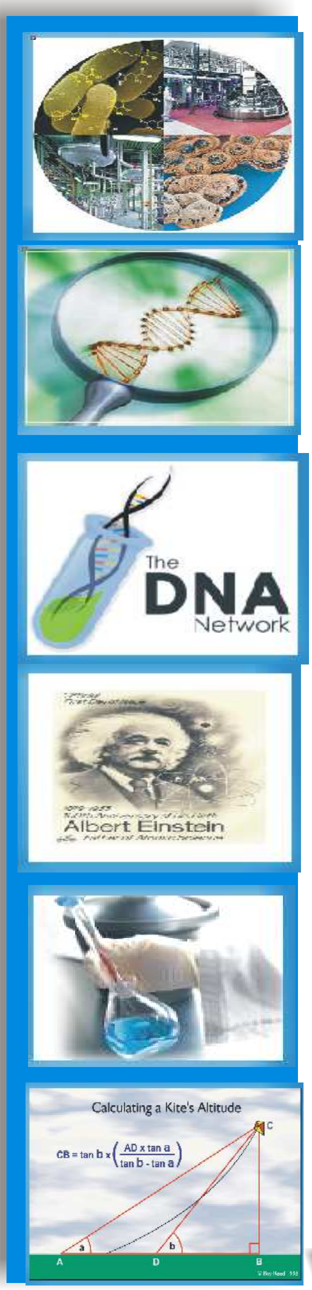

GATE - ENGINEERING SCIENCE
MOCK TEST PAPER

- A total of 65 questions are to be attempted carrying 100 marks.
- There are 10 question carrying 15 marks in General Aptitude (GA) section, which is compulsory. Question Q.1 - Q.5 carry 1 mark each, and questions Q.6 - Q.10 carry 2 marks each.
- There are 11 questions carrying 15 marks in section A (Engineering Mathematics), which is also compulsory. Questions Q.1 - Q.7 carry 1 mark each and question Q.8 - Q.11 carry 2 marks each.
- Attempt any two optional Sections from B through G. Each of these sections (Sections B through G) contains 22 questions carrying 35 marks. Questions Q.1 - Q.9 carry 1 mark each and questions Q.10 - Q.22 carry 2 marks each. The 2 marks questions include two pairs of common data questions and one pair of linked answer questions.
- For all 1 mark questions, 1/3 mark will be deducted for each wrong answer.
  For all 2 marks questions, 2/3 mark will be deducted for each wrong answer.
  There will be no negative marking for numerical answer type questions.
- Pattern of questions : MCQs & Numerical
- Total marks : 100
- Duration of test : 3 Hours

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GENERAL APTITUDE

Q. 1 – Q. 5 carry one mark each.

1. If in the word PROJECTING, all the vowels are first arranged alphabetically and then all the consonants are arranged alphabetically which letter will be fifth from the left?

(A) C

(B) N

(C) J

(D) G

2. The trick involved in any attempt to create a/an _____ of three dimensions when only two are present is well known.

(A)extra

(B)image

(C)angle

(D)illusion

DIRECTION : Each question below has a sentence, from the choices provided, identify the one which best restates the given sentence and mark its number as the answer.

3. That man is aggressive by nature is a hard fact of life and no one can deny it.

(A) That man is aggressive by nature is a hard fact of life which none can deny.

(B) That man is aggressive by nature is a hard fact of life and no one can deny it.

(C) That man is aggressive by nature is a hard fact of life and not one can deny.

(D) That man is aggressive by nature is hard for anyone to deny.

Directions for question 4:Select the pair that does not express a relationship similar to that expressed by the capitalized pair.

4. READY : WIT

(A) upright : carriage

(B) handy : sake

(C) hearty : appetite

(D) keen : intelligence

Directions:5– In each of the following questions two statement are given and these statements are followed by two conclusions numbered I and II. You have to take the given two statements to be true even if they seem to be at variance from commonly known facts. Read the conclusions and then decide which of the given conclusions logically follows from the two given statements, disregarding commonly known facts.

Given Answer :

(A) If only I conclusion follows

(B) If only II conclusion follows

(C) If both I and II follow

(D) If neither I nor II follows and

Statements : All the harmoniums are instruments. All the instruments are flutes.

Conclusions :

I. All the flutes are instruments.

II. All the harmoniums are flutes.

Q. 6 to Q. 10 carry two marks each.

6. Two plots in Bandra were sold for Rs. 1 crore each. The first plot in Pali hill was sold at a gain of 12% and the second one at reclamation was sold at a loss of 12%. Find the total loss or profit percentage?

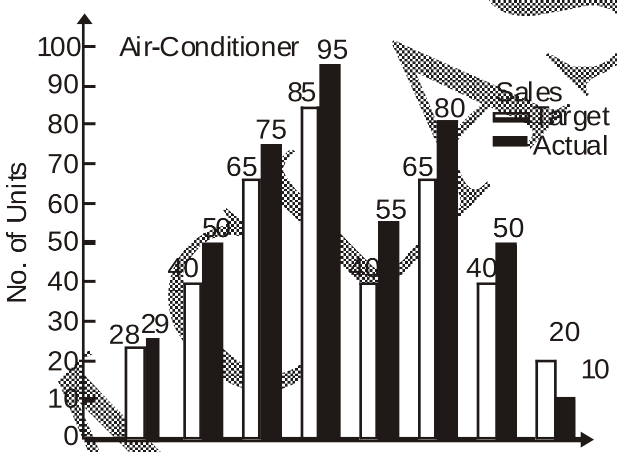
(A) There is neither a profit nor a loss

(B) Gain of 12%

(C) loss of 1.44%

(D) Gain of 1.44%

7. A company manufacturing air-conditioners sets a monthly target. The target and realized values are shown in the bar chart.



As compared to target, total net sales value exceeded by ?

(A) 7.5 %

(B) 7.7 %

(C) 6.9 %

(D) None of these

8. In the following questions two equations numbered I and II are given. You have to solve both the equations and

Give answer	if
(A)	$x > y$
(B)	$x \geq y$
(C)	$x < y$
(D)	$x \leq y$

I. $2x^2 - 9x + 9 = 0$

II. $y^2 - 11y + 24 = 0$

9. Which letter replaces the question mark?

N	252	R
T	500	Y
Y	400	P
K	132	L
G	182	?

(A) P

(B) U

(C) Z

(D) B

10. At a car park there are 100 vehicles, 60 of which are cars, 30 are vans and the remainder are lorries. If every vehicle is equally like to leave, find the probability of lorry leaving first.

(A) 3/10

(B) 7/10

(C) 1/10

(D) 9/10

A: ENGINEERING MATHEMATICS

Q. 1 – Q. 7 carry one mark each.

1. The eigen vectors of a real symmetric matrix corresponding to different eigen values are

(A) orthogonal

(B) singular

(C) non - singular

(D) none of these

2. Let $f(x) = x^2 \sin\frac{1}{x}$ for $x \neq 0$, $f(0) = 0$, then

(A) f(x) is continuous and differentiable at x = 0

(B) f(x) is continuous but not differentiable at x = 0

(C) f(x) is neither continuous nor differentiable at x = 0

(D) None of these

3. The minimum number of equal length subintervals needed to approximate $\int_1^2 xe^x\,dx$ to an accuracy of at least $1/3 \times 10^{-6}$ using the trapezoidal rule is

(A) 1000e

(B) 1000

(C) 100e

(D) 100

4. A has one share in a lottery in which there is 1 prize and 2 blanks; B has three shares in a lottery in which there are 3 prizes and 6 blanks; Compare the probability of A's success to that of B's success.

(A) 7 : 16

(B) 16 : 7

(C) 6 : 14

(D) 14 : 6

5. If $y_1(x) = x$ is a solution of differential equation $x^2\frac{d^2y}{dx^2} - 2x(1+x)\frac{dy}{dx} + 2(1+x)y = 0$ then the second linearly independent solution is

(A) $-\frac{x}{2} + \frac{c_1}{2}e^{2x} + c_2$

(B) $\frac{x}{2} + c_1e^{-2x} + c_2$

(C) $\frac{x}{2} + c_1e^{2x} + c_2$

(D) $-\frac{x}{2} + c_1e^{-2x} + c_2$

6. $\iint\sqrt{a^2 - x^2 - y^2}\,dx\,dy$ over the semicircle $x^2 + y^2 = ax$ in the positive quadrant is equal to–

(A) $\frac{1}{3}a^3\left(\pi - \frac{1}{2}\right)$

(B) $\frac{2}{3}a^3\left(\frac{\pi}{3} - \frac{2}{3}\right)$

(C) $\frac{1}{3}a^3\left(\frac{\pi}{2} - \frac{2}{3}\right)$

(D) $\frac{2}{3}a^3\left(\frac{\pi}{2}-\frac{1}{3}\right)$

7. Let I = $\oint_c \frac{z-3}{z^2+2z+5}dz$

(A) if c : |z| = 1 , I = 0

(B) if c : |z| = 1, I = πi

(C) if c : |z + 1 + i| = 2 , I = π (2 + i)

(D) Both 1 & 3

8. Evaluate $\int_0^{2\pi} e^{2x\cos\theta}d\theta$

(A) $\sum_{n=0}^{\infty}\left(\frac{x^n}{n!}\right)$

(B) $\sum_{n=0}^{\infty}\left(\frac{x^n}{n!}\right)^2$

(C) $\sum_{n=0}^{\infty}\left(\frac{x^{n+1}}{n!}\right)^2$

(D) $\sum_{n=0}^{\infty}\left(\frac{x^{n+1}}{n!}\right)$

9. Using Gauss divergence theorem evaluate

$$\iint_S (x^3\,dy\,dz + y^3\,dz\,dx + z^3\,dx\,dy)$$

where S is the surface of the sphere $x^2 + y^2 + z^2 = a^2$

(A) $4\pi a^5$

(B) $2\pi a^5$

(C) $4\pi a^3$

(D) $2\pi a^3$

10. Using Runge - Kutta Method to solve

$$\frac{dy}{dx} = xy$$

for x = 1.2. Initially x = 1, y = 2 (take h = 0.2)

(A) y(1.2) = 2.4634

(B) y (1.2) = 2.4912

(C) y(1.2) = 2.4921

(D) y (1.2) = 2.4921

11. Find the general solution for

$$x^2 y'' + 3xy' - 8y = \ln^3 x - \ln x, x > 0$$

(A) $y(x) = c_1 x^2 + c_2 x^{-4} - 3/32 \ln x - 1/64 \ln^2 x$

(B) $y(X) = c_1 e^{2x} + c_2 e^{-4x} - 1/8 x^3 - 3/32 x^2 - 1/64 x - 7/25$

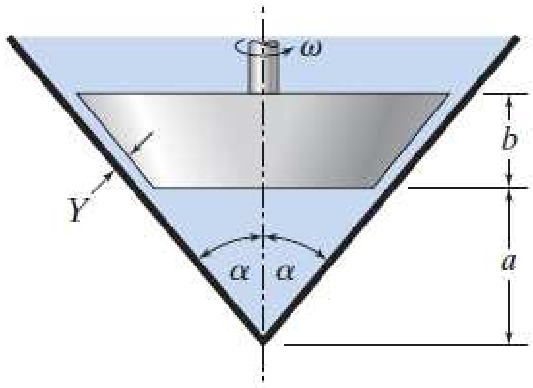
(C) $y(x) = c_1 x^2 + c_2 x^{-4} - 1/8 \ln^3 x - 3/32 \ln^2 x - 1/64 \ln x - 7/256$

(D) No solution

PART B: FLUID MECHANICS

Q. 1 – Q. 9 carry one mark each.

1. In Fig.given below oil of absolute viscosity μ fills the small gap of thickness Y. (a) Neglecting fluid stress exerted on the circular underside, obtain an expression for the torque T required to rotate the truncated cone at constant speed ω. (b) What is the rate of heat generation, in joules per second, if the oil's absolute viscosity is 0.20 N·s/m^2, α = 45°, a = 45 mm, b = 60 mm, Y = 0.2 mm, and the speed of rotation is 90 rpm?



Figure

(A) $\frac{2\pi\mu\omega\tan^3\alpha}{4Y\cos\alpha}\left[(a+b)^2-a^2\right]$, 23.2 J/s

(B) $\frac{2\pi\mu\omega\tan^2\alpha}{4Y\cos\alpha}\left[(a+b)^3-a^3\right]$, 23.2 J/s

(C) $\frac{2\pi\mu\omega\tan^3\alpha}{4Y\cos\alpha}\left[(a+b)^4-a^4\right]$, 32.2 KJ/s

(D) $\frac{2\pi\mu\omega\tan^3\alpha}{4Y\cos\alpha}\left[(a+b)^4-a^4\right]$, 23.2 J/s

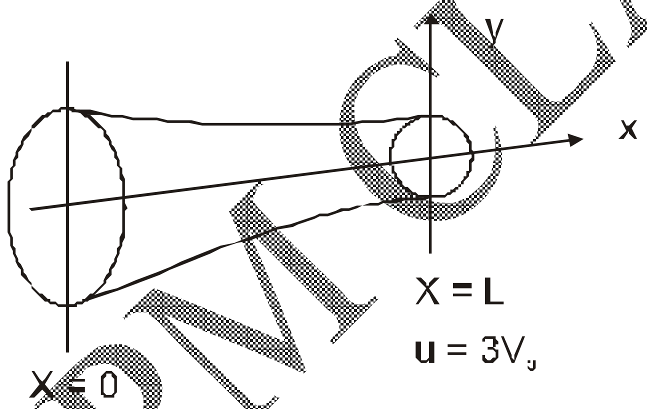
2. Flow through a converging nozzle can be approximated by a one dimensional velocity distribution u = u(x). For the nozzle shown, assume that the velocity varies linearly from $u = V_o$ at the entrance to $u = 3V_o$ at the exit. Compute the acceleration $\frac{D\underline{V}}{Dt}$ as a function of x.

(A) $\frac{2V_0^2}{L}\left(\frac{2x}{L}\right)$

(B) $\frac{2V_0^2}{L}\left(\frac{2x}{L}+2\right)$

(C) $\frac{2V_0^2}{L}\left(\frac{2x}{L}+1\right)$

(D) zero



3. Find the convective acceleration at the middle of a pipe which converges uniformly from 0.4 m diameter to 0.2 m diameter over 2 m length. The rate of flow is 20 lit/s.

(A) 0.048 m/s^2

(B) 0.0408 m/s^2

(C) 48 m/s^2

(D) 0.0048 m/s^2

4. Time of emptying liquid from a hemispherical vessel through an orifice at its bottom is :

(A) $\dfrac{\pi R^{3/2}}{15\ Cda\sqrt{2g}}$

(B) $\dfrac{2\pi R^{3/2}}{15\ Cda\sqrt{2g}}$

(C) $\dfrac{7\pi R^{3/2}}{15\ Cda\sqrt{2g}}$

(D) $\dfrac{14\pi R^{3/2}}{15\ Cda\sqrt{2g}}$

5. While using Boundary layer equations, Bernoulli equation -

(A) Can be used anywhere.

(B) Can be used only outside the boundary layer.

(C) Can be used only inside the boundary layer.

(D) Cannot be used either inside or outside the boundary layer.

6. A nozzle is situated at a distance of 1 m above the ground level and is inclined at an angle of 45° to the horizontal. The diameter of the nozzle is 50 mm and the jet of water from the nozzle strikes the ground at a horizontal distance of 4 m. The rate of flow of water will be ______ m^3/s.

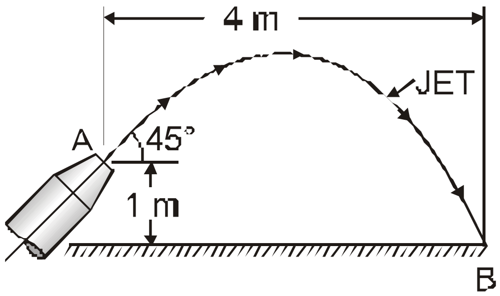


Fig.

