change in temperature due to advection at the mid-point between the stations in 50 s is _________ K (round off to nearest integer).**

Q.20	**Suppose, because of the doubling of atmospheric CO_2 concentration, an ocean water column receives an additional net energy input of 4 Wm^{-2}. If the entire water column of depth 1 km heats up uniformly, the water temperature will increase by 1 K in ____ years (round off to the nearest integer).** **Assume all the additional heat added is retained and not lost. Take density of seawater = 1000 $kg\ m^{-3}$; specific heat capacity of seawater = 4200 $J\ kg^{-1}\ K^{-1}$.**

Q.21	**Consider a layer of atmosphere between 5 and 6 km height. The downwelling longwave radiation at 5 and 6 km is 240 and 230 Wm^{-2}, respectively. The upwelling longwave radiation at these heights is 260 and 240 Wm^{-2}, respectively. The longwave heating rate in this layer is___ K per day. (Round off to one decimal place.)** **Take the average density of air in this layer to be 0.5 kg m^{-3}; Specific heat capacity of air at constant pressure = 1000 J kg^{-1} K^{-1}.**

Q.22	**A spherical asteroid, revolving around the sun in a circular orbit, is in radiative balance. Suddenly, the asteroid enters the shadow of a planet and solar radiation is cut off. Assuming that the asteroid emits as a blackbody in the longwave regime, the time taken to reduce the average temperature of the asteroid by 0.5 K is ______ seconds (round off to the nearest integer). Ignore the temporal change in radiation emitted by the asteroid during this cooling period.** **The physical properties of the asteroid are: diameter = 2 m, density = 3000 kg m^{-3}, specific heat = 2000 J kg^{-1} K^{-1} and albedo = 0.8 in shortwave radiation. Take the solar constant = 500 W m^{-2}, Stefan-Boltzmann constant = 5.67 x 10^{-8} W m^{-2} K^{-4}.**

END OF THE QUESTION PAPER

Food Technology (XE-G)

Q.1 – Q.9 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**In a typical bacterial growth curve, the first order kinetics for growth rate is observed in**
(A)	Lag phase
(B)	Log phase
(C)	Stationary phase
(D)	Death phase

Q.2	**Which one of the following microorganism is NOT a causative agent for food borne diseases?**
(A)	*Campylobacter jejuni*
(B)	*Clostridium perfingens*
(C)	Norovirus
(D)	*Borrelia burgdorferi*

Q.3	**Which of the followings is NOT a fermented food product?**
(A)	Tofu
(B)	Vinegar
(C)	Sauerkraut
(D)	Tempeh

Q.4	**The Protein Efficiency Ratio (PER) is defined as**
(A)	Percentage of absorbed nitrogen retained in the body
(B)	Weight gain in body mass (in gram) per gram protein intake
(C)	Ratio of essential and non-essential amino acids in a protein
(D)	Percent *in vitro* digestibility of a protein

Q.5	**Which one of the following enzymes sequentially releases maltose from starch?**
(A)	α–Amylase
(B)	β–Amylase
(C)	Glucoamylase
(D)	Pullulanase

Q.6	**Which one of the following enzymes is involved in proteolysis of casein in cheese during aging?**
(A)	Myrosinase
(B)	Alliinases
(C)	Cathepsin
(D)	Plasmin

Q.7	**Which one of the following compounds is present in soybean and acts as phytoesterogen?**
(A)	Tangeretin
(B)	Lutin
(C)	Quercetin
(D)	Genistein

Q.8	**Ultra high temperature (UHT) process of pasteurization of milk is achieved by Heating at**
(A)	145°F for 30 minutes
(B)	161°F for 15 seconds
(C)	280°F for 2 seconds
(D)	400°F for 15 seconds

Q.9	**Bittering agent in grape fruit formed after juice extraction under acidic conditions is**
(A)	Quinine
(B)	Theobromine
(C)	Isohumulone
(D)	Limonin

Q. 10–Q. 12 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

Q.10	**The conversion of pyruvate to lactic acid in homolactic fermentation is catalyzed by**
(A)	Lactate dehydrogenase
(B)	Pyruvate dehydrogenase
(C)	Lactase
(D)	Pyruvate decarboxylase

Q.11	**Which one of the following statements is INCORRECT with respect to Controlled Atmosphere Package (CAP) and Modified Atmosphere Package (MAP) of agro-produce?**
(A)	CAP and MAP limit microbial as well as biochemical activities.
(B)	Gas composition inside a MAP during the storage is continuously monitored and regulated.
(C)	CAP implies a greater degree of precision than MAP in maintaining specific levels of the gas composition.
(D)	Modification of the atmosphere inside a MAP is achieved by natural interplay between respiration of products and permeation of gases through the packaging film.

Q.12	Match unit operation in **Column I** with its application in food processing in **Column II**. **Column I**: P. Hydrogenation; Q. Blanching; R. Leaching; S. Winterization **Column II**: 1. Removal of soft wax; 2. Shortening of fat; 3. Inactivation of enzyme; 4. Separation of dye
(A)	P-2, Q-4, R-2, S-I
(B)	P-2, Q-3, R-4, S-1
(C)	P-4, Q-1, R-2, S-3
(D)	P-4, Q-2, R-1, S-3

Q.13 – Q.19 Multiple Select Question (MSQ), Carry TWO marks each (no negative marks).

Q.13	**Which of the followings are correct pair of GRAS chemical food preservative, affected organism and given food matrix?**
(A)	Sodium lactate-Bacteria-Pre-cooked meats
(B)	Caprylic acid-Insects-Cheese wraps
(C)	Dehydroacetic acid-Molds-Squash
(D)	Sodium nitrite-Clostridia-Meat curing preparations

Q.14	**Choose the correct pair of pigment and their corresponding color in given plant product.**
(A)	Carotene - Yellow-orange-Peppers
(B)	Betanin – Purple/red-Cactus pear
(C)	Lycopene – Red-Red beets
(D)	Flavanols – Orange-Cauliflower

Q.15	**Which of the following compounds act as anti-nutritional factors?**
(A)	Phytate
(B)	Isoflavones
(C)	Trypsin Inhibitor
(D)	Resveratrol

Q.16	**Which of the followings is/are commonly used medium/media in the supercritical fluid extraction of spices and tea?**
(A)	Water
(B)	Carbon dioxide
(C)	Dichloromethane
(D)	Carbon dioxide with Ethanol

Q.17	**Which of the following expressions represent the Reynolds number of a fluid flowing through a uniform circular cross section pipe?**
(A)	$\frac{(\text{density of the fluid}) \times (\text{average velocity of the fluid}) \times (\text{internal diamater of the pipe})}{(\text{dynamic viscosity of the fluid})}$
(B)	$\frac{(\text{average velocity of the fluid}) \times (\text{internal diamater of the pipe})}{(\text{kinematic viscosity of the fluid})}$
(C)	$\frac{(\text{dynamic viscosity of the fluid})}{(\text{average velocity of the fluid}) \times (\text{density of the fluid}) \times (\text{internal diamater of the pipe})}$
(D)	$\frac{(\text{kinematic viscosity of the fluid})}{(\text{average velocity of the fluid}) \times (\text{internal diamater of the pipe})}$

Q.18	**Which of the following combinations of analytical equipment, property measured and food property are correct?**
(A)	Particle size analyzer - particle size distribution - span value
(B)	Texture profile analyzer - morphology - chewiness
(C)	Differential scanning calorimeter - glass transition temperature - degree of caking
(D)	Capillary viscometer - viscosity - sensory

Q.19	**Choose the correct pair(s) of Governing Law and corresponding application(s)**
(A)	Hagen Poiseuille law - Pressure drop
(B)	Rittinger's law - Vapour pressure
(C)	Stefan Boltzmann law - Radiation heat transfer
(D)	Raoult's law - Size reduction

Q. 20 – Q. 22 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

Q.20	**An orange juice sample is concentrated from 10% to 40% (by weight) total soluble solids in a single effect evaporator with a feed rate of 3600 kg hr-1 at 25°C. The evaporator operates at sufficient vacuum to allow the product moisture to evaporate at 55°C. The specific heat of both feed and concentrated juice is 4.0 kJ kg-1 °C-1. If enthalpy of water vapour at 55°C is 2600 kJ kg-1, heat transfer rate through the heating surface area of the evaporator in kilowatt (in integer) will be_________.**

Q.21	**Dry air is fed into a tray dryer. The percentage relative humidity of the air leaving the dryer is 60% at 70°C and 101.35 kPa. If, saturated vapour pressure of water at 70°C is 31.2 kPa, the humidity of the air leaving the dryer in kg water per kg dry air (round off to 3 decimal places) will be ________.** **(Given : Molecular weight of water and air are 18.02 g mol-1 and 28.97 g mol-1 respectively)**

Q.22	**In a cold storage plant, 5000 kg potato having a constant specific heat capacity of 3.65 kJ kg-1 °C-1 are cooled from 28 °C to 2 °C in 24 hours. The heat of respiration of potato per 24 hour is 3.12 kJ kg-1 during the storage. Assuming the efficiency of the storage plant to be 70%, the capacity of the plant in ton of refrigeration (round off to 2 decimal places) is __________.** **(Given: 1 ton of refrigeration = 3.517 kilowatt)**

END OF THE QUESTION PAPER

Polymer Science and Engineering (XE-F)

Q.1 - Q.9 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**Linear low density polyethylene (LLDPE) is a copolymer of ethylene and a small fraction of _______.**
(A)	butadiene
(B)	isoprene
(C)	butene
(D)	hexadiene

Q.2	**Binary polymer blends of polypropylene and polyamide 6 are immiscible. From a thermodynamic viewpoint this is due to ___________.**
(A)	low enthalpy of mixing
(B)	high entropy of mixing
(C)	high enthalpy of mixing
(D)	low entropy of mixing

Q.3	**Which one of the following is an elastomer?**
(A)	Polyamide 6,6
(B)	Poly(ethylene terepthalate)
(C)	Vulcanized polybutadiene
(D)	High density polyethylene

Q.4	**Compression moulded isotropic polypropylene film exhibits ________________ in X-ray diffraction analysis.**
(A)	spot pattern
(B)	circular ring pattern
(C)	circular ring and spot pattern
(D)	arc pattern

Q.5	**Which one of the following is an example of a biodegradable polymer?**
(A)	Polyethylene
(B)	Polyamide 6,6
(C)	Polypropylene
(D)	Polylactic acid

Q.6	**Polymer crystals show a range of melting points in contrast to single melting point of crystals of small molecules, because ________.**
(A)	there is an absence of intermolecular interactions
(B)	there is an absence of long range ordering
(C)	the polymer chains are not in thermodynamic equilibrium in a metastable state
(D)	the melting behavior of polymer crystal is independent of sample thermal history

Q.7	**When the rate of cooling is increased during the solidification process, the glass transition temperature of a polymer ______.**
(A)	decreases
(B)	increases
(C)	stays unaltered
(D)	shows a non-monotonic dependence

Q.8	**Equal and opposite forces of a constant magnitude F are applied at the two ends of a thin elastomeric rod, which is held at a temperature T_1 ($T_g < T_1 < T_m$), where T_g and T_m are the glass transition temperature and melting temperature respectively. If the temperature is increased to T_2 ($T_g < T_2 < T_m$ and $T_2 > T_1$), the rod will ________________.**
(A)	expand along the loading direction and the transverse direction
(B)	shrink along the loading direction
(C)	remain dimensionally unaltered
(D)	expand only along the loading direction

Q.9	**The size of a coiled polymer chain in a dilute solution is R_G in a good solvent, R_I in an ideal solvent and R_P in a poor solvent. Select the correct ordering of sizes.**
(A)	$R_G > R_I > R_P$
(B)	$R_G < R_I < R_P$
(C)	$R_P > R_G > R_I$
(D)	$R_P < R_G < R_I$

Q. 10 – Q. 12 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

Q. 10 **Match the Additive to its Function.**

Additive	**Function**
P. Tritolyl phosphate	1. Coupling Agent
Q. Triethoxy vinyl silane	2. Antioxidant
R. Azoisobutyronitrile	3. Plasticizer
S. 4-Methyl-2,6-di-t-butyl phenol	4. Blowing Agent

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

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

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

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

Q. 11 **Match the polymer processing operation with respect to its typical range of shear rate.**

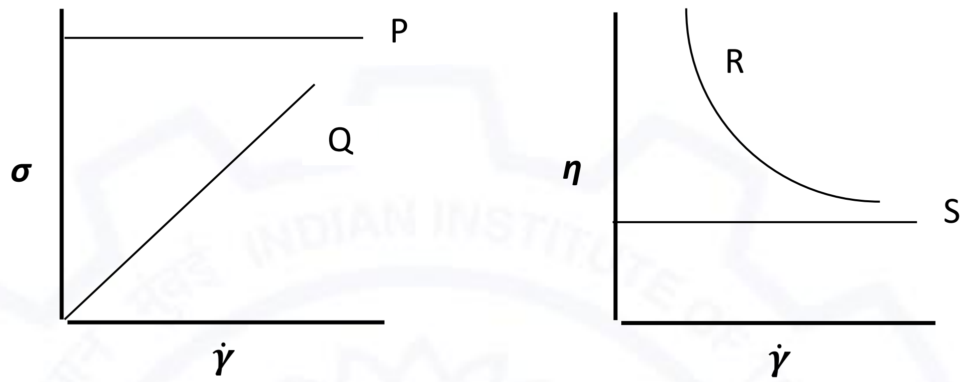
Processing Operation	**Shear rate (s^{-1})**
P. Compression Moulding	1. 1000 - 10000
Q. Extrusion	2. 100 - 1000
R. Calendering	3. 1 - 10
S. Injection Moulding	4. 10 - 100

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

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

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

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

Q. 12	**Shear stress (σ) and shear viscosity (η) are plotted as functions of the shear rate, $\dot{\gamma}$, for idealized "solid-like with yielding (1)" and "liquid-like (2)" materials.**  Associate the shear stress and viscosity plots with the appropriate material responses.
(A)	P-2, Q-1, R-2, S-1
(B)	P-1, Q-2, R-1, S-2
(C)	P-1, Q-2, R-2, S-1
(D)	P-2, Q-1, R-1, S-2

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

Q. 13	**The plateau modulus of polystyrene has a value of 0.2 × 10^6 Pa at 150 °C. Given, the density of polystyrene is 1.05 g/cm^3, the universal gas constant, *R* = 8.3 J K^{-1} mol^{-1}, and the monomer molecular weight is 104 g/mol. The molecular weight between entanglements (*rounded off to the nearest integer*) of polystyrene chains is _____________ g/mol.**

Q. 14	**A unidirectional composite of epoxy and carbon fiber of 50% by volume is made. The elastic modulus of epoxy and carbon fiber are 3.5 GPa and 350 GPa, respectively. The ratio (*rounded off to one decimal place*) of the modulus of the composite to the matrix modulus is __________.**

Q. 15	**A single screw extruder is operating at a rotational speed of 2 revolutions per second for the extrusion of a Newtonian polymer under open-discharge conditions (in absence of a die, the pressure drop, Δp = 0). The extruder has a screw diameter, *D* = 5 cm, a channel depth, *H* = 0.4 cm, distance between flights, *W* = 1 cm, and a helix angle, θ = 20°. Assume the value of π = 3.14. The volumetric flow rate (*rounded off to 2 decimal places*) is ____________ cm^3/s.**

Q. 16	**At 215 °C, the viscosity of a polystyrene of molecular weight 250 × 10^3 g/mol is 8.0 × 10^3 Pa.s. The critical molecular weight of polystyrene, M_c = 35 × 10^3 g/mol. For a similar polystyrene of molecular weight 500 × 10^3 g/mol, the viscosity (*rounded off to nearest integer*) will be __________ × 10^3 Pa.s.**

Q. 17	**There are two different PTFE polymer specimens of the following density (ρ) and % crystallinity. For PTFE-specimen-1, ρ is 2.144 g/cm^3 and % crystallinity is 50. For PTFE- specimen-2, ρ is 2.215 g/cm^3 and % crystallinity is 75. Assuming the polymer is pure and defect free, the density (*rounded off to 3 decimal places*) of 100% amorphous PTFE specimen will be _______ g/cm^3.**

Q. 18	The behavior of a polymer is described by a Maxwell model consisting of a spring element of modulus 10^{10} Pa in series with a dashpot of viscosity 10^{12} Pa.s. In the solid, 50 s after the sudden application of a fixed strain of 1%, the stress (*rounded off to 2 decimal places*) will be _________ $\times 10^7$ Pa.

Q. 19	A particular free radical polymerization process yields a polymer with a number averaged degree of polymerization, $\bar{x}_n = 100$. The monomer concentration is doubled and the initiator concentration is increased by four times. Assuming that all rate coefficients and other parameters remain unchanged, the value of $\bar{x}_n$ (*rounded off to the nearest integer*) is ___________.

Q. 20	A polymer is synthesized from 2 moles of terephthalic acid (molecular weight of the repeat unit, (-OCC_6H_4CO-), is 132 g/mol), 1 mol of ethylene glycol (molecular weight of the repeat unit, (-OCH_2CH_2O-), is 60 g/mol), and 1 mol of butylene glycol (molecular weight of the repeat unit, (-$O(CH_2)_4O$-), is 88 g/mol). The reaction is terminated at 99% conversion of the acid. The number averaged molecular weight, $\bar{M}_n$ (*rounded off to the nearest integer*) is _________ g/mol.

Q. 21	A sample of natural rubber (cis-1,4-polyisoprene) is vulcanized such that one of every 240 chain carbon atoms is cross-linked. The formula unit of the isoprene monomer is C_5H_8 (molecular weight = 68 g/mol). The average molecular weight (*rounded off to the nearest integer*) between cross-links is ___________ g/mol.

Q. 22	A sample of an oriented semi-crystalline polymer is subjected to uniaxial tensile stress, σ, in an X-ray diffractometer. The wavelength of X-ray radiation (Cu K_α) is λ = 1.542 Å. The position of the (002) peak, which was found initially at a Bragg angle of 37.50° at σ = 0 MPa shifted to 37.45° at σ = 160 MPa. Assuming elastic deformation, the strain (*rounded off to three decimal places*) in the sample along the direction of applied stress is __________ $\times 10^{-3}$.

END OF THE QUESTION PAPER

Thermodynamics (XE-E)

Q.1 - Q.7 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**A refrigerator working on a reversed Carnot cycle has a Coefficient of Performance (COP) of 4. If it works as a heat pump and consumes work input of 1 kW, the heating effect will be:**
(A)	1 kW
(B)	4 kW
(C)	5 kW
(D)	6 kW

Q.2	**The liquid phase of a pure substance is termed as __________________, if its temperature is lower than the saturation temperature corresponding to its pressure P.**
(A)	super-heated liquid
(B)	sub-cooled liquid
(C)	metastable liquid
(D)	flashing liquid

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.4	**If** **h is the mass specific enthalpy,** **s is the mass specific entropy,** **P is the pressure,** **T is the temperature,** **C_V is the mass specific heat at constant volume,** **C_P is the mass specific heat at constant pressure,** **β is the coefficient of thermal expansion,** **v is the mass specific volume,** **κ is the isothermal compressibility,** **then the partial derivative $\left(\frac{\partial h}{\partial s}\right)_P =$**
(A)	$\left(T - \frac{1}{\beta}\right)\left(\frac{C_P}{C_V}\right)$
(B)	$\left(T - \frac{1}{\beta}\right)$
(C)	$T\left(1 - \frac{v\beta}{\kappa C_V}\right)$
(D)	T

Q.5	**If** v **is the mass specific volume,** s **is the mass specific entropy,** P **is the pressure,** T **is the temperature,** **then using Maxwell relations,** $\left(\frac{\partial s}{\partial P}\right)_T =$
(A)	$\left(\frac{\partial v}{\partial T}\right)_P$
(B)	$-\left(\frac{\partial v}{\partial T}\right)_P$
(C)	$\left(\frac{\partial v}{\partial T}\right)_s$
(D)	$-\left(\frac{\partial v}{\partial T}\right)_s$

Q.6	**A closed system consists of a solution of liquid water and ethanol in equilibrium with its vapours. Using the Gibbs phase rule, the degree of freedom of the system is:**
(A)	0
(B)	1
(C)	2
(D)	3

Q.7	**For a real gas passing through an insulated throttling valve, the outlet temperature of the gas ____________________ with respect to the inlet temperature.**
(A)	is always higher
(B)	is always lower
(C)	may be higher, lower or same
(D)	is always same

Q.8 Multiple Select Question (MSQ), Carry ONE mark each (no negative marks).

Q.8	**Atmospheric air with Dry Bulb Temperature (DBT) of 24°C and Relative Humidity of 35%, entering in a circular duct (assume no pressure drop in the duct) is heated by an electrical resistance arrangement inside the duct. The DBT of air measured at the outlet of the duct is equal to 30°C. Considering the flow to be steady, which of the following statement(s) is (are) correct as regards to the outlet air, with respect to the inlet air?**
(A)	There is no change in the Relative Humidity
(B)	There is no change in the Dew Point Temperature
(C)	There is no change in the Specific Humidity
(D)	There is no change in the Specific Enthalpy

Q.9 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

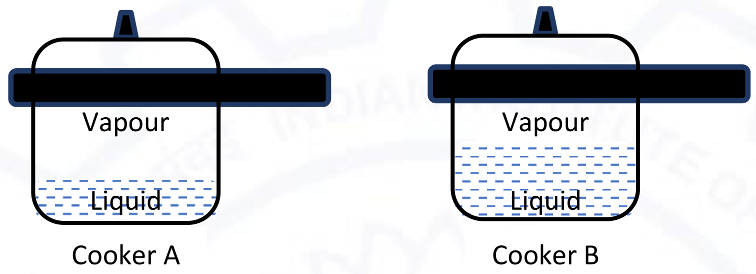
Q.9	**A cylinder of volume 1 m^3 contains a mixture of CO_2 (20% by mol) and O_2 (80% by mol) at 100 kPa and 300 K. This cylinder is connected to a 1 MPa pressure line carrying N_2 at 300 K. The cylinder is filled isothermally till the pressure of gas mixture inside it becomes 500 kPa, and then the filling is stopped. The amount of N_2 gas that has entered the cylinder is _________ (in mole, 2 decimal places).** **The universal gas constant is 8.3145 J/(mol K).**