7. The velocity components in a two-dimensional flow are

$$u = y^3/3 + 2x - x^2y \text{ and } v = xy^2 - 2y - x^3/3.$$

Then these components represent a possible case of an irrotational flow in which rotation is ________.

(A) zero

(B) one

(C) Two

(D) None of these

8. If for a two-dimensional potential flow, the velocity potential is given by

$$\phi = x(2y - 1)$$

Determine the value of stream function ψ at the point P.

(A) $-y - x^2$

(B) $y^3 - y^2 - x$

(C) $y^2 + y + x^2$

(D) $y^2 - y - x^2$

9. The strength of a free vortex is $2m^2/s$ and it is placed in a uniform flow of 3 m/s in the x direction. Calculate the pressure difference between the main stream and a point at x = 0.5 and y = 0.5. The density of the fluid is 997 kg/m^3.

(A) -17844 pascal

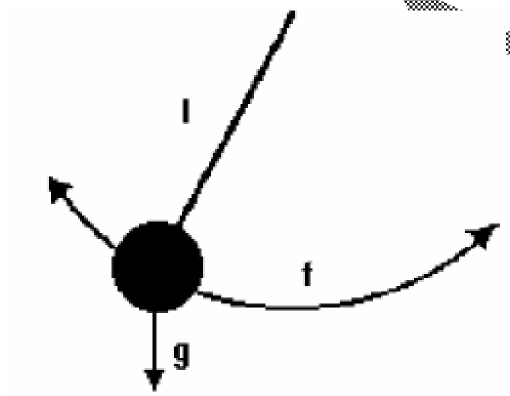
(B) -11964 pascal

(C) -15454 pascal

(D) -19556 pascal

Q. 10 - Q. 22 carry two marks each.

10. Which of the following shows the relationship between f, l and g for the simple pendulum.



(A) $(1/3\pi)(g/l)^{1/2}$

(B) $(1/2\pi)(g/l)^{1/2}$

(C) $(1/8\pi)(g/l)^{1/2}$

(D) $(1/4\pi)(g/l)^{1/2}$

11. The resistance to motion 'R' for a sphere of diameter 'D' moving at constant velocity 'v' through a compressible fluid is dependent upon the density 'ρ' and the bulk modulus 'K'. The resistance is primarily due to the compression of the fluid in front of the sphere, then find out the dimensionless relationship between these quantities is -

(A) N_e = function (M_a).

(B) N_e = function $(2M_a)$.

(C) N_e = function $(89M_f)$.

(D) N_e = function $(9M_p)$.

12. A fluid flows from a large pressurized tank through a 100 mm long, 4 mm diamater tube. In a 600 sec time period, 1300 cm^3 of fluid are collected in a measuring cup. If the head loss in the tube is 1 m, the kinematic viscosity v is ________.

13. The Chezy's coefficient C is related to Darcy-Weisbach friction factor as

(A) $C = \sqrt{g/8f}$

(B) $C = \sqrt{8g/f^{1/4}}$

(C) $C = \sqrt{8g/f}$

(D) $C = \sqrt{f/8g}$

14. The displacement thickness δ* for a Laminar BL modeled by the equation

$u = u_1 \sin(\pi y/2\delta)$ is

(A) $3.64\delta^2$

(B) 0.364δ

(C) 36.4δ

(D)None of these

15. A metal ball of diameter 1.2 ft and weight 99 lb is dropped into the ocean. _______fps will be the maximum velocity the ball will achieve if, for seawater, $\rho = 2.0$ slugs/ft^3 and $\mu = 3.3 \times 10^{-5}$ lb-s/ft^2.

16. A horizontal venturimeter with inlet and throat diameters 30 cm and 15 cm respectively is used to measure the flow of water. The reading of differential manometer connected to the inlet and the throat is 20 cm of mercury. The rate of flow will be______ lit/s. Take $C_d = 0.98$.

Common Data Questions

Common Data For Ques 17 and 18

A smooth pipe of diameter 80 mm and 800 m long carries water at the rate of 0.480 m^3/minute. Take kinematic viscosity of water as 0.015 stokes. Take the value of co-efficient of friction 'f' from the relation given as

$$f = \frac{.0791}{(R_e)^{1/4}}, \text{ where } R_e = \text{Reynolds number.})$$

17. Calculate the loss of head.

(A) 234.2m

(B) 0.2342m

(C) 23.42cm

(D) 23.42m

18. Calculate the thickness of laminar sub-layer.

(A) 2.274 cm

(B) 0.02274 cm

(C) 0.02274 m

(D) 0.02274 cm

Common Data For Ques 19 and 20

Experiments were conducted in a wind tunnel with a wind speed of 50km/h. on a flat plate of size 2m long and 1m wide. The plate is kept at such an angle that the co-efficient of lift and drag are 0.75 and 0.15 respectively.

Take $\rho = 1.2\ kg/m^3$.

Given: $A = 2m^2$; $C_L = 0.75$; $C_D = 0.15$; $\rho = 1.2\ kg/m^3$; U= 13.89m/s

19. The Resultant force will be________ N

20. The Power required to maintain the flow will be ______kW.

Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

A uniform flow of 12 m/s is flowing over a doublet of strength 18 m^2/s. The doublet is in the line of the uniform flow.

21. Determine the shape of the Rankine oval.

(A) Hyperbola

(B) ellipse

(C) Parabola

(D) circle

22. What will be the radius of the Rankine circle?

(A) 0.587m,

(B) 0.488m,

(C) 0.458m,

(D) 0.677m,

PART-C (MATERIAL SCIENCE)

Q. 1 – Q. 9 carry one mark each.

1. Copper has fcc structure and its atomic radius is 1.273 Å, the bond length and the density of copper is (atomic weight of copper = 63.5 and Avogadro number = 6.02×10^{23} molecules per gm mole)

(A) 5.7 Å, 6.082×10^3 kg/m^3

(B) 3.6 Å, 6.082×10^3 kg/m^3

(C) 3.6 Å, 9.043×10^3 kg/m^3

(D) 5.7 Å, 9.043×10^3 kg/m^3

2. The radius of sodium ions and chlorine ions in sodium chloride is 0·098 nm and 0·181 nm. Determine the packing factor for sodium chloride.

(A) 0·555

(B) 0·662

(C) 0·465

(D) 0·789

3. Copper having FCC with atomic radius 0·128 nm. Find the spacing with (1 1 1) planes.

(A) 0.362 nm

(B) 0.548 nm

(C) 0.209 nm

(D) 0.852 nm

4. Maxwell and Kelvin-Voigt models are to be set up to simulate the creep behaviour of a plastic. The elastic and viscous constants for the Kelvin-Voigt models are 2·2 GN/m^2 and 110 GN s/m^2 respectively and the viscous constant for the Maxwell model is 200 GN s/m^2. Estimate a suitable value for the elastic constant for the Maxwell model if both models are to predict the same creep strain after 50 sec.

(A) 28·53 G N/m^2

(B) 27·98 G N/m^2

(C) 26·79 G N/m^2

(D) 25.66 G N/m^2

5. A hypoentectoid plain-carbon steel that was slow-cooled from the austenite region to room temperature contains 8·2 wt% eutectoid ferrite. Assuming no change in structure just below the eutectoid temperature to room temperature, what is the carbon content of the steel ?

(A) 0·1455 % C

(B) 0·0052 % C

(C) 0·0507 % C

(D) 0·0985 % C

6. What is the maximum temperature to which a brass rod may be heated from 20°C, without exceeding a compressive stress of 172 MPa. Modulus of elasticity of brass is 100 GPa and linear coefficient of thermal expansion is 20×10^{-6} (°C)$^{-1}$ at 20°C.

(A) 96°C

(B) 106°C

(C) 154°C

(D) 236°C

7. A reaction bonded silicon nitride ceramic has a strength of 300 MPa and a fracture toughness of 3.6 MPa$\sqrt{m}$. What is the largest-size internal crack that this material can support without fracturing? Use Y = 1 in the fracture toughness equation.

(A) 65·4 μm

(B) 91·6 μm

(C) 43·7 μm

(D) 87·5 μm

8. If a copper wire of commercial purity is to conduct 12 A of current with a maximum voltage drop of 0·6 V/m, what must be its minimum diameter ?

Assume, electrical conductivity of material 'σ' is $5{\cdot}85 \times 10^{7}$ $(\Omega m)^{-1}$.

(A) $6{\cdot}013 \times 10^{-4}$ m

(B) $7{\cdot}541 \times 10^{-4}$ m

(C) $8{\cdot}310 \times 10^{-4}$ m

(D) $9{\cdot}605 \times 10^{-4}$ m

9. Calculate the density of MgO using the following data :

structure : FCC anion packing, cations in the octahedral voids.

Radius of Mg^{2+} ion = 0·78 Å

Radius of O^{2-} ion = 1·32 Å

(A) 1110 kg/m^3

(B) 4201 kg/m^3

(C) 3610 kg/m^3

(D) 2235 kg/m^3

Q. 10 - Q. 22 carry two marks each.

10. Match the following and choose the correct combination

Group 1	**Group 2**
Characteristics	**Element**
P. Atomic configuration $1s^2 2s^2 2p^6 3s^2 3p^6$	1. Na
Q. Strongly electropositive	2. Si
R. Strongly electronegative	3. Ar
S. Covalent bonding	4. Cl

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

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

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

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

11. The atomic percentage ratio of Cu to Au in an intermetallic compound which consists of 49·2 wt% Cu and 50·8 wt% Au is ________ (Cu = 64, Au = 197).

12. A sample of glass has a crack of half length 2 µm. The Young's modulus of the glass is 70 GN/m^2 and specific surface energy is 1J/m^2. Estimate its fracture strength.

(A) 935 MPa

(B) 783 MPa

(C) 632 MPa

(D) 576 MPa

13. A sign board weighing 4 kN is supported by a two bar truss ACB as shown in Fig. The truss consists of two bars AC and BC pinned to each other at C and supported by pins at A and B. The sectional area required for the bar AC and the diameter of the pin at the support B will be ________. Allow a safe tensile stress of 125 N/mm^2 and a safe shear stress of 50 N/mm^2.

14. The percentage volume change that occurs when iron changes from a body centered cubic structure to a face centered cubic structure is ______.

15. The packing efficiency and the density of diamond will be ________ and _______ kg/m^3, respectively. The mass of carbon atom is 12 amu and lattice size is 0·357 nm. The diamond having cubic unit cell.

16. Consider the gas carburizing of a gear of 1020 steel at 927 °C. The time (in minutes) necessary to increase the carbon content to 0·40 wt% 0·50 mm below the surface will be ______hrs. Assume that the carbon content at the surface is 0·90 wt% and that the steel has a nominal carbon content of 0·20 wt%. Given : Diffusivity of C in Fe (g) at 927 °C, D = 1·28 × 10^{-11} m^2/s, if erf(z) = 0·7143, z = 0·755.

Common Data Questions

Common Data For Ques 17 and 18

A certain orthorhombic crystal has axial units a : b : c 0.424 : 1 : 0.367.

17. The Miller indices of crystal faces whose intercepts is 0.212 : 1 : 0.183 is _______.

18. The Miller indices of crystal faces whose intercepts is 0.848 : 1:0.732 is______.

Common Data For Ques 19 and 20

A unidirectional fiber-epoxy composite contains 65% by volume fibers and 35% epoxy resin.

19. The weight percentages of fiber and epoxy resin in composite material is _____% and ________% respectively.

20. If Young's modulus of the fiber is 400 GPa and that of epoxy resin matrix is 50 GPa, the Young's modulus of the composite is ________ GPa.

Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

Glass fibers (diameter = 20 mm) provide longitudinal reinforcement for nylon subjected to tensile loadings. Young's modulus of glass fiber and nylon are 70,000 MPa and 2800 MPa respectively.

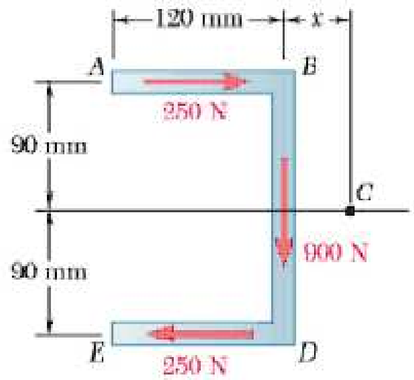
21. If the volume fraction of the glass fiber used is 0·45, Then fraction load carried by this glass fiber will be _____ N.

22. If the average stress in the composite is 14 MPa. Then the amount of stress in glass will be _______ MPa.

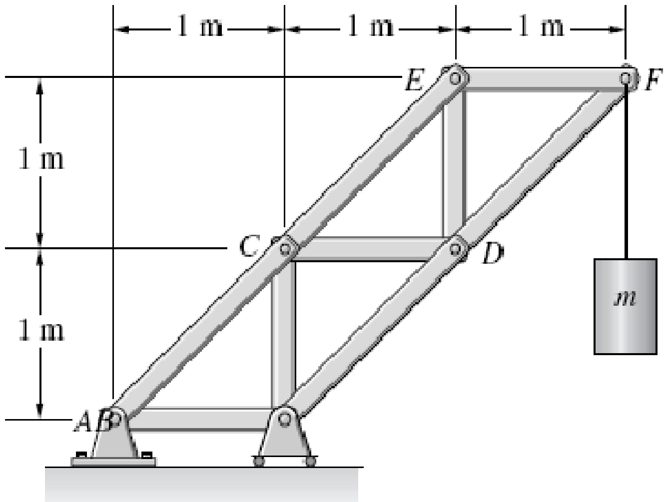
PARTD: SOLID MECHANICS

Q. 1 – Q. 9 carry one mark each.

1. The shearing forces exerted on the cross section of a steel channel can be represented as 900N vertical and two 250 N horizontal forces. Replacing these forces with a SINGLE force at C (C is called the shear center), the value of x will be _______.



2. Each member of the truss will safely support a tensile force of 4 kN and a compressive force of 1 kN. The largest mass m that can safely be suspended is _________.



3. The coefficient of static and kinetic friction between a body and the surface are .75 and .50 respectively. A force is applied to the body to make it just slide with a constant acceleration which is _______ times g.

4. A particle moves with uniform acceleration along a straight line ABC. The speed of the particle at positions A and C are 5 cm/sec and 15cm/ sec respectively. If point B lies midway between A and C, the ratio of time taken by the particle to travel distances AB and BC is _________.

5. A 2.0-kg box is attached by a string to a 5.0-kg box. A compressed spring is placed between them. The two boxes are initially at rest on a friction-free track. The string is cut and the spring applies an impulse to both boxes, setting them in motion. The 2.0-kg box is propelled backwards and moves 1.2 meters to the end of the track in 0.50 seconds. The time it takes the 5.0-kg box to move 0.90 meters to the opposite end of the track will be _______ s.

6. A bar of circular cross-section varies uniform by from a cross-section 2D to D if extension of the bar is calculated treating it as a bar of average diameter, then the percentage cross will be _________ %.

7. All the failure theories give nearly the same result–

(A) When one of the principal stresses at a point is large in comparison to the other.

(B) When shear stress act

(C) When both the principal stresses are numerically equal.

(D) For all situation of stress

8. A cylindrical bar of 20 mm diameter and 1m length is subjected to a tensile test Its longitudinal strain in 4 times that of its lateral strain. If the modulus of elasticity is 2×10^5 N/mm^2, then its modulus of rigidity will be –

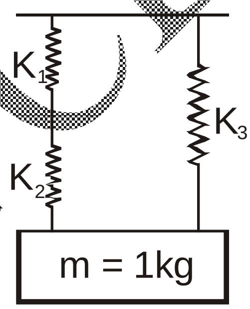
(A) 8×10^6 N/mm^2

(B) 8×10^5 N/mm^2

(C) 0.8×10^4 N/mm^2

(D) 0.8×10^5 N/mm^2

9. A mass of 1 kg in suspended by means of 3 springs as shown in figure the spring constants K_1, K_2 and K_3 are 1 kN/m, 3 kN/m and 2kN/m respectively. The natural frequency of the system in approximately given as ________Hz.



Q. 10 - Q. 22 carry two marks each.

10. Shown in Fig. is a statically determinate simple truss, loaded by concentrated loads at pins D and B. What is the total deflection of pin C as a result of these loads?

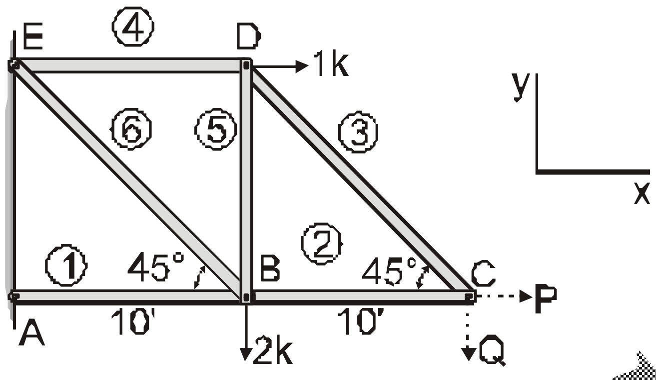


Figure. Simple plane truss.

(A) $\Delta_C = \frac{1}{AE}(-20i - 106.6j)$ ft

(B) $\Delta_C = (-20i - 106.6j)$ ft

(C) $\Delta_C = \frac{1}{AE}(-20i)$ ft

(D) $\Delta_C = \frac{1}{AE}(-106.6j)$ ft

11. A point in a two-dimensional state of strain is subjected to pure shearing strain of magnitude γ_{xy} radians. The maximum principal strain will be _____ times γ_{xy}.

12. The maximum deflection of the pin-connected beams shown in Fig will be ______m. The weight of the beam has been included in the 180 N/m uniform loading. Take $E = 2 \times 10^{11}$ Pa.

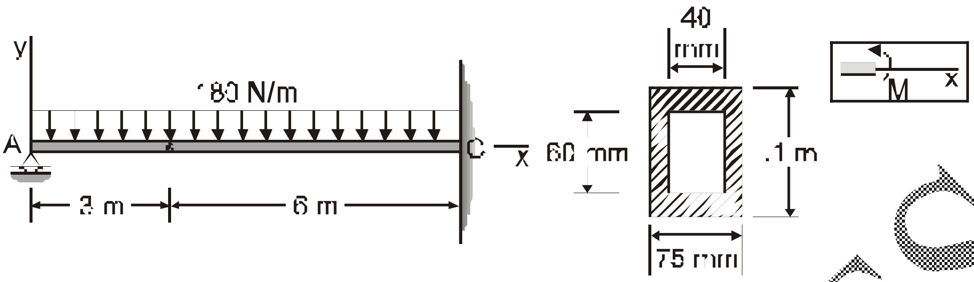
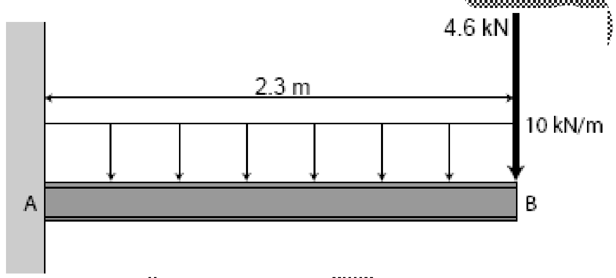


Figure. Pin-connected beams.

13. A W300 × 0.77 wide-flange steel beam acts as a cantilever, subject to the loads shown below. The maximum bending stress in the beam will be ________MPa. (Assume that the maximum shear stress is along the centroidal axis.)



14. A circular shaft can transmit a torque of 5kNm. If the torque is reduced to 4 kNm. Then the maximum value of bending moment that can be applied to the shaft is ___________ kNm.

15. A torsion member is fabricated from two concentric thin tubes. At the ends, the tubes are welded to rigid discs so that both the tubes are twisted as a unit. The radius of the outer tube is 2r and that of the inner tube is τ, then the shear stress in the inner tube will be _______ τ.

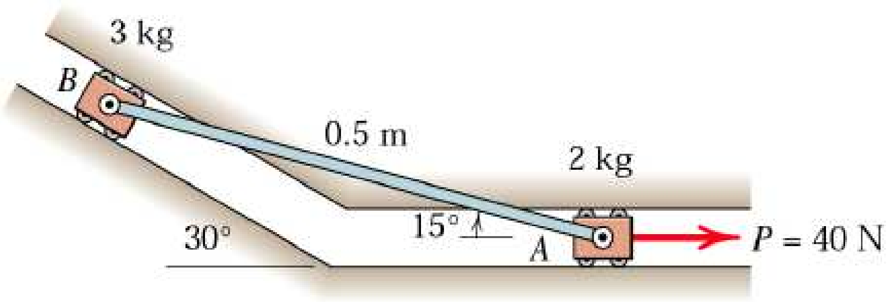
16. A spring with 25 active coils cannot be accommodated within a given space, hence 5 coils of the spring are cut. The stiffness of the new spring will be ________ times the original spring.

Common Data Questions

Common Data For Ques 17 and 18

The sliders A and B are connected by a light rigid bar and move with negligible friction in the slots, both of which lie in a horizontal plane.

For the position shown, the velocity of A is 0.4 m/s to the right.



17. Determine the acceleration of each slider.

(A) $a_A = 7.95\ m/s^2$, $a_B = -8.04\ m/s^2$

(B) $a_A = 7.41\ m/s^2$, $a_B = 8.97\ m/s^2$

(C) $a_A = 6.34\ m/s^2$, $a_B = -7.47\ m/s^2$

(D) $a_A = -7.34\ m/s^2$, $a_B = 7.56\ m/s^2$

18. What will be the force in the bar at this instant?

(A) T = 24.1 N

(B) T = 25.7 N

(C) T = 25.0 N

(D) T = 19.8 N

Common Data For Ques 19 and 20

The cantilever beam shown in Fig., supports a uniform loading w_0 10 kN/m and a concentrated couple-moment M_0 having the value of 100 kN-m. The beam is 10 m long.

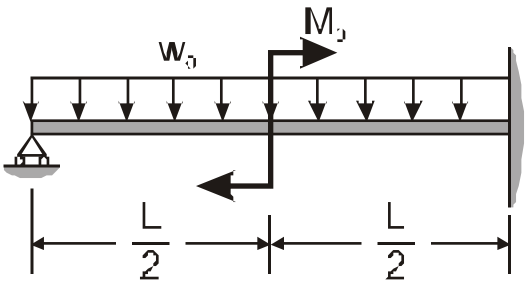


Figure. Cantilever beam.

19. Find the supporting forces

(A) $R_1 = 26.3$ kN, $R_2 = 73.7$ kN

(B) $R_1 = 45.3$ kN, $R_2 = 13.87$ kN

(C) $R_1 = 15.3$ kN, $R_2 = 10.87$ kN

(D) $R_1 = 18.45$ kN, $R_2 = 16.44$ kN

20. What will be the deflection curve in terms of EI?

(A) $v = \frac{1}{EI}\left(R_1\frac{x^3}{2} - \frac{10x^4}{4} + 100\frac{x^2}{3} + C_3x + C_4\right)$

(B) $v = \frac{1}{EI}\left(R_1\frac{x^3}{6} - \frac{10x^4}{24} + 100\frac{x^2}{2} + C_3x + C_4\right)$

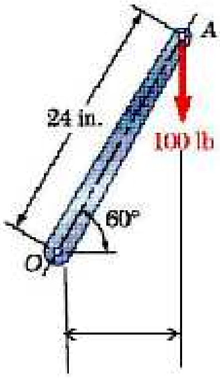
(C) $v = \frac{1}{EI}\left(R_1\frac{x^3}{24} - \frac{10x^4}{45} + 100\frac{x^2}{13} + C_3x + C_4\right)$

(D) $v = \frac{1}{EI}\left(R_1\frac{x^3}{24} - \frac{10x^4}{45} + 100\frac{x^2}{13} + C_3x + C_4\right)$

Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

A 100-lb vertical force is applied to the end of a lever which is attached to a shaft at O.



21. Determine moment about O.

(A) 1200 k lb_{in}

(B) -1200 k lb_{in}

(C) -1200 k lb_{in}

(D) 1200 k lb_{in}

22. The horizontal force at A which creates the same moment will be,

(A) -57.7 lb

(B) 57.7 lb

(C) -57.7 lb

(D) 57.7 lb

E: THERMODYNAMICS

Q. 1 – Q. 9 carry one mark each.

1. Calculate the work done when 50 g of iron reacts with hydrochloric acid in (i) a closed vessel of fixed volume (ii) an open beaker at 25°C.

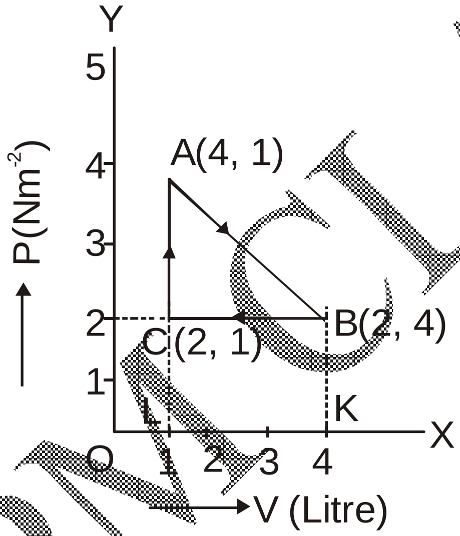
(A) 0, 2122.22J

(B) 0, -2212.22J

(C) 0, 0

(D) 21.2, –2122.22J.

2. The P–V diagram for a cyclic process is a triangle ABC drawn in order. The co-ordinates of A, B, C are (4, 1), (2, 4) and (2, 1). The co-ordinates are in the order (P, V) Pressure is in Nm^{-2} and volume is in litre. Calculate work done in the complete cycle.



(A) 3×10^{-7} J

(B) 3×10^{-3} J

(C) 3×10^{-1} J

(D) 3×10^{-2} J

3. A gas is contained in a cylinder with a moveable piston on which a heavy block is placed. Suppose the region outside the chamber is evacuated and the total mass of the block and the movable piston is 102 kg. When 2140 J of heat flows into the gas, the internal energy of the gas increases by 1580 J. What is the distance s through which the piston rises?

(A) .54 m

(B) .45 m

(C) .74 m

(D) .47 m

4. If heat is added to a system and the temperature of a system increases, without knowing anything else, which form of energy will definitely increase?

(A) The kinetic energy of the system

(B) The potential energy of the system

(C) The work done by the system

(D) The internal energy (i.e., the molecular energy) of the system

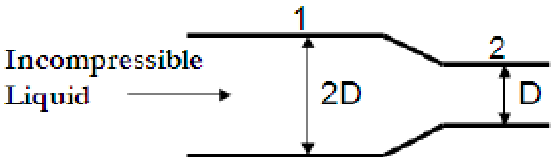
5. An incompressible liquid flows through the pipe shown in the figure. The velocity at location 2 is

(A) $\frac{1}{4}\vec{V}$

(B) $\frac{1}{2}\vec{V}_1$

(C) $2\vec{V}_1$

(D) $4\vec{V}_1$



6. For a particular power plant, the heat added and rejected both occur at constant temperature; no other processes experience any heat transfer. The heat is added in the amount of 3150 kJ at 440°C and is rejected in the amount of 1294.46 kJ at 20°C. Calculate the cycle efficiency for this cycle.

(A) 59.8%

(B) 55.4%

(C) 58.9%

(D) 54.5%

7. A cyclic steam power plant is to be designed for a steam temperature at turbine inlet of 360^0 C and an exhaust pressure of 0.08 bar. After isentropic expansion of steam in the turbine, the moisture content at the turbine exhaust is not to exceed 15%. Determine the greatest allowable steam pressure at the turbine inlet, and calculate the Ranking cycle efficiency for these steam conditions. Estimate also the mean temperature of heat addition.

(A) 15.377 bar, 33%, 180.21^0C

(B) 16.012 bar, 32.76%, 179.77^0C

(C) 14.96 bar, 34.03%, 163.79^0C

(D) 16.832 bar, 31.68%, 187.51^0C

8. Modern automobile gasoline engines have efficiencies of about 25%. About _______ percentage of the heat of combustion is not used for work but released as heat.

9. A gas-turbine power plant operating on an ideal Brayton cycle has a pressure ratio of 8. The gas temperature is 300 K at the compressor inlet and 1300 K at the turbine inlet. Utilizing the air-standard assumptions, determine the gas temperature at the exits of the compressor and the turbine.

(A) 550 K, 775 K

(B) 545 K, 772 K

(C) 540 K, 770 K

(D) 548 K, 771 K

Q. 10 - Q. 22 carry two marks each.

10. Calculate the standard internal energy change for the reaction.

$$OF_{2(g)} + H_2O_{(g)} \longrightarrow O_{2(g)} + 2HF_{(g)}$$

at 298 K. The standard enthalpies of formation of $OF_{2(g)}$, $H_2O_{(g)}$, $HF_{(g)}$ are +20, +250 and –270 kJ mol^{-1}.

(A) 312.4775 kJ

(B) 215.4387 kJ

(C) –115.376 kJ

(D) –312.4775 kJ

11. A reversible, polytrophic process begins with a fluid at P_1 = 10 bar, T_1 = 200°C and ends at P_2 = 1 bar. The exponent n has the value 1.15. Find the final heat transferred per kg of fluid if (A) the fluid is air, (B) the fluid is steam.

(A) 147.35kJ

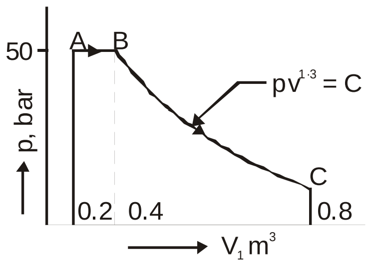
(B) 146.45kJ

(C) 145.37kJ

(D) 143.57kJ

12. A reservoir at 300 K absorbs 500 J of heat from a second reservoir at 400 K. Then _____ (J) amount of work is lost during the process.

13. The total work done by a gas system following an expansion process as shown in Figure.



(A) 2.152 MJ

(B) 2.251 MJ

(C) 2.132 MJ

(D) 0.251 MJ

14. 1g of water at 373 K is converted into steam at the same temperature. The volume of 1 cm^3 of water becomes 1671 cm^3 on boiling. The change in internal energy of the system, if heat of vaporisation is 540 cal. g^{-1} will be ________ J. (Given standard atmospheric pressure is 1.013×10^5 Nm^{-2}.)

15. An automobile tire with a volume of 100 liters is inflated to a gage pressure of 210 kPa. Then the mass of air in the tire if the temperature is 20°C and the increase in gauge pressure if the temperature in the tire reaches 50°C are ____kg and _____kPa.(Assume that atmospheric pressure is 100 kPa.)

16. A cylinder containing one gram molecule of the gas was compressed adiabatically until its temperature rose from 27ºC to 97ºC. The heat produced in the gas (γ = 1.5) will be ________ cal.

Common Data Questions

Common Data For Ques 17 and 18

A gas expands against a constant external pressure and does 25 kJ of expansion work on the surroundings. During the process, 60 kJ of heat is absorbed by the system.

17. The values of ΔH will be ______ kJ.

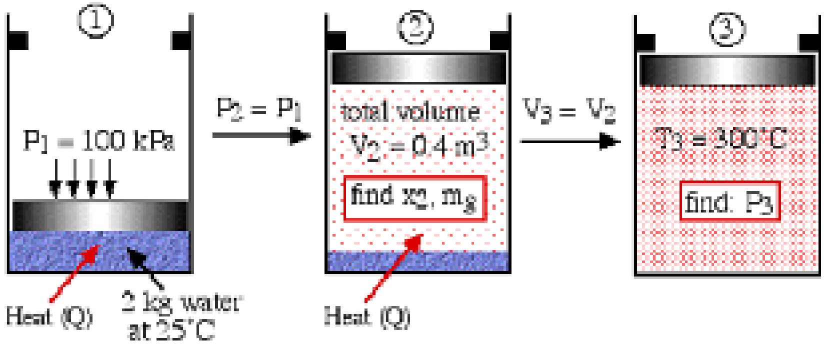
18. The value of ΔU will be ________kJ.