Q. 10 – Q. 13 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

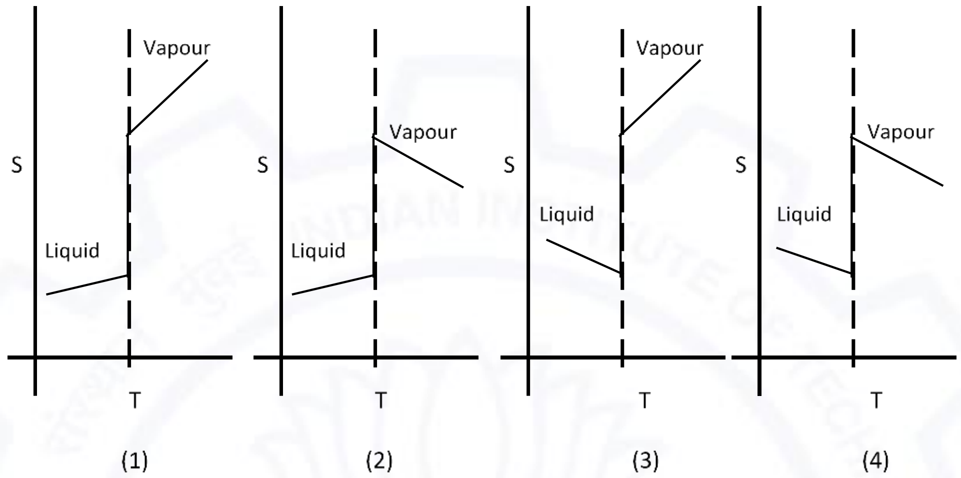
Q. 10	**The saturation pressure P_{sat} of a pure liquid is represented by an equation of the form:** $\ln P_{sat} = A - (B/T)$, **where, A and B are constants, and T is the absolute temperature. For this substance, which of the following expression for specific entropy difference between the saturated vapour and the saturated liquid phase (s_{fg}) is correct?** **Note: Subscripts f and g refer to saturated liquid and saturated vapour phases, respectively, and v_{fg} is the specific volume difference between the saturated vapour and the saturated liquid phases.**
(A)	$s_{fg} = v_{fg}\dfrac{BP_{sat}^2}{T^2}$
(B)	$s_{fg} = v_{fg}\dfrac{BP_{sat}}{T^2}$
(C)	$s_{fg} = v_{fg}\dfrac{BP_{sat}}{T^3}$
(D)	$s_{fg} = v_{fg}\dfrac{BP_{sat}^3}{T^2}$

Q. 11	**For a refrigeration cycle, the ratio of actual COP to the COP of a reversible refrigerator operating between the same temperature limits is 0.8. The condenser and evaporator temperatures are 51°C and −30°C, respectively. If the cooling capacity of the plant is 2.4 kW, then the power input to the refrigerator is:** **(COP: Coefficient of Performance)**
(A)	1.00 kW
(B)	1.33 kW
(C)	1.25 kW
(D)	2.08 kW

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. 13	**Four different Entropy (S) - Temperature (T) diagrams, representing liquid to vapour phase transition process of a pure substance in a closed system under constant pressure are shown. The diagram, which correctly represents the process, is:** 
(A)	1
(B)	2
(C)	3
(D)	4

Q. 14 – Q. 22 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

Q. 14	**Air having a mass flow rate of 2 kg/s enters a diffuser at 100 kPa and 30°C, with a velocity of 200 m/s. Exit area of the diffuser is 400 cm^2 while the exit temperature of the air is 45°C. The rate of heat loss from the diffuser to the surrounding is 8 kJ/s. The pressure at the diffuser exit is ____________ kPa (2 decimal places).** **For air, the characteristic gas constant is 287 J/(kgK) and specific heat capacity at constant pressure is 1005 J/(kgK). Assume air to be an ideal gas and the flow in the diffuser is steady.**

Q. 15	**For the Refrigerant R-134 (at 1 MPa and 50℃), the difference between the specific volume computed by assuming it to be an ideal gas and its actual specific volume is: $v_{ideal} - v_{actual} = 4.529 \times 10^{-3}$ m^3/kg. If the compressibility factor associated with this state is $Z = 0.84$, then $v_{com} - v_{actual} =$ _______________ $\times 10^{-3}$ m^3/kg (3 decimal places).** **Here v_{com} is the specific volume calculated using the compressibility factor.** **For Refrigerant R-134 (at 1 MPa and 50℃):** **The characteristic gas constant: 0.0815 kJ/(kgK), The critical pressure and temperature are, respectively, P_{cr} = 4.059 MPa and T_{cr}= 374.2 K.**

Q. 16	**A mixture of air and water vapour enters a steady-flow adiabatic saturator at 50℃ and 100 kPa. It leaves the saturator in a completely saturated state at temperature of 25℃ and pressure of 100 kPa. Liquid water enters the saturator at 25℃. If air is considered to be an ideal gas, with constant specific heat capacity, the relative humidity of the air entering the saturator is ______ % (1 decimal place).** **Use the following data:** **at 25℃ h_f = 104.87 kJ/kg, h_g = 2547.17 kJ/kg, P_{sat}=3.161 kPa** **at 50℃ h_f = 209.31 kJ/kg, h_g = 2592.06 kJ/kg, P_{sat}=12.335 kPa** **Specific heat capacity of air at constant pressure C_P=1.005 kJ/(kgK)**

Q. 17	**Air at a pressure of 1 MPa and 300 K is flowing in a pipe. An insulated evacuated rigid tank is connected to this pipe through an insulated valve. The volume of the tank is 1 m^3. The valve is opened and the tank is filled with air until the pressure in the tank is 1 MPa. Subsequently, the valve is closed. Consider air to be an ideal gas and neglect bulk kinetic and potential energy. The final temperature of air in the tank is _______ K (1 decimal place).** **Specific heat capacity of air at constant pressure C_P=1.005 kJ/(kgK) and characteristic gas constant for air = 0.287 kJ/(kgK)**

Q. 18	**A cylinder of volume 0.1 m^3 is filled with 100 mol of propane (C_3H_8) at 2 MPa. If propane is assumed to obey the van der Waals equation of state, then its temperature is ______ K (1 decimal place).** **The van der Waals constants for propane are: $a = 939.2$ kPa (m^3/kmol)^2 and $b = 0.0905$ m^3/kmol. The universal gas constant is 8.3145 J/(mol K).**

Q. 19	**A frictionless piston cylinder device contains 1 kg of an ideal gas. The gas is compressed according to $Pv^{1.3}$ = constant (P is pressure and v is mass specific volume), from 100 kPa, 250 K, till it reaches a temperature of 500 K. The heat transfer from the piston cylinder device to its surroundings is ______________ kJ (2 decimal places).** **The characteristic gas constant is 287 J/(kgK) and the ratio of specific heat capacities is 1.4.**

Q. 20	**A 0.8 m^3 insulated rigid tank contains 1.5 kg of an ideal gas at 100 kPa. Electric work is done on the system until the pressure in the tank rises to 135 kPa. The loss in availability (exergy) associated with the process is __________ kJ (2 decimal places).** **For the ideal gas, the characteristic gas constant is 188.9 J/(kgK) and the specific heat capacity at constant volume is 680 J/(kgK). The temperature of the dead state is 298 K.**

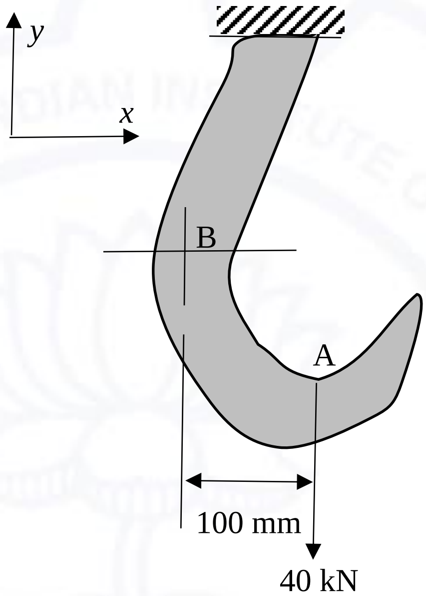
Q.21	**A rigid tank contains 1.0 kg of pure water consisting of liquid and vapour phases in equilibrium at 10 bar. If the liquid and vapour phase each occupies one half of the volume of the tank, then the net enthalpy of the contents of the tank is ________ kJ (1 decimal place).** **For saturated liquid and vapour at 10 bar, the thermodynamic data table provides the following values:** $v_f = 1.127 \times 10^{-3}$ m^3/kg, $v_g = 194.3 \times 10^{-3}$ m^3/kg, $h_f = 762.6$ kJ/kg, $h_g = 2776.2$ kJ/kg

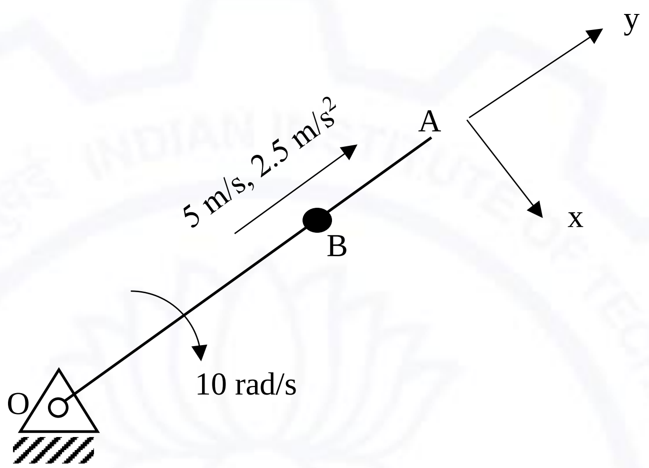
Q.22	**An air-standard Diesel cycle with a compression ratio of 16 takes air at 1 bar and 300 K. If the maximum temperature in the cycle is 2100 K, then the thermal efficiency of the cycle is _______ % (1 decimal place).** **The ratio of the specific heat capacities of air is 1.4.**

END OF THE QUESTION PAPER

Solid Mechanics (XE-D)

Q.1 – Q.8 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**A force F = 40 kN is applied on the hook as shown. The equivalent force-couple system at B is** 
(A)	40 kN in +y direction and M = 0
(B)	40 kN in –y direction and M = 0
(C)	40 kN in +y direction and M =4000 Nm counter clockwise
(D)	40 kN in -y direction and M = 4000 Nm clockwise

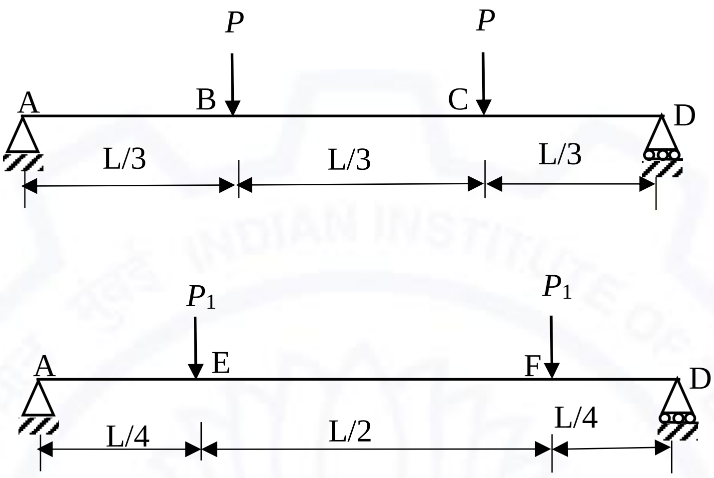
Q.2	**A rigid rod OA rotates clockwise at an angular velocity of 10 rad/s. A bead B (OB = 1 m) translates outward on the rod at a speed of 5 m/s and acceleration 2.5 m/s2 (both quantities with respect to the rod). The Coriolis component of acceleration is** 
(A)	2.5 m/s2 in +x direction
(B)	100 m/s2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

Q.3	**A two force member in equilibrium is one in which**
(A)	Forces act at two points and forces are collinear
(B)	Forces act at two points and member is always straight
(C)	Forces act at two points but the member is free to carry moment at any point
(D)	Force acts at one point and moment acts at second point

Q.4	**If the yield point shear stress obtained from the torsion test of a cylindrical specimen is τy, then what is the maximum value of principal strain at yielding? (μ is Poisson's ratio and E is Young's modulus)**
(A)	$\frac{\tau_y}{E}$
(B)	$\frac{(1+\mu)\tau_y}{E}$
(C)	$\frac{\tau_y}{2E}$
(D)	$\frac{(1-\mu)\tau_y}{E}$

Q.5	**If the ratio of Young's modulus to bulk modulus of a material is 3/2, then the ratio of shear modulus to the Young's modulus of the material is**
(A)	1
(B)	2/5
(C)	1/3
(D)	3/5

Q.6	**With respect to the plane of maximum shear stress, which of the following statements is INCORRECT?**
(A)	The normal stress on this plane is zero.
(B)	The maximum shear stress is equal to the largest of the one half the difference of principal stresses
(C)	The plane of maximum shear stress occurs at 45° to the principal planes.
(D)	The magnitude of the maximum shear stress is equal to the largest of the radius of the Mohr's circles.