Common Data For Ques 19 and 20

Two kilograms of water at 25°C are placed in a piston cylinder device under 100 kPa pressure as shown in the diagram (State (A)). Heat is added to the water at constant pressure until the piston reaches the stops at a total volume of 0.4 m3 (State (B)). More heat is then added at constant volume until the temperature of the water reaches 300°C (State (C)).

19. The quality and mass of the vapor at state (B) will be ________ and _______ kg respectively.

20. The pressure of the fluid at state (C) will be ______ MPa.



Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

A mass of 0.25 kg of an ideal gas has a pressure of 300 kPa, a temperature of 80^0C, and a volume of $0.07 m^3$.

21. The gas undergoes an irreversible adiabatic process to a final pressure of 300 kPa .Final volume of $0.10\ m^3$, during which the work done on the gas is 25 kJ..The value of c_v will be ________ kJ/kg K.

22. The value of c_p will be ________ kJ/kg K.

F: POLYMER SCIENCE AND ENGINEERING

Q. 1 – Q. 9 carry one mark each.

1. Which of the following agent is used as die hardener?

(A) Cyanoacrylate

(B) Nail polish

(C) Volatile relief agents

(D) Composite resin

2. Ormocers are :

(A) Organically modified composites

(B) Inorganically modified composites

(C) Organically modified glass ionomer cement

(D) Inorganically modified glass ionomer cement

3. All the following are materials used for fabrication of maxillofacial prosthesis except :

(A) Vinyl choloride polymers

(B) Acrylic resins

(C) Silicone rubber

(D) Fiber reinforced composite.

4. The % of free monomer in a heat cured acrylic resin is :

(A) 3 to 5%

(B) 8 to 10%

(C) 0.2 to 0.5%

(D) 0.6 to 0.8%

5. Liquid used in polycarboxylate cement is :

(A) Polycry acid

(B) Phosphoric acid

(C) Eugenol

(D) Methacrylic acid

6. In free radical polymerization, one of the following techniques permits simultaneous increase in rate of polymerization and polymer molecular weight.

(A) Solution polymerization.

(B) Suspension polymerization.

(C) Bulk polymerization

(D) Emulsion polymerization/

7. A reinforced polymer composite is made by the incorporation of

(A) elastomers into the polymer.

(B) fibers into the polymer.

(C) plastocizers into the polymer.

(D) gaseous additives into the polymer.

8. Out of all the elastomers, natural rubber has the longest elongation range & flexibility of the order of __________ percent.

(A) 1-1000

(B) 2000-2500

(C) 1000-1500

(D) 1500-2000

9. Due to its excellent permeability to air/gas and oxidation resistance, the tubes of automobile tyres is made of

(A) butyl rubber

(B) Buna S

(C) cold SBR

(D) Bunai N

Q. 10 - Q. 22 carry two marks each.

10. If a type of polyethylene has an average degree of polymerization of 10,000, what is its average molecular weight?

(A) 280,000 g/mol

(B) 240,600 g/mol

(C) 270,000 g/mol

(D) 340,050 g/mol

11. A nylon 6,6 has an average molecular weight of 12,000 g/mol. Calculate the average degree of polymerization (see Sec. 10.7 for its mer structure M.W. = 226 g/mol).

(A) 36 mers

(B) 45 mers

(C) 53 mers

(D) 68 mers

12. Fillers such as zinc oxide and carbon black are added to the crude natural rubber before vulcanisation in order to improve its

(A) elasticity

(B) plasticity

(C) strength

(D) weathering characteristics

13. Which of the following polymers is used for making a non stick coating on frying pans?

(A) Bakelite

(B) Teflon

(C) Perspex

(D) PVC

14. Addition of plasticisers to polymers results in partial neutralisation of intermolecular forces of attraction between the macro-molecules thereby increasing its

(A) tensile strength

(B) chemical resistance

(C) flexibility

(D) all (a), (b) & (c)

15. Which one among the following is a thermosetting plastic. [MPPMT 1993, 95]

(A) PVC

(B) Bakelite

(C) PVA

(D) Perspex

16. Bakelites are

(A) Rubber

(B) Resins

(C) Rayon

(D) Plasticisers 30.

Common Data Questions

Common Data For Ques 17 and 18

Consider these data:

Year	U.S. Population (millions)	Plastics Produced in the United States (billions of pounds)
1997	269	89
2003	290	107

17. How many pounds of plastic were produced per person in 2003?

(A) 257 lb/person

(B) 370 lb/person

(C) 462 lb/person

(D) 598 lb/person

18. Between 1997 and 2003, what is the percent change in the number of pounds of plastic produced per person?

(A) 10%

(B) 8%

(C) 12 %

(D) 14%

Common Data For Ques 19 and 20

Linked Answer Questions

Consider the polymerization of 1000 ethylene molecules to form a large segment of polyethylene

$$1000\, CH_2{=}CH_2 \xrightarrow{R\cdot} -\!\!\left(CH_2CH_2 \right)\!\!-_{1000}$$

19. Calculate the energy change during this reaction.

(A) 1.14×10^5 kJ

(B) 2.33×10^5 kJ

(C) 3.78×10^5 kJ

(D) 4.23×10^5 kJ

20. To carry out this reaction, heat must be supplied or removed from the polymerization vessel? Explain.

(A) supplied to the polymerization vessel

(B) removed from the polymerization vessel

(C) initially supplied and the removed from the polymerization vessel

(D) None of the above

Statement for Linked Answer Questions 21 and 22:

A tensile test is performed to determine the parameters strength constant C and strain-rate sensitivity exponent m for a certain metal. The temperature at which the test is performed = 500°C. At a strain rate = 12/s, the stress is measured at 160 MPa; and at a strain rate = 250/s, the stress = 300 MPa.

21. Determine the value of m.

(A) 0.4

(B) 0.2

(C) 0.5

(D) 0.3

22. Determine the value of C.

(A) 95.7

(B) 90.4

(C) 88.8

(D) 81.23

G: FOOD TECHNOLOGY

Q. 1 – Q. 9 carry one mark each.

1. Pasteurization is a

(A) low temperature treatment

(B) steaming treatment

(C) high temperature treatment

(D) low and high temperature treatment

2. Clostridium perfingens poison is an

(A) exotoxin

(B) enterotoxin produced during sporulation

(C) endotoxin

(D) enterotoxin produced during vegetative phase

3. Which of the following is NOT an intrinsic factor in food spoilage?

(A) pH

(B) Moisture content

(C) Available nutrients

(D) Temperature

4. The major functions of carbohydrates include

(A) Structural framework

(B) Storage

(C) Both (A) and (B)

(D) None of these

5. In polysaccharides, monosaccharaides are joined by

(A) peptide bond

(B) glucose bond

(C) glycosidic bond

(D) covalent bond

6. Which of the following are the combinations of symptoms of diverticular disease?

(1) abdominal cramps

(2) severe constipation

(3) rapid weight loss

(A) (1) and (2) only

(B) (1) and (3) only

(C) (2) and (3) only

(D) (1), (2) and (3)

7. Which of the following processes involves dextrinisation?

(A) boiling milk and flour to make custard

(B) beating egg-whites to make meringue

(C) churning cream to make butter

(D) toasting bread

8. Fats and oils have an important function in food preparation.

They can

(A) sweeten a food product.

(B) assist some foods to retain moisture.

(C) assist in binding ingredients in a cake.

(D) contribute to the aeration of food products.

9. Developing criteria for evaluation is a stage in the design process in Food and Technology. It involves

(A) creating a set of questions to ask the client.

(B) making a list of food items to be produced.

(C) identifying key processes that will be used in producing food items.

(D) creating a set of questions that focus on the specifications found within the design brief

Q. 10 – Q. 22 carry two mark each.

10. Which of the following food safety issues is a responsibility of state government?

(A) approving all food safety auditors

(B) inspecting all food premises annually

(C) issuing permits for community markets

(D) developing and updating the Food Standards Code

11. Bacteria that cause food spoilage

(A) are a type of enzyme.

(B) are only present in chicken.

(C) will give the food an 'off' odour.

(D) need a moist, damp environment in which to grow.

12. 'Reverse osmosis' is a form of membrane technology that is used to

(A) cool pasteurize food.

(B) produce some fruit juices.

(C) change the characteristics of some plant foods.

(D) improve the characteristics of some baked products.

13. Plant sterols are

(A) a functional ingredient.

(B) classified as a probiotic substance.

(C) important in improving the health of the eyes.

(D) able to stimulate the growth of bacteria in the intestine.

14. When making jam, to test whether a gel has formed it is important to

(A) stir the jam well with a fork.

(B) make sure that a skin does not form on the jam sample.

(C) place a saucer in the freezer before beginning the test.

(D) ensure that a saucer is at room temperature before beginning the test.

15. Which of the following packages is an example of aseptic packaging?

(A) Tetra Pak drinking boxes

(B) paper bag

(C) milk carton

(D) plastic bread bag

16. What is the operating principle behind oven drying for determining moisture content of foods?

(A) colour change is measured

(B) loss of weight represents loss of water

(C) change in refractive index is measured

(D) change in light absorbance is measured

Common Data Questions

Common Data For Ques 17 and 18

A multienzyme complex has three different catalytic activities with eight sites for each activity. Compare the frequencies of defective complexes produced in the following two situations:

17. Determine the frequency of defective complexes when the complex is synthesized in one step as one long polypeptide chain containing 8,000 amino acid residues.

(A) 8×10^{-2}

(B) 7×10^{-2}

(C) 6×10^{-2}

(D) 5×10^{-2}

18. Determine the frequency of defective complexes when the complex is constructed in three steps. First, 24 polypeptides are synthesized: 8 × 200, 8 × 300, and 8 × 500 amino acid residues. Next, trimers consisting of one of each chain type are formed. Last, these eight trimers are assembled to form the complex. (Assume in both cases that the error frequency is 10^{-5} for each operation and that a single mistake will cause complete rejection.)

(A) 8×10^{-2}

(B) 7×10^{-2}

(C) 6×10^{-2}

(D) 5×10^{-2}

Common Data For Ques 19 and 20

Given the peptide

Ala-Ser-Thr-Lys-Gly-Arg-Ser-Gly

19. What peptides would be released from the given peptide by treatment with trypsin ?

(A) Ala-Ser-Thr-Lys

(B) Gly-Lys

(C) Ser-Thr

(D) Ser-Thr-Lys

20. If each of the products were treated with fluoro-2, 4-dinitrobenzene (FDNB) and subjected to acid hydrolysis, what DNP-amino acids could be isolated?

(A) DNP-Ala

(B) DNP-Gly

(C) DNP-Ser

(D) All of these

Linked Answer Questions

Statement for Linked Answer Questions 21 and 22:

For the dimerization reaction 2A, A_2, in which A is a protein of molar weight 40,000 g mol^{-1}, the equilibrium constant in the mol L^{-1} scale is 10^6.

21. Calculate the percentage by weight of dimer when the total concentration of the protein is 1 g L^{-1}.

(A) 87.0

(B) 13.5

(C) 4.4

(D) 95.6

22. Calculate the percentage by weight of dimer when the total concentration of the protein is 10 g L^{-1}.

(A) 87.0

(B) 13.5

(C) 4.4

(D) 95.6

ANSWER KEY

GENERAL APTITUDE

Question	1	2	3	4	5	6	7	8	9	10
Answer	D	D	A	B	B	C	B	D	C	C

A: ENGINEERING MATHEMATICS

Question	1	2	3	4	5	6	7	8	9	10	11
Answer	A	A	A	A	A	C	D	B	A	D	C

B: FLUID MECHANICS

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	D	C	D	D	B	0.011	A	D	B	B	A	0.00028m^2/s	C	B	13.43
Question	16	17	18	19	20	21	22								
Answer	125.176	D	D	177.03	482.26	D	B								

C: MATERIAL SCIENCE

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	C	B	C	C	D	B	B	A	C	C	1:3	A	6.65 mm	–8.1	0.344, 3502.47
Question	16	17	18	19	20	21	22								
Answer	2.38	212	121	69.61, 30.39	277.5	9.317×10^{-3}	30								

D: SOLID MECHANICS

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	50mm	36kg	1/4	1:1	0.94	11	A	D	52.44	A	1/2	–0.0440	32	3	0.5
Question	16	17	18	19	20	21	22								
Answer	1.25	A	C	A	B	B	B								

E: THERMODYNAMICS

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	B	B	A	D	D	C	D	75	C	D	A	125	B	2087.83	0.369, 342
Question	16	17	18	19	20	21	22								
Answer	276.7	60	35	0.118, 0.235	129	0.658	0.896								

F: POLYMER SCIENCE AND ENGINEERING

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	A	A	D	C	A	D	B	A	A	A	C	D	B	C	B
Question	16	17	18	19	20	21	22								
Answer	B	B	C	A	B	B	A								

G: FOOD PRESERVATION

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	C	B	D	C	C	A	C	D	D	A	D	B	A	C	A
Question	16	17	18	19	20	21	22								
Answer	B	A	B	A	D	A	D								

HINTS AND SOLUTION

1.(D) On arranging the letters of 'PROJECTING' according to the given conditions, we get

E I O C [G] J N P R T

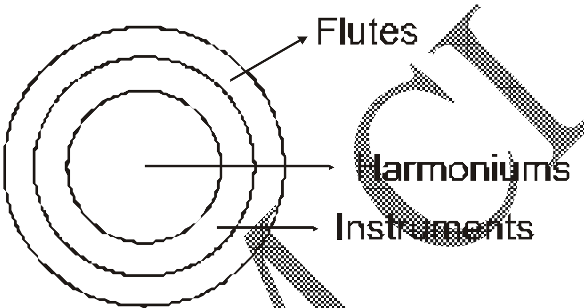
In this rearrangement the fifth letter from the left is 'G'.

2.(D) The word trick should give you the clue, only the word 'illusion' fits in with ' trick'. Hence, (D).

3.(A) Choice (a) best restates the given sentence, though choice (b) is the repetition of the given statement. 'Not one can deny' in choice (c) and for any one to deny' in choice (d) make them incorrect. Hence correct choice is (a).

4.(B) The relationship is that of standard adjectives and nouns used in common parlance. Thus, 'upright' is a standard adjective used to describe one's carriage (posture), and so on. The odd one out is option B - there is no such thing as a 'handy : sake'.

5.(B)



Only II follows.

6.(C) Let a and b be the CP of the first and second plot respectively.

The SP of the first plot = 1.12a = 1 crore

a = 1/1.12

Similarly,

b = 1/0.88

Total CP = $\frac{1}{1.12}+\frac{1}{0.88}$

But total SP = 2 crore

Percentage profit = $\frac{2-\frac{1}{1.12}-\frac{1}{0.88}}{\frac{1}{1.12}+\frac{1}{0.88}} \times 100$

$= \frac{2(1.12)(0.88)-0.88-1.12}{2} \times 100$ = -1.44

There is a loss of 1.44%

7.(B) Total Actual Sales = 29+50+75+95+55+80+50+10 = 444

Total targeted sales = 28+40+65+85+40+65+40+20 = 383

Actual Sales % = $\frac{444}{8}$ = 55.5 %

Targeted sales % = $\frac{383}{8}$ = 47.8 %

Net sales exceeded by = 55.5 - 47.8 = 7.7 %

8.(D) **I.** $2x^2 - 9x + 9 = 0$

$\Rightarrow 2x^2 - 3x - 6x + 9 = 0$

$\Rightarrow x(2x-3) - 3(2x-3) = 0$

$\Rightarrow (2x-3)(x-3) = 0$

$\therefore x = 3/2$ or 3

II. $y^2 - 11y + 24 = 0$

$\Rightarrow y^2 - 8y - 3y + 24 = 0$

$\Rightarrow$ y(y – 8) – 3 (y – 8) = 0

$\Rightarrow$ y = 3 or 8

Clearly $y \geq x$

9.(C) In each row, multiply the numerical values of the left and right hand letters, putting the result in the centre.

For example N= 14 and R=18, NOW 14X 18= 252.

10.(C) Let B be the event of a lorry leaving first

n(B) = 100 - 60 - 30 = 10

Probability of a lorry leaving first p(B) $= \frac{10}{100} = \frac{1}{10}$

A: ENGINEERING MATHEMATICS

1.(A) Let A be a real symmetric matrix, therefore

$A^T = A$

Let α_1 and α_2 be different eigen value of the matrix A, and X_1 and X_2 be the corresponding vector, then

$AX_1 = \alpha_1 X_1$ and $AX_2 = \alpha_2 X_2$

Taking transpose of the second equation

$(AX_2)^T = (\alpha_2 x_2)^T$

$\Rightarrow$ $X_2^T A^T = \alpha_2 . X_2^T$

But $A^T = A,$

$\therefore$ $X_2^T A = \alpha_2 . X_2^T$

Post multiply by X_1, we get

$$X^T_2 AX_1 = \alpha_2 X_2^T X_1$$

But $AX_1 = \alpha_1 X_1$

$\therefore$ $X^T_2 X_1 = 0$ i.e. X_2 and X_1 are orthogonal.

2.(A) Continuity at x = 0:

$L.\lim_{x\to 0} f(x) = \lim_{h\to 0} f(0-h)$

$= \lim_{h\to 0} (0-h)^2 \sin\frac{1}{0-h}$

$= \lim_{h\to 0} -h^2 \sin\frac{1}{h}$

$= 0 \times$ [finite quantity between -1 and 1] $= 0$

$R.\lim_{x\to 0} f(x)$

$= \lim_{h\to 0} f(0+h)$

$= \lim_{h\to 0} (0+h)^2 \sin\frac{1}{(0+h)}$

$= \lim_{h\to 0} h^2 \sin = 0$

Also $f(0) = 0$

$L.\lim_{x\to 0} f(0) = R.\lim_{x\to 0} f(x) = f(0)$

Derivability at x = 0

$L.f'(0) = \lim_{h\to 0}\frac{f(0-h)-f(0)}{-h}$

$= \lim_{h \to 0} h \sin \frac{1}{h}$

$= 0 \times \text{finite quantity} = 0$

$R.f'(0) = \lim_{h \to 0} \frac{f(0+h) - f(0)}{h}$

$= \lim_{h \to 0} \frac{h^2 \sin\frac{1}{h} - 0}{h} = \lim_{h \to 0} h \sin = 0$

$\therefore$ L.f'(0) = R.f'(0)

$\therefore$ f(x) is derivable at x = 0

$\therefore$ The correct answer is (A)

3.(A) Here, the function being integrated is

$f(x) = xe^x$

$f'(x) = xe^x + e^x = e^x(x+1)$

$f''(x) = xe^x + e^x = e^x(x+2)$

Since, both e^x and x are increasing functions of x, maximum value of $f''(\xi)$ in interval $1 \le \xi \le 2$, occurs at $\xi = 2$

So, $\max |f''(\xi)| = e^2(2+2) = 4e^2$

Truncation Error for trapezoidal rule = TE (bound)

$= \frac{h^3}{12} \max |f''(\xi)| * N_i$

where N_i is number of subintervals

$N_i = \frac{b-a}{h}$

$\therefore \quad T_{\in(\text{bound})} = \frac{h^3}{12}\max\left|f''(\xi)\right| * \frac{b-a}{h}$

$= \frac{h^2}{12}(2-1)\left(4e^2\right) = \frac{h^2}{3}e^2$

Now putting $\quad T_{\in(\text{bound})} = \frac{1}{3}\times 10^{-6}$

We get $\quad \frac{h^2}{3}e^2 = \frac{1}{3}\times 10^{-6}$

$\Rightarrow \quad h^2 = \frac{10^{-6}}{e^2}$

$\Rightarrow \quad h = \frac{10^{-3}}{e}$

Now, Number of intervals = N_i

$= \frac{b-a}{h} = \frac{2-1}{\left(10^{-3}/e\right)} = 1000\,e$

4.(A) A can draw a ticket in ${}^3C_1 = 3$ ways.

Number of cases in which A can get a prize is clearly 1.

$\therefore$ Probability of A's success = $\frac{1}{3}$.

Again B can draw a ticket in ${}^9C_3 = \frac{9.8.7}{3.2.1}$

= 84 way.

Number of way in which B gets all blanks

$= {}^6C_3 = \frac{6.5.4}{3.2.1} = 20.$

∴ Number of ways of getting a prize

$= 84 - 20 = 64$

Thus, probability of B's success = $\frac{64}{84} = \frac{16}{21}$

∴ A's probability of success : B's probability of success

$= \frac{1}{3} : \frac{16}{21} = 7 : 16$

5.(A) Putting $y = \upsilon x$

∴ $\frac{dy}{dx} = x\frac{d\upsilon}{dx} + \upsilon$, $\frac{d^2y}{dx^2} = x\frac{d^2\upsilon}{dx^2} + 2\frac{d\upsilon}{dx}$

Now, putting all these values in equation (A), we get

$$\frac{d^2\upsilon}{dx^2} - 2\frac{d\upsilon}{dx} = 1 \quad \text{.... (A)}$$

Let $p = \frac{d\upsilon}{dx'}$ then (A) gives $\frac{dp}{dx} - 2p = 1$

which is a linear equation of the form $\frac{dy}{dx} + Py = Q$ whose I.F. = $e^{\int P dx}$ then

I.F. = $e^{-2\int dx} = e^{-2x}$

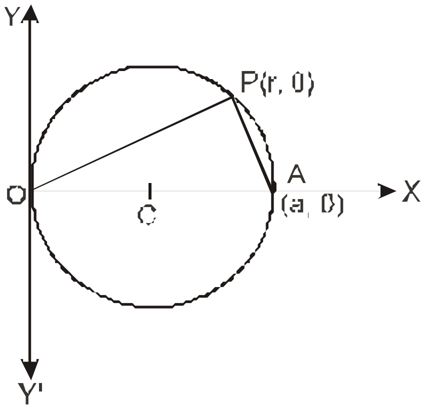
∴ solution is $pe^{-2x} = \int 1.e^{-2x}dx + C_1 = -\frac{1}{2}e^{-2x} + C_1$

∴ $p = \frac{d\upsilon}{dx} = -\frac{1}{2} + Ce^{+2x}$

On integrating, we get

$\upsilon = -\frac{1}{2}x + \frac{C_1}{2}e^{2x} + C_2$ which is second L.I.

6.(C) Let $P(r, \theta)$ be any point on the circle $x^2 + y^2 = ax$



$\therefore\ x = r\cos\theta,\ y = r\sin\theta$

$$\therefore \quad \frac{\partial(x,y)}{\partial(r,\theta)} = \begin{vmatrix} \frac{\partial x}{\partial r} & \frac{\partial x}{\partial \theta} \\ \frac{\partial y}{\partial r} & \frac{\partial x}{\partial \theta} \end{vmatrix}$$

$$= \begin{vmatrix} \cos\theta & -r\sin\theta \\ \sin\theta & r\cos\theta \end{vmatrix}$$

$$= r(\cos^2\theta + \sin^2\theta) = r$$

and the equation of the circle

$$r^2(\cos^2\theta + \sin^2\theta) = ar\cos\theta$$

$$r = a\cos\theta$$

$$\therefore \quad \iint \sqrt{a^2 - x^2 - y^2}\, dx\, dy$$

$$= \int_0^{\pi/2} \int_0^{a\cos\theta} \sqrt{a^2 - r^2(\cos^2\theta + \sin^2\theta)}\, r\, dr\, d\theta$$

$$= \int_0^{\pi/2} \left[-\frac{1}{3}(a^2 - r^2)^{3/2} \right]_0^{a\cos\theta} d\theta$$

$$= \frac{1}{3}a^3 \int_0^{\pi/2} \left(1 - \sin^3\theta\right)_0^{3/2} d\theta$$

$$= \frac{1}{3}a^3 \left[(\theta)_0^{\pi/2} - \frac{2}{3}\right] = \frac{1}{3}a^3\left(\frac{1}{2}\pi - \frac{2}{3}\right)$$

$\therefore$ The correct answer is C.

7.(D) The poles of the function $f(z) = \frac{z-3}{z^2+2z+5}$ are given by $z^2 + 2z + 5 = 0$ i.e. by

$z = \frac{1}{2}\ [2 \pm \sqrt{(4-20)}] = -1 \pm 2\ i.$

(A) The poles $z = -1 + 2i$ and $z = -1 - 2\ i$ are both outside the circle $|z| = 1$. So $f(z)$ is analytic everywhere inside C.

Hence by Cauchy's Theorem we have

$$I = \oint_C \frac{(z-3)dz}{(z^2+2z+5)} = 0$$

(B) If C is the circle $|z + 1 + i| = 2$, then its centre is $z = -1 - i$ and radius 2.

$\therefore$ We find that only pole $z = -1 - 2i$ lies inside the circle C. Therefore f(z) is analytic everywhere inside C except at the pole $z = -1 - 2\ i$.

$\therefore$ $$\underset{z=-1-2i}{\text{Res}}\ f(z) = \lim_{z\to -1-2i}\left[(z+1+2\ i)f(z)\right]$$

$$= \lim_{z\to -1-2i}\left[\frac{(z+1+2i)\,(z-3)}{z^2+2z+5}\right]$$

$$= \lim_{z\to -1-2i}\left[\frac{z-3}{(z+1-2\ i)}\right] = \frac{(-1-2\ i)-3}{(-1-2i)+1-2i}$$

$= (-4 - 2\ i)/(-4\ i) = i.$

Hence by Residue Theorem, we have

$I = \oint_C f(z) = dz = 2\pi i$ [residue at $z = -1 - 2i$],

$= 2\pi i[\frac{1}{2} - i] = \pi i + 2\pi = \pi(2+i).$

8.(B) Cauchy integral formula for nth derivative is

$$f^n(A) = \frac{n!}{2\pi i}\int_C \frac{f(z)dz}{(z-a)^{n+1}} \quad \text{...(A)}$$

where C is any closed contour surrounding the origin

$$\therefore \quad f^n(0) = \frac{n!}{2\pi i}\frac{f(z)dz}{z^{n+1}} \quad \text{...(B)}$$

Let us assume $f(z) = e^{xz}$

Differentiating with respect to z, we get

$f'(z) = e^{xz}.x$

$f''(z) = e^{xz}.x^2$

$f^n(z) = e^{xz}.x^n$

$\therefore \quad f^n(0) = x^n$

Substituting this value in equation (B), we get

$$x^n = \frac{n!}{2\pi i}\int_C \frac{e^{xz}dz}{z^{n+1}}$$

$$\Rightarrow \quad \frac{x^n}{n!} = \frac{1}{2\pi i}\int_C \frac{e^{xz}dz}{z^{n+1}} \quad \text{...(C)}$$

Multiplying both sides by $\frac{x^n}{n!}$, we get

$$\left(\frac{x^n}{n!}\right)^2 = \frac{1}{2\pi i}\int_C \frac{x^n}{n!}\frac{e^{xz}dz}{z^{n+1}}$$

$$\sum_{n=0}^{\infty}\left(\frac{x^n}{n!}\right)^2 = \frac{1}{2\pi i}\int_C \frac{e^{xz}}{z}dz\sum_{n=0}^{\infty}\frac{x^n}{n!\,z^n} = \frac{1}{2\pi i}\int_C \frac{e^{xz}}{z}dz\sum_{n=0}^{\infty}\frac{(x/z)^n}{n!}$$

$$= \frac{1}{2\pi i}\int_C \frac{e^{xz}}{z}dz.e^{x/z} = \frac{1}{2\pi i}\int_C \frac{e^{x\left(z+\frac{1}{z}\right)}}{z}dz \qquad ...(D)$$

Now Putting $z = e^{i\theta} \Rightarrow dz = ie^{i\theta}d\theta$

$$\frac{dz}{z} = \frac{i\,e^{i\theta}\,d\theta}{e^{i\theta}} = id\theta$$

$$z + \frac{1}{z} = e^{i\theta} + e^{-i\theta} = 2\cos\theta$$

Substituting this value in (D), we get $\sum_{n=0}^{\infty}\left(\frac{x^n}{n!}\right)^2 = \frac{1}{2\pi}\int_0^{2\pi} e^{2x\cos\theta}d\theta$

9.(A) By Gauss divergence theorem

$$\iint_S \vec{A}.\vec{dS} = \iiint_V \text{div}\,\vec{A}\,dV$$

$$\Rightarrow \qquad \iint_S (A_x dy\,dz + A_y\,dz\,dx + A_z\,dx\,dy) = \iiint_V\left(\frac{\partial A_x}{\partial x}+\frac{\partial A_y}{\partial y}+\frac{\partial A_z}{\partial z}\right)dx\,dy\,dz$$

Here $A_x = x^3, A_y = y^3, A_z = z^3$

$$\therefore \iint_S (x^3dy\,dz + y^3\,dz\,dx + z^3\,dx\,dy) = \iint_S\left\{\frac{\partial}{\partial x}(x^3)+\frac{\partial}{\partial y}(y^3)+\frac{\partial}{\partial z}(z^3)\right\}dx\,dy\,dz$$

$$= \iiint_V (3x^2 + 3y^2 + 3z^2)dx\,dy\,dz$$

$$= 3\iiint_V (x^2 + y^2 + z^2)dx\,dy\,dz$$

$= 3\iiint_V a^2 \, dx\, dy\, dz \qquad (\because x^2 + y^2 + z^2 = a^2)$

$= 3a^2 \iiint_V dx\, dy\, dz$

$= 3a^2 \cdot \left(\frac{4}{3}\pi a^3\right) = 4\pi a^5$

10.(D) As pointed out earlier we shall use scheme 1 of the fourth order Runge - Kutta method viz,

$k_1 = hf(x_0, y_0)$

$$k_2 = hf\left(x_0 + \frac{1}{2}h, y_0 + \frac{1}{2}k_1\right)$$

$$k_3 = hf\left(x_0 + \frac{1}{2}h, y_0 + \frac{1}{2}k_2\right)$$

$$k_4 = hf(x_0 + h, y_0 + k_3)$$

$$k = \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

$y = (x_0 + h) = y_0 + k$

(i) Here $f(x, y) = xy$, $h = 0.2$, $x_0 = 1$, $y_0 = 2$

Hence $k_1 = 0.2\,(1 \times 2) = 0.4$, $K_2 = (0.2)\,(1.1)\,(2.2) = 0.484$

$k_3 = (0.2)(1.1)(2.242) = 0.49324$

$k_4 = (0.2)\,(1.2)\,(2.49324) = 0.5983776$

Hence $y(1.2) = 2 + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + 2k_4) = 2.4921429$

11.(C) Taking the transformation $x = e^t$ the equation reduces to:

$y_t'' + (3 - 1)y_t' - 8y = t^3 - t$

or

$y_t'' + 2y_t' - 8y = t^3 - t$

Corresponding homogeneous equation: $y_t'' + 2y_t' - 8y = 0$

Characteristic equation: $r^2 + 2r - 8 = (r + 4)(r - 2) = 0$

Zeros are: $r_1 = 2$, and $r_2 = -4$

Fundamental set of solutions: $F = \{e^{2t}, e^{-4t}\}$

Complementary solution: $y_c(t) = c_1 e^{2t} + c_2 e^{-4t}$.

Non-homogeneous term is: $b(t) = t^3 - t$

The UC set of $t^3 - t$ is $S_1 = \{t^3, t^2, t, 1\}$.