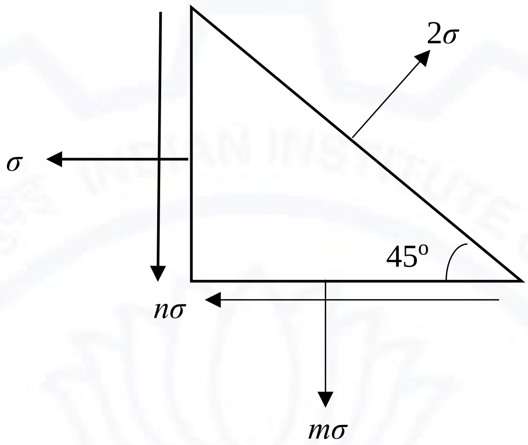
Q.7	**A simply supported beam of length L is loaded by two symmetrically applied point loads P at L/3 from each support. Both the loads are then shifted to new points which are at a distance L/4 from each support. The bending moments at the mid-section of the beam in both the cases are same. The magnitude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

Q.8	**A beam having rectangular cross section is subjected to transverse loading. The ratio of maximum shear stress developed in the beam to the average shear stress is**
(A)	1.50
(B)	1.25
(C)	1.33
(D)	1.66

Q.9 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

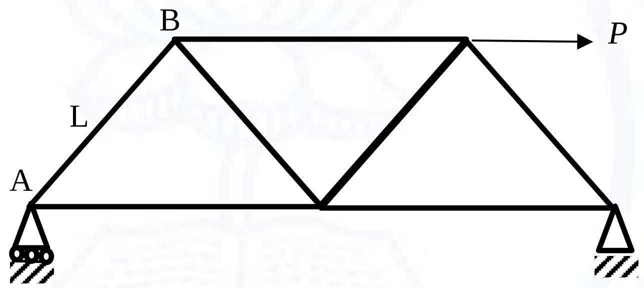
Q.9	**During an earthquake, a structure vibrates and the vibration can be assumed to be in simple harmonic motion at 5 Hz. At a measurement point, the RMS value of acceleration is 10 m/s^2. The approximate amplitude of motion (in mm) at this point (*rounded off to two decimal places*) is ____________**

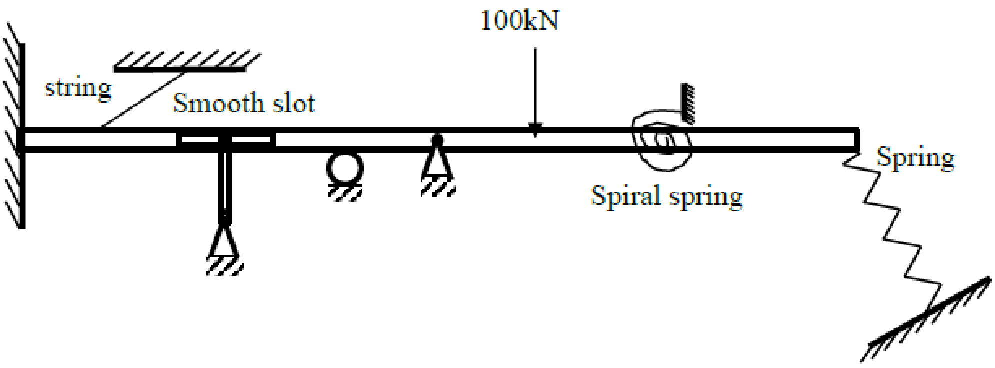
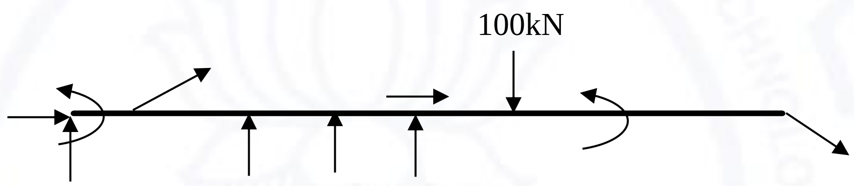
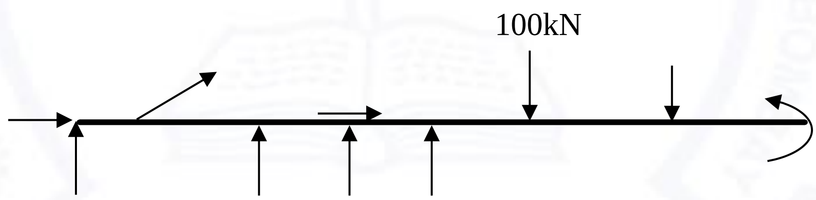
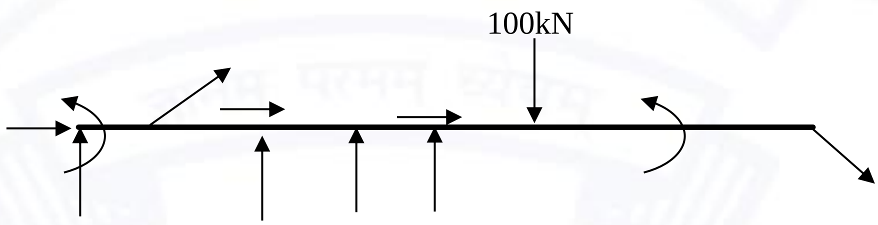
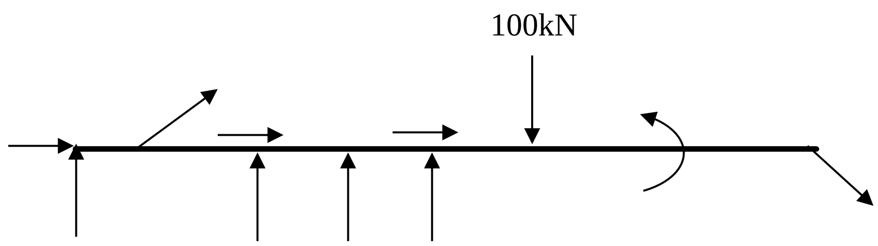
Q. 10–Q. 15 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

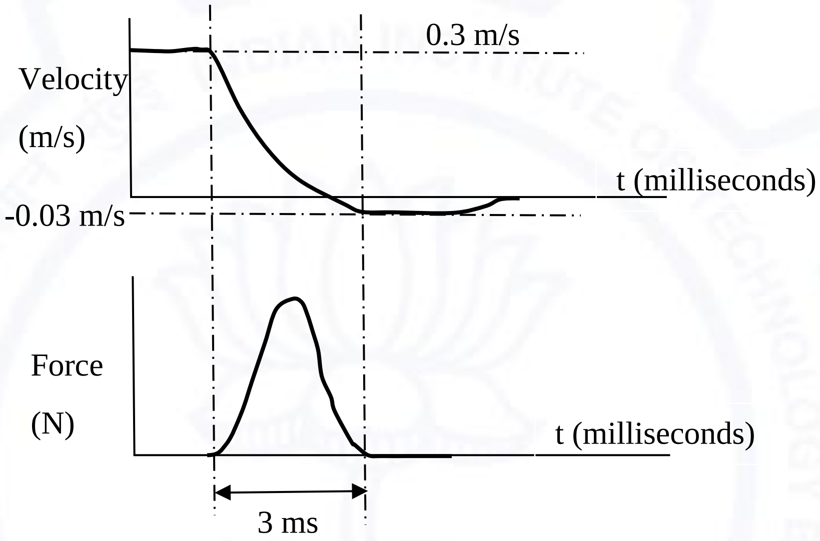
Q.10	**For the state of plane stress shown, the components of normal and shear stresses are given in terms of stress σ and unknown constants m and n. If the normal and shear components of stress on a 45o plane are 2σ and zero, the values of m and n would be:** 
(A)	$m = 1, n = 2$
(B)	$m = 2, n = 1$
(C)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

Q.11	**For a state of plane strain, the normal strains are given by** **εxx = 1000 × 10-6, εyy = 200 × 10-6 and the maximum shear strain is γmax = 1000 × 10-6. The value of shear strain γxy for this strain state is**
(A)	600×10^{-6}
(B)	183×10^{-6}
(C)	1000×10^{-6}
(D)	800×10^{-6}

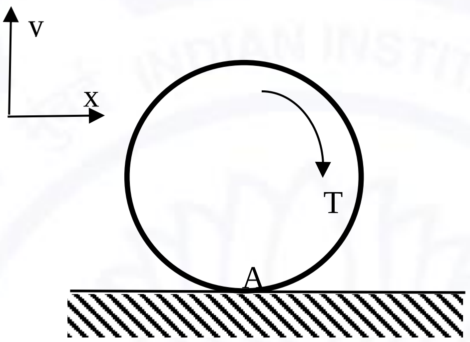
Q.12	**A thin cylinder (closed at its ends) of radius r and thickness t (r ≫ t) is subjected to internal pressure p. The maximum shear stress in the wall of the cylinder is**
(A)	$\frac{pr}{t}$
(B)	$\frac{pr}{2t}$
(C)	$\frac{pr}{4t}$
(D)	$\frac{3pr}{2t}$