The equation for particular solution is:

$y_p(t) = At^3 + Bt^2 + Ct + D$

computing the derivatives,

$y_p'(x) = 3At^2 + 2Bt + C$

$y_p''(x) = 6At + 2B$

substituting into the equation,

$6At + 2B + 6At^2 + 4Bt + 2C - 8At^3 - 8Bt^2 - 8Ct - 8D = t^3 - t$

then $-8A = 1$ $\qquad$ $A = -1/8$

$6A - 8B = 0 \qquad B = -6/64 = -3/32$

$6A + 4B - 8C = -1 \qquad C = -1/64$

$2B + 2C - 8D = 0 \qquad D = -7/256$

and $y_p(t) = -1/8\, t^3 - 3/32\, t^2 - 1/64\, t - 7/256$

$y(t) = c_1 e^{2t} + c_2 e^{-4t} - 1/8\, t^3 - 3/32\, t^2 - 1/64\, t - 7/256$

since $x = e^t$ and $t = \ln x$, then the general solution of the original equation is:

$y(x) = c_1 x^2 + c_2 x^{-4} - 1/8 \ln^3 x - 3/32 \ln^2 x - 1/64 \ln x - 7/256.$

B: FLUID MECHANICS

1.(D) (a) $U = \omega r$; for small gap $Y, \dfrac{du}{dy} = \dfrac{U}{Y} = \dfrac{\omega r}{Y}$

$$\tau = \mu \frac{du}{dy} = \frac{\mu \omega r}{Y};\ dA = 2\pi r\, ds = \frac{2\pi r\, dy}{\cos\alpha}$$

$$dF = \tau dA = \frac{\mu \omega r}{Y}\left(\frac{2\pi r\, dy}{\cos\alpha}\right)$$

$$dT = r dF = \frac{2\pi\mu\omega}{Y\cos\alpha} r^3 dy; \quad r = y\tan\alpha$$

$$dT = \frac{2\pi\mu\omega\tan^3\alpha}{Y\cos\alpha} y^3 dy$$

$$T = \frac{2\pi\mu\omega\tan^3\alpha}{Y\cos\alpha}\int_a^{a+b} y^3 dy; \left.\frac{y^4}{4}\right|_a^{a+b} = \left[\frac{(a+b)^4}{4} - \frac{a^4}{4}\right]$$

$$T = \frac{2\pi\mu\omega\tan^3\alpha}{4Y\cos\alpha}\left[(a+b)^4 - a^4\right]$$

(b) $[(a+b)^4 - a^4] = (0.105\text{ m})^4 - (0.045\text{ m})^4 = 0.0001175\text{ m}^4$

$$\omega = \left(90\frac{\text{rev}}{\text{min}}\right)\left(2\pi\frac{\text{radians}}{\text{rev}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right) = 3\pi\text{ rad/s} = 3\pi s^{-1}$$

Heat generation rate = power = $T_\omega = \frac{2\pi\mu\omega^2\tan^3\alpha}{4Y\cos\alpha}\left[(a+b)^4 - a^4\right]$

$$= \frac{2\pi\left(0.20\text{N}\cdot\text{s/m}^2\right)\left(3\pi s^{-1}\right)^2(1)^3\left[0.0001175\text{ m}^4\right]}{4\left(2\times10^{-4}\text{m}\right)\cos45°}$$

= 23.2 N·m/s = 23.2 J/s

2.(C) We have $\underline{V} = u(x)\hat{i}, \frac{Du}{Dt} = u\frac{\partial u}{\partial x} = a_x$

$$\boxed{\begin{aligned} &u(x) = mx + b \\ &u(0) = b = V_0 \\ &m = \frac{\Delta t}{\Delta x} = \frac{3V_0 - V_0}{L} = \frac{2V_0}{L}\end{aligned}}$$

Assume linear variation $\quad u(x) = \frac{2V_0}{L}(x) + V_0 = V_0\left(\frac{2x}{L} + 1\right)$

Between inlet and exit $\quad \frac{\partial u}{\partial x} = \frac{2V_0}{L} \Rightarrow \boxed{a_x = \frac{2V_0^2}{L}\left(\frac{2x}{L} + 1\right)}$

@ $x = 0$ $\quad a_x = 200\ \text{ft/s}^2$

@ $x = L$ $\quad a_x = 600\ \text{ft/s}^2$

3.(D) Given :Diameter at section 1,

$D = 0.4\ \text{m}$; $D_2 = 0.2\ \text{m}$, $L = 2\ \text{m}$,

$Q = 20\ \text{l/s} = 0.02\ \text{m}^3/\text{s}$ as one litre $= 0.001\ \text{m}^3 = 1000\ \text{cm}^3$

Given the rate of flow is constant and equal to $0.02\ \text{m}^3/\text{s}$. The velocity of flow is in x-direction only. Hence this is one-dimensional flow and velocity components in y and z directions are zero or $v = 0$, $z = 0$

$\therefore$ Convective acceleration $= u\dfrac{\partial u}{\partial y}$ only ...(i)

Let us find the value of u and $\dfrac{\partial u}{\partial x}$ at a distance x from inlet

The diameter (D_x) at a distance x from inlet or at section X-X is given by

$$D_x = 0.4 - \frac{0.4 - 0.2}{2} \times x$$

The area of cross-section (A_x) at section X-X is given by,

$$A_x = \frac{\pi}{4} D_x^2 = \frac{\pi}{4}(0.4 - 0.1\,x)^2$$

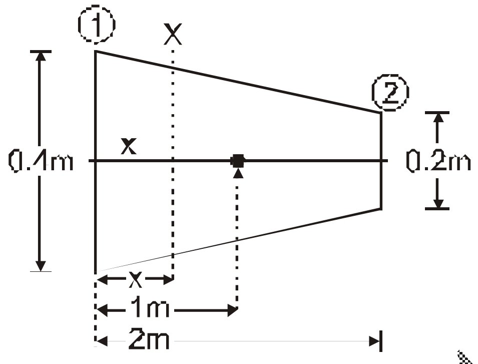


Fig.

Velocity (u) at the section X-X in terms of Q (i.e., in terms of rate of flow)

$$u = \frac{Q}{Area} = \frac{Q}{A_x} = \frac{Q}{\frac{\pi}{4}D_x^2} = \frac{4Q}{\pi(0.4 - 0.1x)^2}$$

$$= \frac{1.273Q}{(0.4 - 0.1x)^2} = 1.273\,Q\,(0.4 - 0.1x)^{-2}\ \text{m/s} \quad ...(ii)$$

To find $\frac{\partial u}{\partial x}$, we must differentiate equation (ii) with respect to x.

$$\frac{\partial u}{\partial x} = \frac{\partial}{\partial x}[1.273\,Q\,(0.4 - 0.1\,x)^{-1}]$$

$$= 1.273\,Q\,(-2)\,(0.4 - 0.1\,x)^{-1} \times (-0.1)$$

[Hence Q is constant]

$$= 0.2546\,Q\,(0.4 - 0.1\,x)^{-1} \quad ...(iii)$$

Substituting the value of u and $\frac{\partial u}{\partial x}$ in equation (i), we get

Convective acceleration $= [1.273\ Q\ (0.4 - 0.1\ x)^{-2}] \times [0.2546\ Q (0.4 - 0.1\ x)^{-1}]$

$= 1.273 \times 0.2546 \times Q^2 \times (0.4 - 0.1\ x)^{-3}$

$= 1.273 \times 0.2546 \times (0.02)^2 \times (0.4 - 0.1\ x)^{-3}$

$[\because\ Q = 0.02\ m^3/s]$

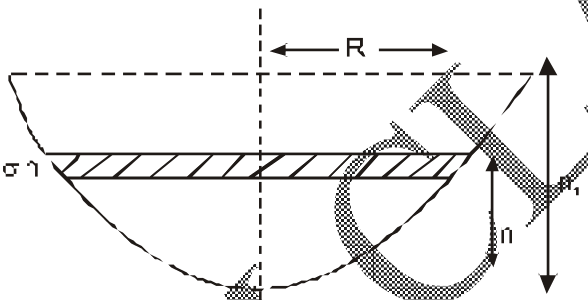
$\therefore$ Convective acceleration at the middle (where x = 1 m)

$= 1.273 \times 0.2546 \times (0.02)^2 \times (0.4 - 0.1 \times 1)^{-3}\ m/s^2$

$= 1.273 \times 0.2546 \times (0.02)^2 \times (0.3)^{-3}\ m/s^2$

$=$ **$0.0048\ m/s^2$.**

4.(D)



$$A = \pi x^2$$

$$x = \sqrt{2Rh - h^2}$$

Acceleration $= a_c = \dfrac{\pi}{Cda\sqrt{2g}} \displaystyle\int_{h_1}^{0} -\frac{2Rh - h^2}{\sqrt{h}}\, dh$

$$a_c = \frac{14\pi R^{3/2}}{15 Cda\sqrt{2g}}$$

5.(B) Bernoulli's equation is applicable for non - viscous flow. At boundary layer viscous flow, viscous force acts. Due to this Bernoulli's equation can be used only outside the boundary layer.

6. **.011**

Given :

Distance of nozzle above ground = 1

Angle of inclination, $\theta = 45°$

Dia. of nozzle, $d = 50 \text{ mm} = .05 \text{ m}$

$\therefore$ Area, $A = \frac{\pi}{4}(.05)^2 = .001963 \text{ m}^2$

The horizontal distance , $x = 4$ m

The co-ordinates of the point B, which is on the centre-line of the jet of water and is situated on the ground, with respect to A (origin) are

x = 4 m and y = – 1.0 m {From A, point B is vertically down by 1 m}

The equation of the jet is given as $y = x\tan\theta - \frac{gx^2}{2U^2}\sec^2\theta$

Substituting the known values as

$$-1.0 = 4\tan 45° - \frac{9.81\times 4^2}{2U^2}\times \sec^2 45°$$

$$= 4 - \frac{78.48}{U^2}\times\left(\sqrt{2}\right)^2 \left\{\sec 45° = \frac{1}{\cos 45°} = \frac{1}{\frac{1}{\sqrt{2}}} = \sqrt{2}\right\}$$

$$-1.0 = 4 - \frac{78.48\times 2}{U^2} \quad \text{or} \quad \frac{78.48\times 2}{U^2} = +4.0 + 1.0 = 5.0$$

$$\therefore \quad U^2 = \frac{78.48\times 2.0}{5.0} = 31.39$$

$$\therefore \quad U = \sqrt{31.39} = 5.60 \text{ m/s}$$

Now the rate of flow of fluid = Area × Velocity of jet

= A × U = .001963 × 5.6 m^3/sec

= 0.01099 ≈ **.011 m^3/s.**

7.(A) Given : $u = y^3/3 + 2x - x^2y$

$$\therefore \quad \frac{\partial u}{\partial x} = 2 - 2y$$

$$\frac{\partial u}{\partial y} = \frac{3y^2}{3} - x^2 = y^2 - x^2$$

Also $v = xy^2 - 2y - x^3/3$

$$\therefore \quad \frac{\partial v}{\partial y} = 2xy - 2$$

$$\frac{\partial v}{\partial x} = y^2 - \frac{3x^2}{3} = y^2 - x^2.$$

(i) For a two-dimensional flow, continuity equation is $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$

Substituting the value of $\frac{\partial u}{\partial x}$ and $\frac{\partial v}{\partial y}$, we get

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 2 - 2xy + 2xy - 2 = 0$$

∴ It is a possible case of fluid flow.

(ii) Rotation, ω_z is given by $\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) = \frac{1}{2}[(y^2 - x^2) - (y^2 - x^2)] = 0$

∴ Rotation is zero, which means it is case of irrotational flow.

8.(D) Given : $\phi = x(2y - 1)$

The velocity components in the direction of x and y are

$$u = -\frac{\partial \phi}{\partial x} = -\frac{\partial}{\partial x}[x(2y-1)] = -[2y - 1] = 1 - 2y$$

$$v = -\frac{\partial \phi}{\partial y} = -\frac{\partial}{\partial y}[x(2y-1)] = -[2x] = -2x$$

At the point P (4, 5), i.e., at x = 4, y = 5

$u = 1 - 2 \times 5 = -9$ units/sec

$v = -2 \times 4 = -8$ units/sec

∴ Velocity at P $= -9i - 8j$

or Resultant velocity at P $= \sqrt{9^2 + 8^2} = \sqrt{81 + 64}$ = 12.04 units/sec = 12.04 units/sec.

Value of Stream Function at P

We know that $\frac{\partial \psi}{\partial y} = -u = -(1 - 2y) = 2y - 1$ ...(i) and $$\frac{\partial \psi}{\partial x} = v = -2x \qquad ...(ii)$$

Integrating equation (i) w.r.t. 'y', we get

$$\int d\psi = \int (2y - 1)\, dy \quad \text{or} \quad \psi = \frac{2y^2}{2} - y + \text{Constant of integration.}$$

The constant of integration is not a function of y but it can be a function of x. ie the value of constant of integration is k. Then

$$\psi = y^2 - y + k. \qquad ...(iii)$$

Differentiating the above equation w.r.t. 'x', we get

$$\frac{\partial \psi}{\partial x} = \frac{\partial k}{\partial x}.$$

But from equation (ii), $\frac{\partial \psi}{\partial x} = -2x$

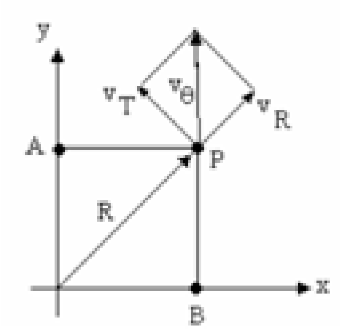
Equating the value of $\frac{\partial \psi}{\partial x}$, we get $\frac{\partial k}{\partial x} = -2x.$

Integrating this equation, we get $k = \int -2x\,dx = -\frac{2x^2}{2} = -x^2.$

Substituting this value of k in equation (iii), we get $\boldsymbol{\psi = y^2 - y - x^2}$.

9.(B) The velocity of the combined flow at this point is v_θ. This the vector sum of the radial and tangential velocities so

$$v_\theta = \left\{v_T^2 + v_R^2\right\}^{1/2}$$



C = 2   u = 3

$v_R = d\phi/dr = u\cos\theta$

$v_T = d\psi/dr = C/r - u\sin\theta$

At point A, $\theta = 90°$, R = 0.5, $v_R = 0$,

hence V_T = 7 m/s and $V_{\theta A}$ = 7m/s

At point B, $\theta = 0°$, R = 0.5 , V_R = 3 m/s,

hence V_T = 4 m/s and $v_{\theta B}$ = 5 m/s

The mainstream pressure is p and the velocity is u.

Apply Bernoulli between the main stream and point A.

$$p + \rho u^2/2 = p_A + \rho v_{\theta A}^2/2$$

Apply Bernoulli between the main stream and point B.

$$p + \rho u^2/2 = p_B + \rho v_{\theta B}^2/2$$

The pressure difference is then

$$p_A - p_B = (r/2)\,\{\rho/2\}\{w_{\theta B}^2 - V_{\theta A}^2\} = -11964 \text{ Pascal}$$

10.(B) First write down the indecial form of the equation (covered overleaf).

$f = C l^a g^b$

Next write down the basic dimensions of all the variables.

$[f] = T^{-1}$

$[l] = L^1$

$[g] = LT^{-2}$

Next substitute the dimensions in the place of the variables.

$T^{-1} = (L^1)^a (LT^{-2})^b$

Since the equation must be homogeneous then the power of each dimension must be the same on the left and right side of the equation. If a dimension does not appear at all then it is implied that it exists to the power of zero. The equation is written as follows.

$M^0 L^0 T^{-1} = L^{1a} LT^{-2b} M^0$

equate powers of each dimension. First equate powers of Time.

$T^{-1} = T^{-2b}$

$-1 = -2b$

$b = 1/2$

equate powers of Length.

$L^0 = L^{1a} L^b$

$0 = 1a + b$ hence $a = -b = -1/2$

$M^0 = M^0$ yields nothing in this case.