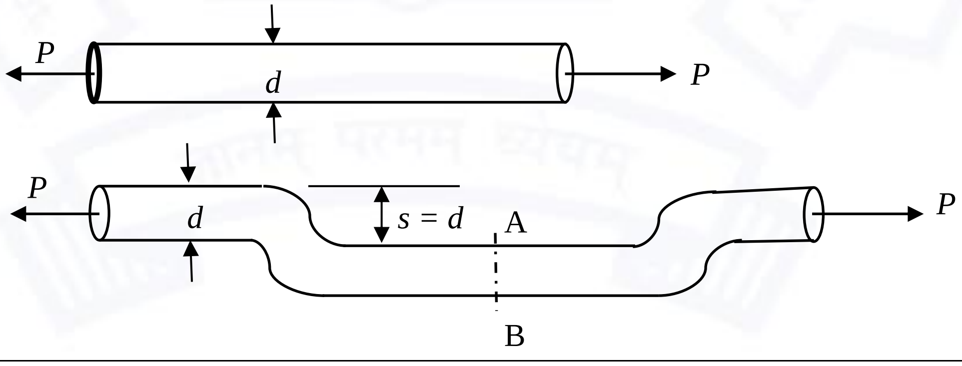
Q.13	**The truss shown is subjected to a force P. All members of the truss have the same length L. The reaction at A and force in member AB are** 
(A)	$\frac{P\sqrt{3}}{4}$ and $\frac{P}{2}$
(B)	$\frac{P\sqrt{3}}{8}$ and $\frac{P\sqrt{3}}{4}$
(C)	$\frac{P\sqrt{3}}{4}$ and $\frac{P}{4}$
(D)	P and $\frac{P}{4}$

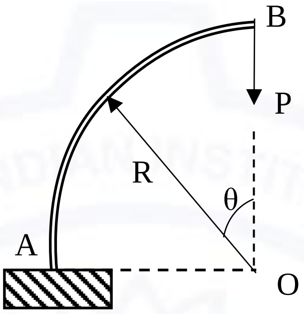
Q.14	The figure shows a structure with supports. The correct free body diagram when the supports are removed is 
(A)	
(B)	
(C)	
(D)	

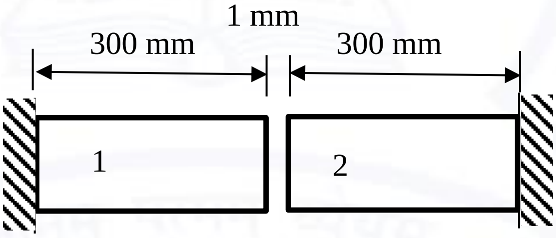
Q.15	**A hammer of mass 1 kg is used to break an almond shell. The velocity time graph of the hammer during the impact duration is shown in the figure. The shape of force time graph is also given, which can be approximated as a triangle. A force of 300 N is required for breaking the shell, while a force of 200 N will not be able to break it, but just introduce a crack. Which one of the following events will happen?** 
(A)	The almond shell will crack but not break
(B)	The almond shell will not crack.
(C)	The almond shell will break
(D)	Cannot be determined from the given data

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

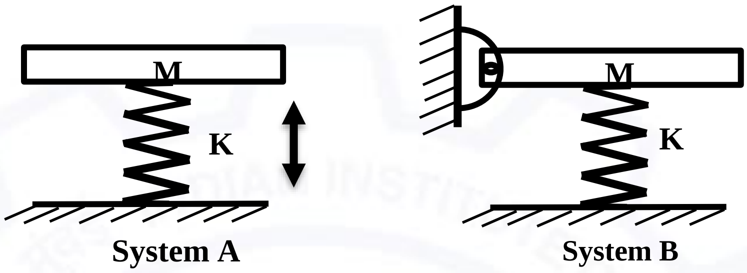
Q.16	**A rigid circular disc of radius 0.2 m and mass 10 kg rolls without slip on the ground at A. The coefficient of static friction μ between ground and disc is 0.7. A torque T of 9 Nm acts on the disc as shown. Given acceleration due to gravity g = 10 m/s^2 . The friction force (in N) acting on the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

Q.17	**A prismatic solid circular rod of diameter d is bent to introduce an offset s = d as shown. The rod is further subjected to an axial load P. If the maximum longitudinal stress at a section A-B in the rod (with offset) is n times the longitudinal stress in the straight rod, the value of n (in integer) would be ____________________** 

Q.18	A naturally curved steel beam AB having Young's modulus 208 GPa, area moment of inertia I = 26.7 cm^4 and radius R = 2 m is subjected to a vertical load P = 1000 N at B. The end A at θ = 900 is rigidly fixed. The bending strain energy of the beam (in Nm, rounded off to two decimal places) is ______________ 

Q.19	At room temperature of 25°C, a gap of 1 mm exists between the ends of the rods 1 and 2 as shown. Given the cross section area A of the rods is 1500 mm^2, Young's modulus E = 75 GPa and the coefficient of thermal expansion $\alpha = 23 \times 10^{-6}$ /°C. When the temperature has reached 150°C, the magnitude of normal stress in each of the rods (in MPa, rounded off to two decimal places) is ______________ 

Q.20	A tube of inner radius 4 cm and outer radius 5 cm can carry a maximum torque of T. This tube is now replaced by a solid circular shaft of the same material. The minimum radius of the solid circular shaft (in cm, rounded off to two decimal places) to carry the same amount of torque T is ____________________

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.22	A coronavirus droplet of mass 1 microgram ejects from the mouth of a patient with a velocity of 0.7 m/s and travels through air. The gravitational force experienced by it can be neglected due to the buoyancy effect. However, the droplet experiences air drag force proportional to its velocity and the drag coefficient is given as 1.0 μN-s/m. The distance travelled by the droplet before its velocity drops to 10% of its initial velocity (in m, rounded off to two decimal places) is _________________.

END OF THE QUESTION PAPER

Materials Science (XE-C)

Q.1 – Q.7 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**Condition to be satisfied for α and β phases to be in equilibrium in a two-component (A and B) system at constant temperature and pressure is** **(*Given: μ is the chemical potential*)**
(A)	entropy of the system should be maximum
(B)	Gibbs energy of the system should be minimum and $\mu_A^{\alpha} = \mu_B^{\alpha}$, $\mu_A^{\beta} = \mu_B^{\beta}$
(C)	Gibbs energy of the system should be minimum and $\mu_A^{\alpha} = \mu_A^{\beta}$, $\mu_B^{\alpha} = \mu_B^{\beta}$
(D)	Helmholtz energy should be minimum

Q.2	**Amino acids react to form peptides and proteins. This process is known as**
(A)	addition polymerization
(B)	nucleophilic substitution
(C)	condensation polymerization
(D)	hydration

Q.3	**The most favoured slip system in face centered cubic metal is**
(A)	(111) [110]
(B)	(110) $[1\bar{1}1]$
(C)	$(11\bar{1})$ [112]
(D)	(111) $[1\bar{1}0]$

Q.4	**The dielectric constant of a material at ultraviolet frequencies is mainly due to**
(A)	dipolar polarizability
(B)	ionic polarizability
(C)	electronic polarizability
(D)	interfacial polarizability

Q.5	Match the different transformations/reactions in **Column I** with the most suitable information in **Column II**. **Column I** / **Column II** (P) Eutectoid reaction — (1) involves no diffusion (Q) Martensitic transformation — (2) one solid phase transforms into two solid phases (R) Precipitation reaction — (3) occurs in supersaturated solutions
(A)	P-2; Q-3; R-1
(B)	P-1; Q-2; R-3
(C)	P-2; Q-1; R-3
(D)	P-3; Q-2; R-1

Q.6	**In scanning electron microscopy, the resolution of backscattered electron (BSE) image is poorer compared to that of secondary electron (SE) image, because**
(A)	energy of BSE is lower
(B)	sampling volume of BSE is larger
(C)	yield of BSE is lower
(D)	sampling volume of SE is larger

Q.7	**Which of the following deposition conditions favour the formation of larger grains in thin film?**
(A)	Low deposition rate and low substrate temperature
(B)	Low deposition rate and high substrate temperature
(C)	High deposition rate and low substrate temperature
(D)	High deposition rate and high substrate temperature

Q.8 Multiple Select Question (MSQ), Carry ONE mark each (no negative marks).

Q.8	**A metal has a melting point of 600 °C. By rapid cooling, liquid metal can be made to solidify either at 500 °C or 400 °C or 300 ºC. Critical size of the solid nuclei is**
(A)	same for solidification at 400 °C and 500 °C
(B)	smaller for solidification at 400 ºC as compared to solidification at 500 °C
(C)	larger for solidification at 400 °C as compared to solidification at 500 °C
(D)	the smallest for solidification at 300 °C

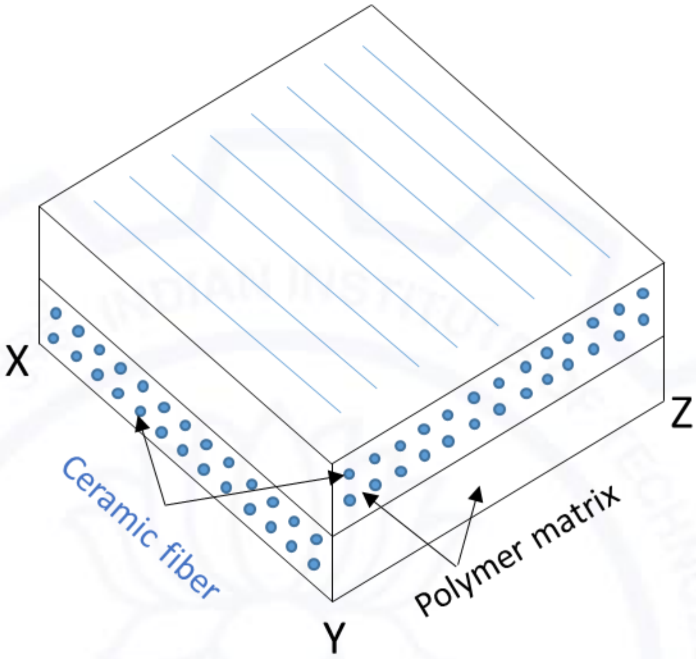
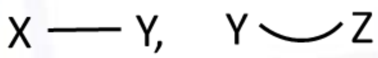
Q.9 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

Q.9	**A magnet of mass 50 g has a magnetic moment of 4.2×10^{-7} A m^2. The density of the magnet is 7.2 g cm^{-3}. The intensity of magnetization in A m^{-1} is _________ (*round off to 3 decimal places*)**

Q. 10 – Q. 12 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

Q.10	In the context of scanning electron microscopy, match the information in **Column I** with most appropriate information in **Column II**. **Column I** (P) Secondary electrons (Q) Backscattered electrons (R) Characteristic X-rays (S) Diffracted backscattered electrons **Column II** (1) Crystallographic orientation of grains (2) Failure analysis of fractured surfaces (3) Chemical composition analysis (4) Distinguishing chemically distinct phases
(A)	P-3; Q-2; R-1; S-4
(B)	P-2; Q-4; R-3; S-1
(C)	P-1; Q-3; R-2; S-4
(D)	P-4; Q-2; R-1; S-3

Q.11	Match the heat treatment processes given in **Column I** with the most suitable outcomes in **Column II**. **Column I** (P) Quenching (Q) Annealing (R) Tempering (S) Carburizing **Column II** (1) hardens the steel (2) softens the cold worked steel (3) toughens the steel (4) hardens the surface of steel
(A)	P-3; Q-2; R-1; S-4
(B)	P-2; Q-4; R-3; S-1
(C)	P-1; Q-2; R-3; S-4
(D)	P-1; Q-3; R-4; S-2

Q.12	**A co-joined cross-ply laminate composite, as shown in figure, is distorted upon heating. What are the resultant shapes of edges XY and YZ ?** 
(A)	
(B)	
(C)	
(D)	

Q. 13 Multiple Select Question (MSQ), Carry TWO marks each (no negative marks).

Q.13	**X-ray diffraction peak broadening enables the estimation of**
(A)	crystallite size of the material
(B)	microstrain in the material
(C)	precise lattice parameter
(D)	residual macrostress acting on the material