Now substitute the values of a and b back into the original equation and we have the following.

$$f = Cl^{-1/2} g^{1/2}$$

$$f = C(g/l)^{1/2}$$

The frequency of a pendulum may be derived from basic mechanics and shown to be

$$f = (1/2\pi)(g/l)^{1/2}$$

we could find C by plotting a graph of f against $(g/1)^{1/2}$.

11.(A) $R = \text{function}(D\, v\, \rho\, K) = C D^a v^b \rho^c K^d$

There are 3 dimensions and 5 quantities so there will be 5 – 3 = 2 dimensionless numbers. Identify that the one dimensionless group will be formed with R and the other with K.

Π_1 is the group formed between K and D v ρ

Π_2 is the group formed between R and D v ρ

$K = \Pi_2 D^a v^b \rho^c$ $\qquad$ $R = \Pi_1 D^a v^b \rho^c$

$[K] = ML^{-1}T^{-2}$ $\qquad$ $[R] = NLT^{-2}$

$[D] = L$ $\qquad$ $[D] = L$

$[v] = LT^{-1}$ $\qquad$ $[v] = LT^{-1}$

$[\rho] = ML^{-3}$ $\qquad$ $[\rho] = ML^{-3}$

$ML^{-1}T^{-2} = L^a(LT^{-1})^b(ML^{-3})^c$ $\qquad$ $MLT^{-2} = L^a(LT^{-1})^b(ML^{-3})^c$

$ML^{-1}T^{-2} = L^{a+b-3c}M^cT^{-b}$ $\qquad$ $ML^1T^{-2} = L^{a+b-3c}M^cT^{-b}$

Time $-2 = -b$ ⇒ $b = 2$ Time $-2 = -b, b = 2$

Mass $c = 1$ Mass $c = 1$

Length $-1 = a + b - 3c$ Length $1 = a + b - 3c$

$a = 0$ $1 = a + 2 - 3$, $a = 2$

$K = \Pi_2 D^{\circ} v^2 \rho^1$ $R = \Pi_1 D^2 v^2 \rho^1$

$$\Pi_2 = \frac{K}{\rho v^2} \qquad \Pi_1 = \frac{R}{\rho v^2 D^2}$$

It was shown earlier that the speed of sound in an elastic medium is given by the following formula.

It follows that $(k/\rho) = a^2$ and so $\Pi_2 = (a/v)^2$

The ratio v/a is called the Mach number (Ma) so $(Ma)^{-2}$

Π_1 is the Newton Number Ne.

The equation may be written as $\Pi_1 = \phi\Pi_2$ N_e or $Ne = \phi(M_a)$

12. **0.00028m^2/s**

First, we will calculate the flow rate by the fundamental relationship Q = volume/time. The volume is

$1300\ cm^3/(10^6\ cm^3/m^3) = 13 \times 10^{-4}\ m^3$. The time is 600 s.

$$Q = \frac{Volume}{Time} = \frac{13\times10^{-4}}{600} = 2.17\times10^{-6}\ m^3/s$$

$$Q = \frac{\pi d^4 \gamma h_L}{128\mu\ell} = \frac{\pi d^4(\rho g_n)h_L}{128\mu\ell} = \frac{\pi d^4 g_n h_L}{128 v\ell} \qquad \dots (A)$$

Now, solving the above equation for v,

$$v = \frac{\pi d^4 g_n h_L}{128 Q \ell} = \frac{3.14 \times (4/1000)^4 \times 9.81 \times 1}{128 \times (217 \times 10^{-6}) \times (100/1000)} = 0.00028\ m^2/s$$

13.(C) By Chezy's formula

$$V = C\sqrt{mi}$$

where $m = \frac{A}{P} = \frac{d}{4}$

$$i = \frac{h_f}{L}$$

By Darcy Weiscbach equation

$$h_f = \frac{flV^2}{2gd}$$

Substituting Values

$$h_f = \frac{fLc^2(mi)}{2gd}$$

$$h_f = \frac{f \times L \times C^2 \times \frac{d}{4} \times \frac{h_f}{L}}{2 \times g \times d}$$

$$8g = fc^2$$

$$C^2 = \frac{8g}{f}$$

$$C = \sqrt{\frac{8g}{f}}$$

14.(B) $\delta^* = \int_0^\delta \left[1 - \frac{u}{u_1}\right] dy = \int_0^\delta \left[1 - \sin\left\{\frac{\pi y}{2\delta}\right\}\right]$

$$\delta^* = \left[y + \frac{2\delta}{\pi}\cos\left\{\frac{\pi y}{2\delta}\right\}\right]_0^{\delta} = \{\delta + 0\} - \left\{0 + \frac{2\delta}{\pi}\right\} = 0.364\delta$$

15. **13.43**

$F_D = W - F_b = C_D\rho(V^2/2)A$

$W - (\gamma)(\pi D^3/6) = C_D\rho(V^2/2)(\pi D^2/4)$

$99 - [(62.4)(2.0/1.94)](\pi)(1.2)^3/6 = C_D(2.0)(V^2/2)(\pi)(1.2)^2/4$

$99 - 58.20 = 1.131 C_D V^2$

$C_D V^2 = 36.07$

$N_R = DV\rho/\mu = (1.2)(V)(2.0)/(3.3 \times 10^{-5}) = 72\,727V$

Try $C_D = 0.4; 0.4V^2 = 36.07$, $V = 9.496$ ft/s, $N_R = (72\,727)(9.496) = 6.91 \times 10^5$. $C_D = 0.20$. Try $C_D = 0.20: 0.20V^2 = 36.07$, $V = 13.43$ ft/s, $N_R = (72\,727)(13.43) = 9.77 \times 10^5$, $C_D = 0.20$ Hence, V = 13.43 fps.

16. **125.756**

Given :

Dia. at inlet, $d_1 = 30$ cm

$\therefore$ Area at inlet, $a_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4}(30)^2 = 706.85 \text{ cm}^2$

Dia. at throat, $d_2 = 15$ cm

$\therefore$ $$a_2 = \frac{\pi}{4} \times 15^2 = 176.7 \text{ cm}^2$$

$$C_d = 0.98$$

Reading of differential manometer = x = 20 cm of mercury.

$\therefore$ Difference of pressure head is given as

or $$h = x\left[\frac{S_h}{S_o} - 1\right]$$

where S_h = Sp. gravity of mercury = 13.6, S_o = Sp. gravity of water = 1

$$= 20\left[\frac{13.6}{1} - 1\right] = 20 \times 12.6 \text{ cm} = 252.0 \text{ cm of water.}$$

The discharge through venturimeter is given as

$$Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

$$= 0.98 \times \frac{706.85 \times 176.7}{\sqrt{(706.85)^2 - (176.7)^2}} \times \sqrt{2 \times 9.81 \times 252}$$

$$= \frac{86067593.36}{\sqrt{499636.9 - 31222.9}} = \frac{86067593.36}{684.4}$$

$$= 125756 \text{ cm}^3/\text{s} = \frac{125756}{1000} \text{ lit/s} = \mathbf{125.756 \text{ lit/s.}}$$

17.(D) Given :

Dia. of smooth pipe, d = 80 mm = .08 m

Length of pipe, $L = 800$ m

Discharge, $Q = 0.048\ m^3/\text{minute} = \frac{0.48}{60} = .008\ m^3/s$

Kinematic viscosity, $v = .015$ stokes $= .015 \times 10^{-4}\ m^2/s$ [Stokes = cm^2/s]

Density of water, $\rho = 1000\ kg/m^3$

Mean velocity $V = \frac{Q}{Area} = \frac{0.008}{\frac{\pi}{4}(.08)^2} = 1.591$ m/s

$\therefore$ Reynolds number, $R_e = \frac{V \times d}{v} = \frac{1.591 \times 0.08}{.015 \times 10^{-4}} = 8.485 \times 10^4$

As the Reynolds number of more than 4000, the flow is turbulent.

Now the value of 'f' is given by $f = \frac{.0791}{R_e^{1/4}} = \frac{.0791}{(8.485 \times 10^4)^{1/4}} = .004636$

Head lost is given as

$$h_f = \frac{4\,.\,f\,.\,L\,.\,V^2}{d \times 2g} = \frac{4 \times .004636 \times 800 \times 1.591^2}{.08 \times 2 \times 9.81} = \mathbf{23.42\ m}$$

18.(D) Thickness of laminar sub-layer is given by

$$\delta' = \frac{11.6 \times v}{u_*} = \frac{11.6 \times .015 \times 10^{-4}}{.0765} = 2.274 \times 10^{-4}\ m$$

$= 2.274 \times 10^{-2}$ cm $=$ **.02274 cm.**

(where U_* is calculated by Wall shearing stress, τ_0 is given as

$$\tau_0 = \frac{f \rho V^2}{2} = .0004636 \times \frac{1000}{2} \times 1.591^2 = 5.866\ N/m^2.$$

Centre-line velocity, u_{max} for smooth pipe is given as

$$\frac{u}{u_*} = 5.75 \log_{10} \frac{u_* y}{v} + 5.55$$

where u_* is shear velocity and $= \sqrt{\frac{\tau_0}{\rho}} = \sqrt{\frac{5.866}{1000}} = 0.0765$ m/s)

19. **177.03**

Drag force $= F_D = C_D A(\rho U^2/2) = 34.72$N

Lift force $= F_L = C_L A(\rho U^2/2) = 173.6$N

Resultant force $= F_R = (F_D^2 + F_L^2)^{1/2} = 177.03$ N

20. **482.26**

Power $= F_D \times U = 482.26$ Kw

21.(D) Given: $U = 12$ m/s ; $\mu = 18$ m^2/s

Shape of the Rankine oval

When a uniform flow is flowing over a doublet and doublet and uniform flow are in line, then the shape of the Rankine oval will be a circle of radius $= \sqrt{\frac{\mu}{2\pi U}}$.

22.(B) Radius of the Rankine circle

$$R = r = \sqrt{\frac{\mu}{2\pi U}} = \sqrt{\frac{18}{2\pi \times 12}} = \mathbf{0.488\ m.}$$

C : MATERIAL SCIENCE

1.(C) In the fcc system of crystals, atomic radius $r = \frac{a}{2\sqrt{2}}$ Where a is lattice parameter or bond length.

So that bond length $a = 2\sqrt{2}(r) = 2\sqrt{2} \times 1.273 = 3.6$ Å

We know that density is given by

$$\rho = \frac{nA}{Na^3}$$

Where n is number of atoms per unit cell, A is atomic weight N is Avogadro number and a is lattice parameter.

Since copper has fcc structure hence the number of atoms per unit cell n = 4.

$$\therefore \quad \rho = \frac{4 \times 63.5}{6.02 \times 10^{26} \times (3.6 \times 10^{-10})^3}$$

$\because$ N = 6.02×10^{23} molecules per gm mole

= 6.02×10^{26} molecules per Kg mole

$\therefore$ $\rho = 0.9043 \times 10^4 = 9.043 \times 10^3$ Kg/m^3

2.(B) We know that, in the unit cell there are four sodium ions and four chlorine ions. Thus, the total volume of unit cell,

$$V = 4\left[\frac{4}{3}\pi(r_{Na})^3 + \frac{4}{3}\pi(r_{Cl})^3\right] = \frac{16}{3}\pi\left[(0{\cdot}098)^3 + (0{\cdot}181)^3\right] = 0{\cdot}1151 \text{ nm}^3.$$

The cubic unit cell has a side of length,

$a = 2\,(r_{Na} + 2\,r_{Cl})$

$= 2\,[0{\cdot}098 + 0{\cdot}181] = 0.558$ nm

$\therefore$ Volume of the unit cell

$= (0{\cdot}558)^3 = 0{\cdot}1737 \text{ nm}^3$

Thus, the packing factor

$$= \frac{0{\cdot}1151}{0{\cdot}1737} = 0{\cdot}662$$

3.(C) We know that, interplaner spacing, d is given by

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

where, a = lattice of unit cell

In case of FCC structure,

$$a = \frac{4r}{\sqrt{2}}$$ where, r is atomic radius of copper atom

$$\therefore \quad a = \frac{4 \times 0{\cdot}128}{\sqrt{2}} = 0{\cdot}362 \text{ nm}$$

$$d_{111} = \frac{0{\cdot}362}{\sqrt{(1^2 + 1^2 + 1^2)}} = 0{\cdot}209 \text{ nm.}$$

4.(C) The Maxwell model strain at any time t is

$$\gamma(t) = \frac{\tau_0}{G_1} + \frac{\tau_0 t}{\mu_1}$$ and

Voigt-Kelvin strain at is

$$\gamma(t) = \frac{\tau_0}{G_2}\left[1 - e^{-\frac{G_2 t}{\mu_2}}\right]$$

According to the problem, for t = 50 sec,

Maxwell strain = Voigt-Kelvin strain

$$\Rightarrow \quad \frac{\tau_0}{G_1} + \frac{\tau_0 t}{\mu_1} = \frac{\tau_0}{G_2}\left[1 - e^{G_2 t/\mu_2}\right]$$

$$\Rightarrow \quad \frac{1}{G_1} + \frac{t}{\mu_1} = \frac{1}{G_2}\left[1 - e^{G_2 t/\mu_2}\right]$$

$$\Rightarrow \quad \frac{1}{G_1} + \frac{t}{\mu_1} = \frac{1}{G_2}\left[1 - e^{G_2 t/\mu_2}\right]$$

$$\Rightarrow \quad \frac{1}{G_1} = 3\cdot 7327 \times 10^{-11}$$

$$\Rightarrow \quad G_1 = 26\cdot 79 \times 10^9 \text{ N/m}^2$$

$$\Rightarrow \quad G_1 = 26\cdot 79 \text{ G N/m}^2$$

5.(D) Let, x = the wt.% carbon the hypereutectoid steel.

We also know that,

Eutectoid ferrite = total ferrite – proeutectoid ferrite (i)

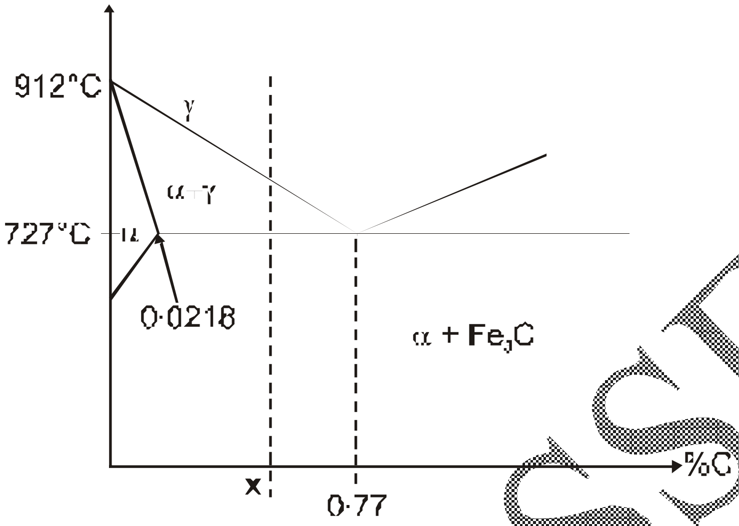


Fig.

Using Fig., and applying lever rule,

We can make the equation (i) as:

$$0\cdot091 = \frac{6\cdot67 - x}{6\cdot67 - 0\cdot0218} - \frac{0\cdot77 - x}{0\cdot77 - 0\cdot0218}$$

$\Rightarrow \quad 0\cdot091 = 0\cdot15042\,(6\cdot67 - x) - 1\cdot3365\,(0\cdot77 - x)$

$\Rightarrow \therefore \quad x = 0\cdot0985$ % C

6.(B) We know that, the temperature stress (σ) is expressed as

$\sigma = E\,\alpha\,\Delta T$

$\Rightarrow \quad \sigma = E\,\alpha\,(T_f - T_0)$

where, σ = tensile temperature stress, E = Young's modulus of elasticity

α = Linear coefficient of thermal expansion, T_f = final temperature,

T_0 = Initial temperature.