Q. 14 – Q. 22 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

Q.14	**Fe - 10 atom % C austenite (fcc), having no Fe vacancies, has a lattice parameter of 4 Å. The density of austenite in g cm^{-3} is _________ (*round off to 2 decimal places*)** **(*Given: atomic weight of Fe* = 55.8; *atomic weight of C* = 12.0; *Avogadro's number* = 6.023 × 10^{23})**

Q.15	**An element transforms from α to β at 773 K and 1 atm pressure with 912 J mol^{-1} as enthalpy of transformation. The molar volumes of α and β phases are 7.377 cm^3 and 7.317 cm^3, respectively. Assume that the difference in molar volumes of α and β is independent of pressure. The pressure (in atm) required for α to β transformation to occur at 723 K is _________ (*round off to nearest integer*)** **(*Given: 1 atm* = 1.01325 × 10^5 Pa)**

Q.16	**A binary A-B alloy has α and β phases at equilibrium. The ratio of weight percentages (wt.%) of α to β is 4. The wt.% of A in α and β phases is 70 and 20, respectively. The wt.% of B in the alloy is _________ (*round off to nearest integer*)**

Q.17	**During heating, Ti undergoes allotropic transformation from hcp to bcc at 882 °C. The percent volume change accompanying this transformation is _________ (*round off to 1 decimal place*)** **(*Given: atomic weight of Ti* = 47.9; *lattice parameter of bcc Ti* = 0.332 nm; *density of hcp Ti* = 4.51 g cm^{-3}; *Avogadro's number* = 6.023 × 10^{23})**

Q.18	**Vickers hardness test is performed with an indenter of square-base diamond pyramid having an included angle of 136° between the opposite faces of the pyramid. If the applied load is 10 kg and the average length of diagonals of square indentation is 0.5 mm, the Vickers hardness in kg mm^{-2} is_________ (*round off to nearest integer*)**

Q.19	The drift mobility of electron in an n-type Si crystal doped with 10^{16} cm^{-3} phosphorous atoms is 1350 cm^2 V^{-1} s^{-1}. The electrical conductivity in Ω^{-1} m^{-1} is _________ (*round off to nearest integer*) (*Given: Intrinsic charge concentration of Si* = 1.45×10^{10} cm^{-3}; *Charge of an electron, e* = 1.6×10^{-19} C)

Q.20	At 1000 K, the linear thermal expansion coefficients of graphite, parallel and perpendicular to the graphite layers, are 0.8×10^{-6} K^{-1} and 29×10^{-6} K^{-1}, respectively. The percentage increase in the volume of graphite when heated from 900 K to 1100 K is _________ (*round off to 2 decimal places*)

Q.21	A certain ceramic has a theoretical density and sintered density of 6.76 g cm^{-3} and 6.60 g cm^{-3}, respectively. The green compact has 18 volume percent porosity. For a sintered cube of side 2 cm, the required side of the cubic green compact in cm is _________ (*round off to 2 decimal places*)

Q.22	When a metal (M) is immersed in de-aerated acid electrolyte, it polarizes anodically by 0.4 V. The M/M^{n+} exchange current density is 10^{-5} A m^{-2} and Tafel slope is 0.1 V/decade for the anodic reaction. Assume that corrosion is uniform and, anodic and cathodic reactions are under activation control. The rate of metal dissolution in A m^{-2} is _________ (*round off to 1 decimal place*)

END OF THE QUESTION PAPER

Fluid Mechanics (XE-B)

Q.1 - Q.8 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**The general relationship between shear stress, τ, and the velocity gradient $\left(\frac{du}{dy}\right)$ for a fluid is given by $\tau = k\left(\frac{du}{dy}\right)^n$, where k is a constant with appropriate units. The fluid is Newtonian if**
(A)	$n > 1$
(B)	$n < 1$
(C)	$n = 1$
(D)	$n = 0$

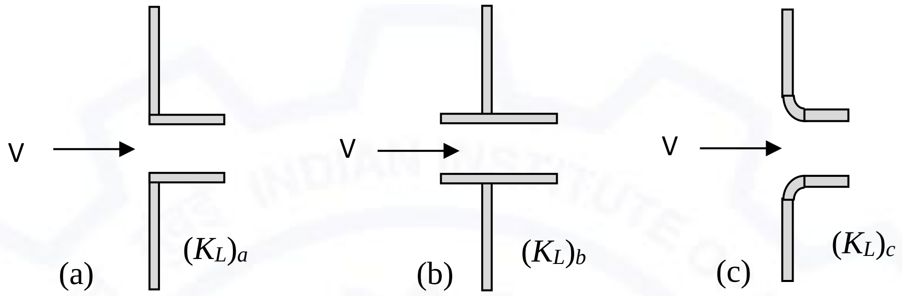
Q.2	**Which one of the following options is TRUE?**
(A)	Pathlines and streaklines are the same in an unsteady flow, **and** streamlines are tangential to the local fluid velocity at a point.
(B)	Streamlines are perpendicular to the local fluid velocity at a point, **and** streamlines and streaklines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

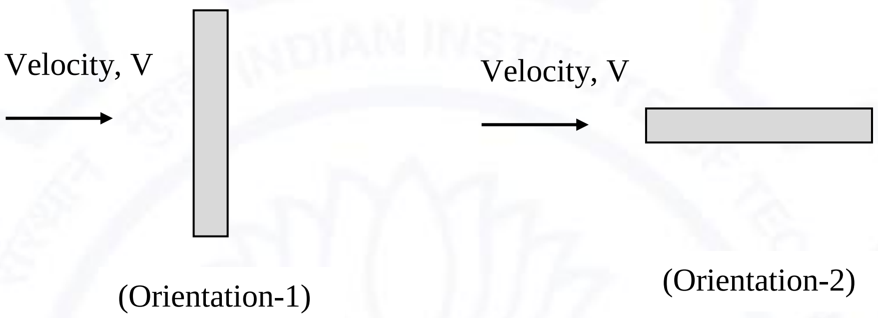
Q.3	**If $P_{in} = 1.2$ Pa and $P_{out} = 1.0$ Pa are the average pressures at inlet and outlet respectively for a fully-developed flow inside a channel having a height of 50 cm, then the absolute value of average shear stress (in Pa) acting on the walls of the channel of length 5 m is**
(A)	0.005
(B)	0.02
(C)	0.01
(D)	0.05

Q.4	**Consider the fully-developed flow of a Newtonian fluid (density ρ; viscosity μ) through a smooth pipe of diameter D and length L. The average velocity of the flow is V. If the length of the pipe is doubled, keeping V, D, ρ, μ constant, the friction factor**
(A)	increases by two times
(B)	remains the same
(C)	decreases by two times
(D)	increases by four times

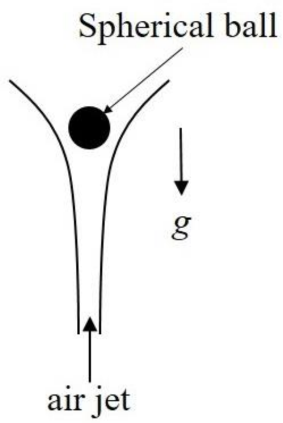
Q.5	**The absolute value of pressure difference between the inside and outside of a spherical soap bubble of radius, R, and surface tension, γ, is:**
(A)	$\frac{2\gamma}{R}$
(B)	$\frac{\gamma}{R}$
(C)	$\frac{\gamma}{2R}$
(D)	$\frac{4\gamma}{R}$

Q.6	**Which one of the following statements is TRUE about the continuity equation $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$ (where u, v, w are the velocity components along the $x, y,$ and z coordinates respectively):**
(A)	The equation is valid only for steady incompressible flows.
(B)	The equation is valid for both steady and unsteady incompressible flows.
(C)	The equation is valid only for steady compressible flows.
(D)	The equation is valid only for unsteady compressible flows.

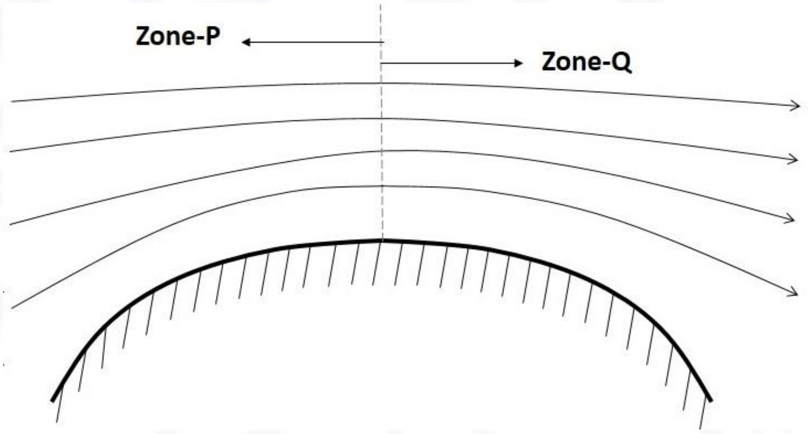
Q.7	**The head loss (K_L) associated with the flow entry of water to an internal passage depends on the shape of the entry. The following figure shows three different types of flow entry into a pipe. Which one of the following relationships correctly represents the head loss associated with the three different flow entries?** 
(A)	$(K_L)_a > (K_L)_b > (K_L)_c$
(B)	$(K_L)_b > (K_L)_a > (K_L)_c$
(C)	$(K_L)_b \leq (K_L)_a = (K_L)_c$
(D)	$(K_L)_b < (K_L)_a < (K_L)_c$

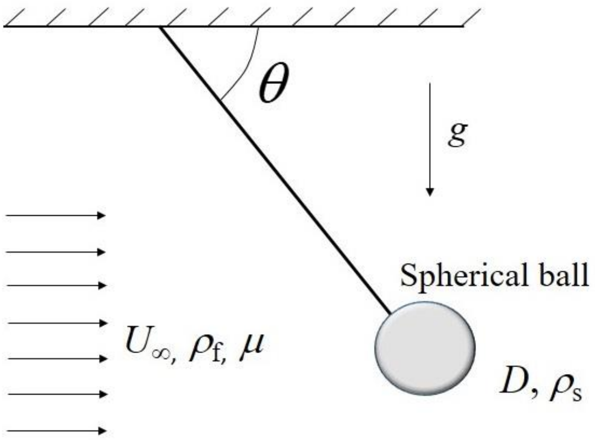
Q.8	**The form and friction drags together contribute to the total drag when flow of air occurs past any object. Two orientations of a finite flat plate are shown in the figure. In Orientation-1, the plate is placed perpendicular to the flow while in Orientation-2, the plate is placed parallel to the flow. If the velocity (V) of air in both orientations is the same, which one of the following options is TRUE?** 
(A)	Orientation-1 has higher form drag and lower friction drag **and** Orientation-2 has lower form drag and higher friction drag
(B)	Orientation-1 has lower form drag and lower friction drag **and** Orientation-2 has higher form drag and higher friction drag
(C)	Orientation-1 has lower form drag and higher friction drag **and** Orientation-2 has higher form drag and lower friction drag
(D)	Orientation-1 has higher form drag and higher friction drag **and** Orientation-2 has lower form drag and lower friction drag

Q.9 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

Q.9	**A spherical ball is steadily supported against gravity by an upward air jet as shown in the figure. Take acceleration due to gravity to be $g = 10$ m/s^2. The mass flow rate of air, reaching the ball, is 0.01 kg/s and the air reaches the ball at an upward velocity of 3 m/s. Neglecting the buoyancy force, and using the principle of integral momentum balance, the mass (in grams, up to one decimal place) of the ball is ____.** 

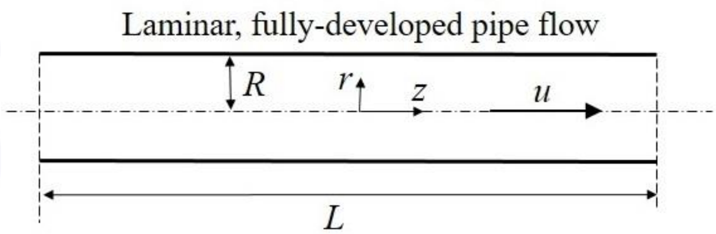
Q. 10 – Q. 12 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

Q. 10	**The incompressible flow of air over a curved surface having possible flow separation is schematically shown in the figure. Two zones P and Q are indicated in the figure. Which one of the following combinations is TRUE for zones P and Q?**  **(a) Acceleration of flow, (b) Deceleration of flow, (c) Adverse pressure gradient, (d) Favorable pressure gradient, (e) No flow separation (f) Possible flow separation.**
(A)	P: (a), (d), (e) and Q: (b), (c), (f)
(B)	P: (a), (d), (f) and Q: (b), (d), (f)
(C)	P: (a), (c), (f) and Q: (a), (d), (e)
(D)	P: (a), (c), (e) and Q: (a), (d), (f)

Q. 11	**A spherical metal ball (of density ρ_s and diameter D), attached to a string, is exposed to a crossflow (of velocity U_∞) of a viscous fluid (of viscosity μ and density ρ_f). Due to the crossflow, the string makes an angle of inclination, θ, with the top surface as shown in the figure. The acceleration due to gravity is denoted by g. For this flow, Reynolds number, $Re = \frac{\rho_f U_\infty D}{\mu} \ll 1$ and buoyancy force in the fluid is negligible compared to viscous force. Assuming the string to be weightless and offering negligible drag, the expression for θ is** 
(A)	$\tan^{-1}\left[\frac{1}{18}\frac{D^2\rho_s^2 g}{\mu U_\infty \rho_f}\right]$
(B)	$\tan^{-1}\left[\frac{1}{18}\frac{D^2\rho_f g}{\mu U_\infty}\right]$
(C)	$\sin^{-1}\left[\frac{2}{9}\frac{D^2\rho_s g}{\mu U_\infty}\right]$
(D)	$\tan^{-1}\left[\frac{1}{18}\frac{D^2\rho_s g}{\mu U_\infty}\right]$

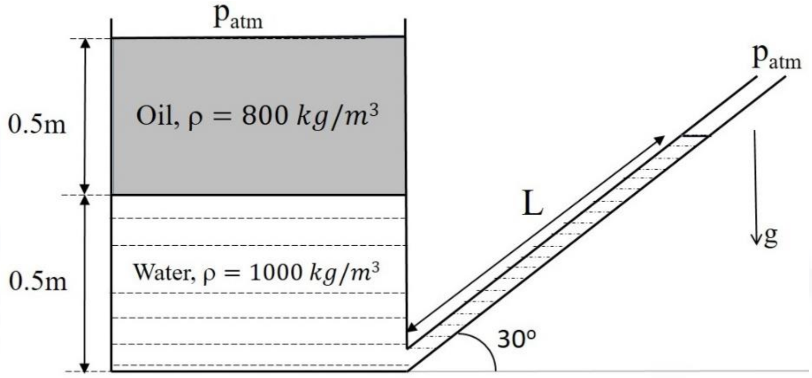
Q. 12	**In a Cartesian coordinate system, a steady, incompressible velocity field of a Newtonian fluid is given by** $$\mathbf{V} = u_0\left(1 - ay^2\right)\ \mathbf{i}$$ **Here, V is the velocity vector in m/s, i is the unit vector in the *x*-direction,** u_0 **is a positive, real constant (in m/s), and *a* is a positive, real constant (in m^{-2}). The viscosity of the fluid is *μ* (in Pa-s). The absolute value of the pressure gradient (in Pa/m) is**
(A)	$a\mu u_0$
(B)	$2a\mu u_0$
(C)	$3a\mu u_0$
(D)	$4a\mu u_0$

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 $P = c\mu L U^2$, where c is a dimensionless constant. The value of the constant c (up to one decimal place) is _________.** 

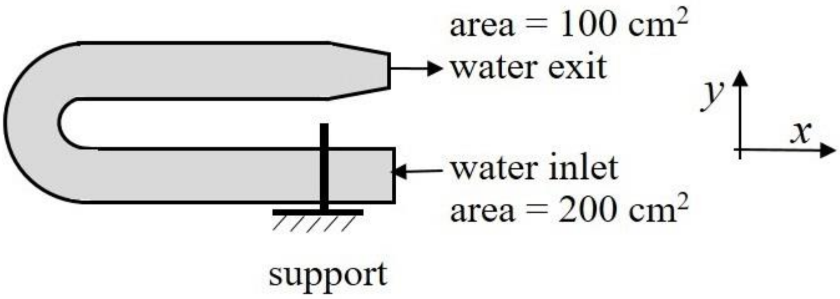
Q. 14	**The two-dimensional velocity field V of a flow in a Cartesian coordinate system is given in dimensionless form by $\mathbf{V} = (x^2 - axy)\,\mathbf{i} + \left(bxy - \frac{y^2}{2}\right)\mathbf{j}$. Here, i and j are the unit vectors along the x and y directions respectively, a and b are independent of x, y and time. If the flow is incompressible, then the value of $(a-b)$, up to one decimal place, is ______.**

Q. 15	**For the configuration shown in the figure, oil of density 800 kg/m^3 lies above water of density 1000 kg/m^3. Assuming hydrostatic conditions and acceleration due to gravity $g = 10$ m/s^2, the length L (in meters, up to one decimal place) of water in the inclined tube is _____.**

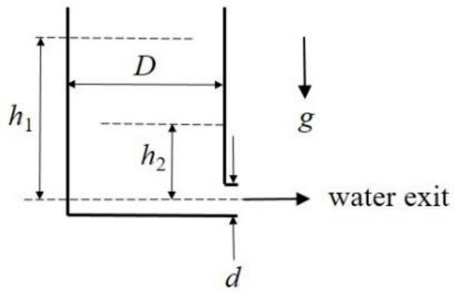


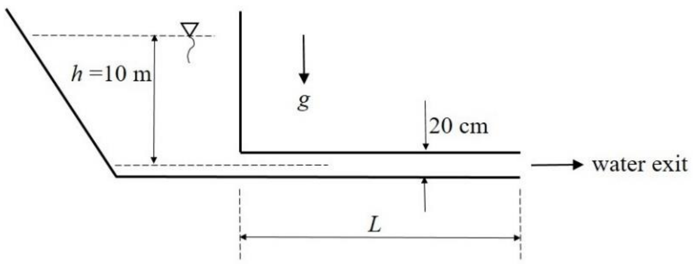
Q. 16	**A two-dimensional Eulerian velocity field is given (in m/s) by $\mathbf{V} = [(\sqrt{5})x]\,\mathbf{i} - [(\sqrt{12})y]\,\mathbf{j}$, where x and y are the coordinates (in meters) in a Cartesian coordinate system. The magnitude of the acceleration (in m/s^2, up to one decimal place) of a fluid particle at $x = 1$ m and $y = -1$ m is ______.**

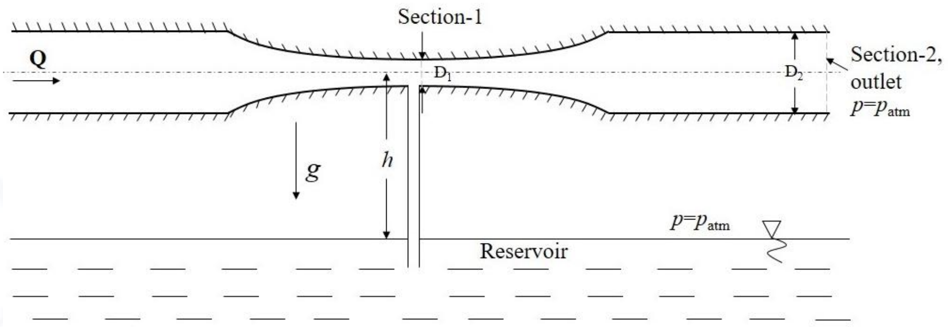
Q. 17	**A large pump is to deliver oil at an average velocity (V) of 1.5 m/s. The pump has an impeller diameter (D) of 40 cm and the pressure rise across the pump is 400 kPa. To design this pump, a lab-scale model pump with an impeller diameter of 4 cm is to be used with water as the fluid. The viscosity (μ) of the oil is 100 times that of water, and the densities (ρ) of oil and water are identical. A complete geometric similarity is maintained between the model and prototype. If the pressure rise is a function only of V, D, ρ and μ, the pressure rise (in kPa, up to one decimal place) across the model pump is ______.**

Q. 18	Water (density = 10^3 kg/m^3) enters steadily into a horizontal pipe bend, which is part of a larger piping system, as shown in the figure. The volumetric flow rate of water is 0.1 m^3/s. The gage pressure at the inlet is 500 kPa, while the exit is open to atmosphere. The x-component of the force on the support is F_x. The absolute value of F_x (in kN, up to one decimal place) is ___. 

Q. 19	Air (of density 0.5 kg/m^3) enters horizontally into a jet engine at a steady speed of 200 m/s through an inlet area of 1.0 m^2. Upon entering the engine, the air passes through the combustion chamber and the exhaust gas exits the jet engine horizontally at a constant speed of 700 m/s. The fuel mass flow rate added in the combustion chamber is negligible compared to the air mass flow rate. Also neglect the pressure difference between the inlet air and the exhaust gas. The absolute value of the horizontal force (in kN, up to one decimal place) on the jet engine 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 $g = 10\ \text{m/s}^2$. 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. 21	**Water discharges steadily from a large reservoir through a long pipeline, as shown in the figure. The Darcy friction factor in the pipe is 0.02. The pipe diameter is 20 cm and the discharge of water is 360 m³/h. Water level in the reservoir is 10 m and acceleration due to gravity $g = 10\ \text{m/s}^2$. If minor losses are negligible, the length L (in meters, up to one decimal place) of the pipeline is ____ .** 

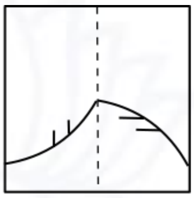
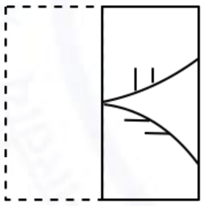
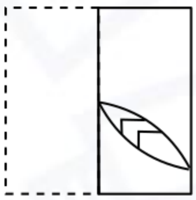
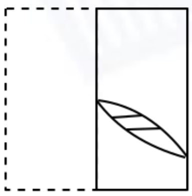
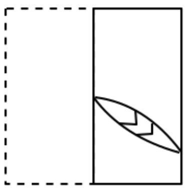
Q. 22	**Water is flowing with a flow rate Q in a horizontal circular pipe. Due to the low pressure created at the venturi section (Section-1 in the figure), water from a reservoir is drawn upward using a connecting pipe as shown in the figure. Take acceleration due to gravity $g = 10$ m/s^2. The flow 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 ___________.** 

END OF THE QUESTION PAPER

General Aptitude (GA)

Q.1 – Q.5 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**Gauri said that she can play the keyboard __________ her sister.**
(A)	as well as
(B)	as better as
(C)	as nicest as
(D)	as worse as

Q.2	 **A transparent square sheet shown above is folded along the dotted line. The folded sheet will look like ________.**
(A)	
(B)	
(C)	
(D)	

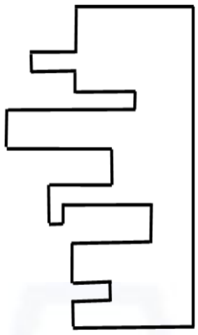
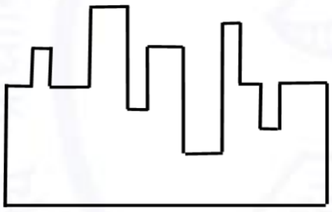
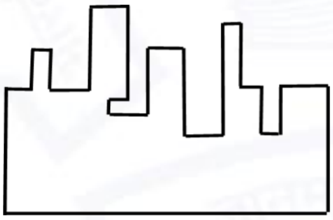
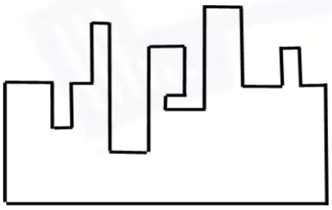
Q.3	**If θ is the angle, in degrees, between the longest diagonal of the cube and any one of the edges of the cube, then, cos θ =**
(A)	$\frac{1}{2}$
(B)	$\frac{1}{\sqrt{3}}$
(C)	$\frac{1}{\sqrt{2}}$
(D)	$\frac{\sqrt{3}}{2}$

Q.4	**If** $\left(x-\frac{1}{2}\right)^2-\left(x-\frac{3}{2}\right)^2=x+2$, **then the value of** x **is:**
(A)	2
(B)	4
(C)	6
(D)	8

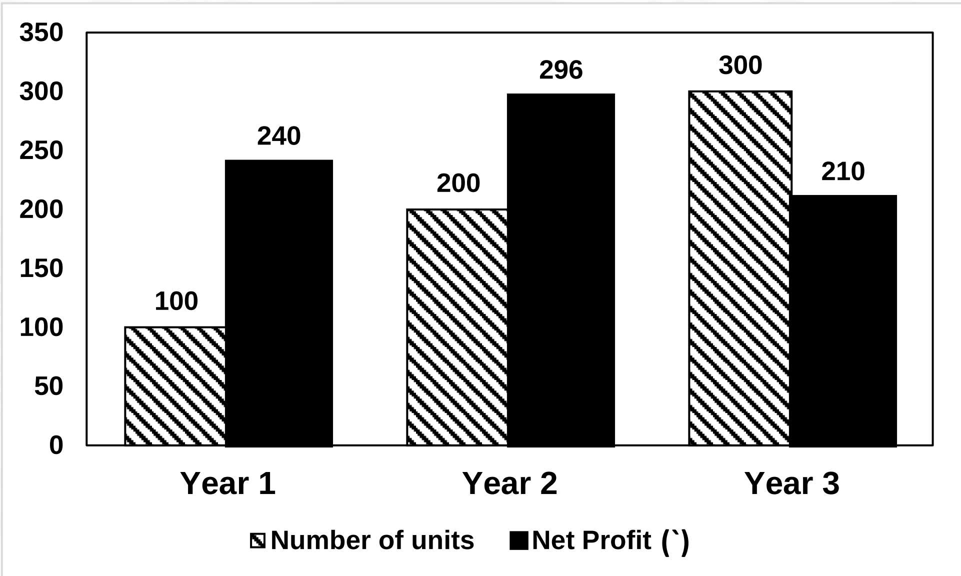
Q.5	**Pen : Write :: Knife : __________** **Which one of the following options maintains a similar logical relation in the above?**
(A)	Vegetables
(B)	Sharp
(C)	Cut
(D)	Blunt

Q. 6 – Q. 10 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

Q.6	**Listening to music during exercise improves exercise performance and reduces discomfort. Scientists researched whether listening to music while studying can help students learn better and the results were inconclusive. Students who needed external stimulation for studying fared worse while students who did not need any external stimulation benefited from music.** **Which one of the following statements is the CORRECT inference of the above passage?**
(A)	Listening to music has no effect on learning and a positive effect on physical exercise.
(B)	Listening to music has a clear positive effect both on physical exercise and on learning.
(C)	Listening to music has a clear positive effect on physical exercise. Music has a positive effect on learning only in some students.
(D)	Listening to music has a clear positive effect on learning in all students. Music has a positive effect only in some students who exercise.

Q.7	 **A jigsaw puzzle has 2 pieces. One of the pieces is shown above. Which one of the given options for the missing piece when assembled will form a rectangle? The piece can be moved, rotated or flipped to assemble with the above piece.**
(A)	
(B)	
(C)	
(D)	

Q.8	**The number of students in three classes is in the ratio 3:13:6. If 18 students are added to each class, the ratio changes to 15:35:21.** **The total number of students in all the three classes in the beginning was:**
(A)	22
(B)	66
(C)	88
(D)	110

Q.9	 The number of units of a product sold in three different years and the respective net profits are presented in the figure above. The cost/unit in Year 3 was ` 1, which was half the cost/unit in Year 2. The cost/unit in Year 3 was one-third of the cost/unit in Year 1. Taxes were paid on the selling price at 10%, 13% and 15% respectively for the three years. Net profit is calculated as the difference between the selling price and the sum of cost and taxes paid in that year. The ratio of the selling price in Year 2 to the selling price in Year 3 is ________.
A)	4:3
(B)	1:1
(C)	3:4
(D)	1:2

Q.10	**Six students P, Q, R, S, T and U, with distinct heights, compare their heights and make the following observations.** **Observation I: S is taller than R.** **Observation II: Q is the shortest of all.** **Observation III: U is taller than only one student.** **Observation IV: T is taller than S but is not the tallest.** **The number of students that are taller than R is the same as the number of students shorter than ______.**
(A)	T
(B)	R
(C)	S
(D)	P

Engineering Mathematics (XE-A)

Q.1 – Q.3 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**Let** $$S = \left\{ AX \ : \ A = \begin{bmatrix} 2 & -4 \\ 1 & 1 \\ 1 & -1 \end{bmatrix} \text{ and } X = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \right\}.$$ **If** $\begin{bmatrix} -1 \\ \alpha \\ 1 \end{bmatrix} \in S$**, then the value of** α **is**
(A)	-4
(B)	-2
(C)	2
(D)	4

Q.2	**Let** C **be the boundary of the region** $R:\ 0 \le x \le \pi,\ 0 \le y \le \sin x$ **in the** xy**-plane and** α **be the area of the region** R**. If** C **traverses once in the counter clockwise direction, then the value of the line integral** $\oint_C (2y\,dx + 5x\,dy)$ **is equal to**
(A)	α
(B)	2α
(C)	3α
(D)	4α

Q.3	**Given that $i = \sqrt{-1}$. The value of** $$\lim_{z \to e^{\frac{\pi i}{3}}} \frac{z^3+1}{z^4+z^2+1}$$ **is**
(A)	$\frac{3}{4} + i\,\frac{\sqrt{3}}{4}$
(B)	$\frac{3}{4} - i\,\frac{\sqrt{3}}{4}$
(C)	$\frac{-3}{4} + i\,\frac{\sqrt{3}}{4}$
(D)	$\frac{-3}{4} - i\,\frac{\sqrt{3}}{4}$

Q.4 – Q.7 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

Q.4	**Let $f(x)$ be a non-negative continuous function of real variable x. If the area under the curve $y = f(x)$ from $x = 0$ to $x = a$ is $\frac{a^2}{2} + \frac{a}{2}\sin a + \frac{\pi}{2}\cos a - \frac{\pi}{2}$, then the value of $f\left(\frac{\pi}{2}\right)$ is __________________ (*round off to one decimal place*).**

Q.5	**If the numerical approximation of the value of the integral $\int_0^4 2^{\alpha x}\, dx$ using the Trapezoidal rule with two subintervals is 9, then the value of the real constant α is __________________ (*round off to one decimal place*).**

Q.6	**Let the transformation $y(x) = e^x v(x)$ reduce the ordinary differential equation** $$x\frac{d^2y}{dx^2} + 2(1-x)\frac{dy}{dx} + (x-2)\,y = 0;\;\; x > 0$$ **to** $$\alpha x\frac{d^2v}{dx^2} + 2\beta\frac{dv}{dx} + 3\gamma v = 0,$$ **where α, β, γ are real constants. Then, the arithmetic mean of α, β, γ is ______________ (*round off to three decimal places*).**

Q.7	**A person, who speaks the truth 3 out of 4 times, throws a fair dice with six faces and informs that the outcome is 5. The probability that the outcome is really 5 is __________________ (*round off to three decimal places*).**

Q. 8 – Q. 9 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

Q. 8	**Let $f(x, y) = x^4 + y^4 - 2x^2 + 4xy - 2y^2 + \alpha$ be a real valued function. Then, which one of the following statements is TRUE for all α ?**
(A)	$(0, 0)$ is not a stationary point of f
(B)	f has a local maxima at $(0, 0)$
(C)	f has a local minima at $(0, 0)$
(D)	f has a saddle point at $(0, 0)$

Q. 9	**Let $u(x, y) = (x^2 - y^2)v(x, y)$ be such that both $u(x, y)$ and $v(x, y)$ satisfy the Laplace equation in a domain Ω of the xy-plane. Then, which one of the following is TRUE in Ω ?**
(A)	$x\frac{\partial v}{\partial x} - y\frac{\partial v}{\partial y} = 0$
(B)	$x\frac{\partial v}{\partial x} + y\frac{\partial v}{\partial y} = 0$
(C)	$x\frac{\partial v}{\partial y} - y\frac{\partial v}{\partial x} = 0$
(D)	$x\frac{\partial v}{\partial y} + y\frac{\partial v}{\partial x} = 0$

Q. 10 – Q. 11 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

Q. 10	**Let I denote the identity matrix of order 7, and A be a 7×7 real matrix having characteristic polynomial $C_A(\lambda) = \lambda^2(\lambda - 1)^\alpha(\lambda + 2)^\beta$, where α and β are positive integers. If A is diagonalizable and $rank(A) = rank(A + 2I)$, then $rank(A - I)$ is ____________ (*in integer*).**

Q. 11	**Let C_1 be the line segment from $(0, 1)$ to $\left(\frac{4}{5}, \frac{3}{5}\right)$, and let C_2 be the arc of the circle $x^2 + y^2 = 1$ from $(0, 1)$ to $\left(\frac{4}{5}, \frac{3}{5}\right)$. If** $$\alpha = \int_{C_1} \left(\frac{2x}{y}\,\hat{\imath} + \frac{1 - x^2}{y^2}\hat{\jmath}\right) \cdot d\vec{r} \quad \text{and} \quad \beta = \int_{C_2} \left(\frac{2x}{y}\,\hat{\imath} + \frac{1 - x^2}{y^2}\hat{\jmath}\right) \cdot d\vec{r}\,,$$ **where $\vec{r} = x\,\hat{\imath} + y\,\hat{\jmath}$, then the value of $\alpha^2 + \beta^2$ is ________________ (*round off to two decimal places*).**

END OF THE QUESTION PAPER