Given data, $T_0 = 20°$;

$\sigma = -172$ MPa;

$E = 100$ GPa;

$\alpha = 20 \times 10^{-6}\ (°C)^{-1}$

Now, $T_f = T_0 - \dfrac{\sigma}{E \cdot \alpha} \Rightarrow T_f = 20 - \dfrac{-172}{(100 \times 10^3)(20 \times 10^{-6})}$

$\therefore \quad T_f = 20 + 86 = 106°C$

7.(B) Given data;

$\sigma_f = 300$ MPa ;

$K_{IC} = 3 \cdot 6\ \text{MPa}\sqrt{m}$;

$Y = 1$

The fracture toughness equation is

$K_{IC} = Y \cdot \sigma \sqrt{\pi \cdot a}$

$\Rightarrow \quad 3 \cdot 6 = 1 \times 300 \sqrt{\pi \cdot a}$

$\Rightarrow \quad a = \left(\dfrac{3 \cdot 6}{300}\right)^2 \dfrac{1}{\pi}$

$\therefore \quad a = 4 \cdot 58 \times 10^{-5}\ \text{m} = 45 \cdot 8\ \mu\text{m}$

Thus, the largest internal crack

$= 2a$

$= 2 \times 45 \cdot 8\ \mu\text{m}$

$= 91{\cdot}6\,\mu m$

8.(A) We know that,

$$V = iR, \text{ and } R = \rho\frac{l}{A}$$

$$\therefore \quad V = i \times \rho\frac{l}{A}$$

$$\Rightarrow \quad A = i\,\rho\,\frac{l}{A}$$

$$\Rightarrow \quad \frac{\pi}{4}d^2 = i\,\rho\cdot\frac{l}{A}$$

$$\frac{\pi}{4}d^2 = i\cdot\frac{1}{\sigma}\frac{l}{V} \qquad \left[\because \rho = \frac{1}{\sigma}\right]$$

$$\therefore \quad d = \sqrt{\frac{4\,i\,l}{\pi\,\sigma\,V}}$$

Given that, $i = 12$ A

$V = 0{\cdot}6$ V for 1 m of wire,

$l = 1{\cdot}0$

$\sigma = 5{\cdot}85 \times 10^7\ (\Omega\ m)^{-1}$, thus

$$d = \sqrt{\frac{4\times12\times1}{\pi\times5{\cdot}85\times10^7\times0{\cdot}6}}$$

$$d = 6{\cdot}013 \times 10^{-4}\ m$$

9.(C) The lattice parameter 'a' for MgO is

$a = 2\,(r_{Mg^{2+}} + r_{O^{2-}})$

$\Rightarrow \quad a = 2\,(0{\cdot}78 + 1{\cdot}32)$

$\therefore \quad a = 4{\cdot}20$ Å

The effective number of oxygen anions at FCC positions in the unit cell = 4.

The effective number of magnesium cations in the octahedral voids

$$= 1 \text{ (body centre)} + 12 \times \frac{1}{4} \text{ (mid point of cube edges)} = 4$$

$$\text{Now, Density} = \frac{\text{Mass of atoms in unit cell}}{\text{Volume of unit cell}}$$

$$= \frac{(16 + 24\times 3)\times 1{\cdot}660\times 10^{-27}\times 4}{4{\cdot}20^3\times 10^{-30}} = 3610 \text{ kg/m}^3.$$

10.(C) In Atomic configuration $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ all shell are fill so this is configuration of inert gas (Ar) [P $\rightarrow$ 3].

Na is a strongly electropositive metal [Q $\rightarrow$ 1], Cℓ is a strongly electronegative element because it have negative [R $\rightarrow$ 4].

Si is four valent element So easily can share electron with other so made covalent bond [S $\rightarrow$ 2].

11. **1 : 3**

If we denote the respective weight compositions as $C_{Cu} = 49{\cdot}2\%$ and $C_{Au} = 50{\cdot}8\%$

Atomic weight, Cu = 64 amu and Au = 197 amu

The percentage of atom is given by,

$$C'_{Cu} = \frac{C_{Cu}A_{Cu}}{C_{Cu}A_{Cu} + C_{Au}A_{Au}} \times 100$$

$$= \frac{(49\cdot2)(64)}{(49\cdot2)(64) + (50\cdot8)(197)} \times 100 = 23\cdot93 \text{ at } \%$$

$$C'_{Au} = \frac{C_{Au}A_{Au}}{C_{Cu}A_{Cu} + C_{Au}A_{Au}} \times 100$$

$$= \frac{(50\cdot8)(197)}{(50\cdot8)(197) + (49\cdot2)(64)} \times 100 = 76\cdot07 \text{ at}\%$$

The atomic percentage ratio is Cu : Au = $\frac{23\cdot93}{76\cdot06} \approx 1 : 3$

12.(A) The fracture strength in case of Brittle materials can be represented as :

$$\sigma_f = \left(\frac{E\gamma_s}{4c}\right)^{1/2}$$

where, σ_f = fracture stress, E = Young's modulus,

γ_s = Specific surface energy, c = half length of crack

According to the given problem,

c = 2 mm; $\gamma_s = 1$ J/m^2;

= 2 × 10^{-6} m;

E = 70 GN/m^2 = 70 × 10^9 N/m^2

$$\therefore \quad \sigma_f = \left(\frac{70\times10^9\times1}{4\times2\times10^{-6}}\right)^{1/2} = 0{\cdot}935 \times 10^8 \text{ N/m}^2 = 935 \text{ MPa}$$

13. 6.65 mm

Let θ be the inclination of AC with the horizontal.

$$\tan\theta = \frac{3}{4},\ \sin\theta = \frac{3}{5},\ \cos\theta = \frac{4}{5}$$

Let T be the tension in the member AC. Fig., shows the free body diagram for the member BC.

Taking moments about the pin B

$$T \sin\theta \times 4 = (2 \times 1) + (2 \times 3.5)$$

$$T = \frac{9}{4\sin\theta} = \frac{9}{4}\cdot\frac{5}{3} = 3.75 \text{ kN}$$

Vertical reaction at B $= V_b = 4 - T \sin\theta$

$$= 4 - 3.75 \times \frac{3}{5} = 1.75 \text{ kN}$$

Horizontal reaction at B $= H_b = T \cos\theta = 3.75 \times \frac{4}{5} = 3$ kN

Resultant reaction at B $= R_b = \sqrt{3^2 + 1.75^2} = 3.473$ kN

Sectional area required for AC $= \frac{3.75 \times 1000}{125} = 30 \text{ mm}^2$

Let d be the diameter of the pin at B

$$2f_s \frac{\pi d^2}{4} = R_b$$

$$\therefore \quad 2 \times 50 \times \frac{\pi d^2}{4} = 3.473 \times 1000$$

$\therefore$ d = 6.65 mm, say 7 mm.

14. – 8·1

In case of BCC structure

Number of atoms per unit cell = 2

and, Lattice parameter, $a = \frac{4r}{\sqrt{3}}$

Thus, the volume per atom is $\frac{a^3}{2} = \left(\frac{4r}{\sqrt{3}}\right)^3 \Big/ 2 = 6.16\ r^3$

In case of FCC structure

No. of atoms per unit cell = 4,

Lattice parameter, $a = \frac{4r}{\sqrt{2}}$

Thus the volume per atom in this structure is

$$\frac{\left(\frac{4r}{\sqrt{3}}\right)^3}{4} = 5 \cdot 66\ r^3$$

Assuming there is no change in the atomic radius, the percentage volume change

$$= \frac{5{\cdot}66\ r^3 - 6{\cdot}16\ r^3}{6{\cdot}16\ r^3} = -\ 8{\cdot}1\ \%$$

The iron thus contracts when the transformation occurs.

15. 0.344, 3502·47

The effective number of atoms in diamond cubic unit cell = corner atoms + face centered atom + atoms completely within the unit cell

$$= \frac{1}{8} \times 8 + \frac{1}{2} \times 6 + 1 \times 4 = 8$$

Volume of each spherical atom $\frac{4}{3} = \cdot \pi r^3 = 4/3\ \pi \left(\frac{a\sqrt{3}}{8}\right)^3$

where, r = radius of the atom ; a = lattice parameter.

$\therefore$ Packing efficiency $= \dfrac{\text{Volume of atom in the unit cell}}{\text{Volume of unit cell}}$

$$= \frac{8 \times \frac{4}{3} \times \pi \left(a\frac{\sqrt{3}}{8}\right)^3}{a^3} = 0{\cdot}344$$

$\therefore$ Density $= \dfrac{\text{Mass of atomic in the unit cell}}{\text{Volume of unit cell}}$

The mass of the carbon atom = 12 amu

$= 12 \times 1{\cdot}664 \times 10^{-27}$ kg

$= 1{\cdot}992 \times 10^{-26}$ kg

$\therefore$ Density $= \dfrac{1{\cdot}992 \times 10^{-26} \times 8}{(0{\cdot}357 \times 10^{-9})^3}$

$= 3502{\cdot}47$ kg/m^3.

16. 2·38

Given data :

C_0 = 0·20 wt % C ; C_s = 0·90 wt % C ;

C_x = 0·40 wt % C ; x = 0·50 mm ;

⇒ x = 5×10^{-4} m ; D = $1 \cdot 28 \times 10^{-11}$ m^2/;

erf (Z) = 0·7143 ; Z = 0·755

We know that $\dfrac{C_x - C_0}{C_s - C_0} = 1 - \text{erf}\left(\dfrac{x}{2\sqrt{D\,t}}\right)$

$$\Rightarrow \quad \frac{0{\cdot}40 - 0{\cdot}20}{0{\cdot}90 - 0{\cdot}20} = 1 - \text{erf}\left(\frac{5 \times 10^{-4}}{2\sqrt{1{\cdot}28 \times 10^{-11} \times t}}\right)$$

$$\Rightarrow \quad 0{\cdot}2857 = 1 - \text{erf}\left[\frac{5 \times 10^{-4}}{2\sqrt{1{\cdot}28 \times 10^{-11} \times t}}\right]$$

$$\Rightarrow \quad 0{\cdot}7114 = \text{erf}\left[\frac{5 \times 10^{-4}}{2\sqrt{1{\cdot}28 \times 10^{-11} \times t}}\right]$$

Now according to the problem

$$0{\cdot}755 = \frac{5 \times 10^{-4}}{2\sqrt{1{\cdot}28 \times 10^{-11} \times t}}$$

⇒ ∴ t = 8565·96 sec. ∴ t = 2·38 hrs.

17. **(212)**

In this problem the axial units are a: b : c :: 0.424 : 1 : 0.367

(i) $m_1 a = 0.212$ or $m_1 \times 0.424 = 0.212$

$\therefore \quad m_1 = \frac{0.212}{0.424} = \frac{1}{2}$

Similarly $\quad m_2 b = 1$ or $m_2 \times 1 = 1 = m_2 = 1.$

Also $\quad m_3 c = 0.183$ or $m_3 \times 0.367 = 0.183$

$$m_3 = \frac{0.183}{0.367} = \frac{1}{2}$$

Hence numerical; parameters of the planes are $\frac{1}{2}, 1, \frac{1}{2}$.

$$\text{Miller indices} = \left(\frac{1}{1/2} : \frac{1}{1} : \frac{1}{1/2}\right) = (212).$$

18. (121)

In this case, numerical parameters of this plane are 2, 1, 2.

$\therefore \quad \text{Miller indices} = \left(\frac{1}{2} : 1 : \frac{1}{2}\right) = (121).$

19. 69.61 & 30.39

Basis is 1 m^3 of composite material. Therefore, we have $0{\cdot}65\ m^3$ of fibres and $0{\cdot}35\ m^3$ of epoxy resin.

$\because \quad \rho = \frac{m}{\nu} \quad \therefore \quad m = \rho \cdot \nu \cdot .$

Take the following assumption : the density of the fibres is $51{\cdot}48$ mg/m^3 and that of the epoxy resin is $1{\cdot}2$ mg/m^3.

Now, mass of fibres $= \rho_f v_f$

$$= 1{\cdot}48 \times 0{\cdot}65 = 0{\cdot}962 \text{ mg}$$

Mass of epoxy resin $= \rho_r v_r$

$= 1\cdot2 \times 0\cdot35 = 0\cdot42$ mg

$$\text{Wt\% fibres} = \frac{0\cdot962}{0\cdot962 + 0\cdot42} \times 100\% = 69\cdot61\%$$

$$\text{Wt\% epoxy resin} = \frac{0\cdot42}{0\cdot962 + 0\cdot42} \times 100\% = 30\cdot39\%$$

20. **277.5**

Also, given that,

$E_f = 400$ GPa; $E_r = 50$ GPa;

We know that,

Young's method of composite

$E_c = E_f v_f + E_r v_r$

$= 400 \times 0\cdot65 + 50 \times 0\cdot35 = 277\cdot5$ GPa

21. $\mathbf{9\cdot317 \times 10^{-3}}$

Given data;

$d_f = 20$ mm; $V_f = 0\cdot45$;

$s_c = 14$ MPa; $E_f = 7000$ MPa; $E_n = 2800$ MPa.

Now,

Volume fraction of the nylon, $V_n = 1 - 0\cdot45 = 0\cdot55$

Cross sectional area of glass fiber, $A_f = \frac{\pi}{4} \times (20\mu)^2 \text{ m}^2$,

$$A_f = 3{\cdot}14 \times 10^{-10}\ m^2$$

The ratio of fibre load to the nylon load,

$$\frac{F_f}{F_n} = \frac{7000 \times 0{\cdot}45}{2800 \times 0{\cdot}55} = 20{\cdot}45 \quad \therefore \quad F_f = 20{\cdot}45\ F_n.$$

$$\%\ \text{load carried by the glass fibre} = \frac{20 \cdot 45}{20 \cdot 45 + 1} = 95{\cdot}34\%$$

We also know that, $A_f = V_f A_c$

$$3{\cdot}14 \times 10^{-10} = 0{\cdot}45 \times A_c \quad \therefore \quad A_c = 6{\cdot}98 \times 10^{-10}\ m^2$$

And,

$$A_n = V_n A_c$$

$$A_n = 0{\cdot}55 \times 6{\cdot}98 \times 10^{-10}$$

$$A_n = 3{\cdot}84 \times 10^{-10}\ m^2$$

$$\therefore \qquad F_c = A_c \cdot s_c$$

$$F_c = 6{\cdot}98 \times 10^{-10} \times 14 \times 10^6 = 9{\cdot}772 \times 10^{-3}\ N$$

Since,

$$F_c = F_f + F_n$$

$$F_c = 20{\cdot}45\ F_n + F_n$$

$$9{\cdot}772 \times 10^{-3} = 21{\cdot}45\ F_n$$

$$\therefore \qquad F_n = 4{\cdot}556 \times 10^{-4}\ N$$

$\therefore \quad F_f = 20{\cdot}45 \times F_n = 20{\cdot}45 \times 4{\cdot}556 \times 10^{-4}$

$F_f = 9{\cdot}317 \times 10^{-3}$ N

22. 29.65

$\therefore$ The amount of stress in glass is

$$\sigma_f = \frac{F_f}{A_f} = \frac{9{\cdot}31 \times 10^{-3}}{3{\cdot}14 \times 10^{-10}}$$

$\therefore \quad \sigma_f = 2{\cdot}964968 \times 10^7 \text{ N/m}^2 = 29{\cdot}65 \text{ MPa}$

D: SOLID MECHANICS

1. 50mm

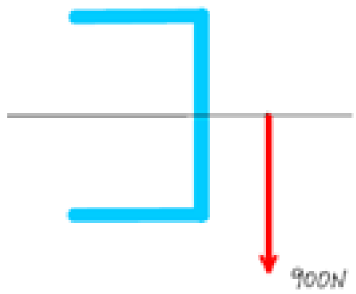
$\underline{R} = \Sigma \underline{F} = 250\underline{i} - 250\underline{i} - 900\underline{j}$ N

$= -900\underline{j}$ N

$\underline{M}_C = -(250 \times 180) + 900 \times x\, \underline{k}$ N

(= 0 for C to be the shear center)

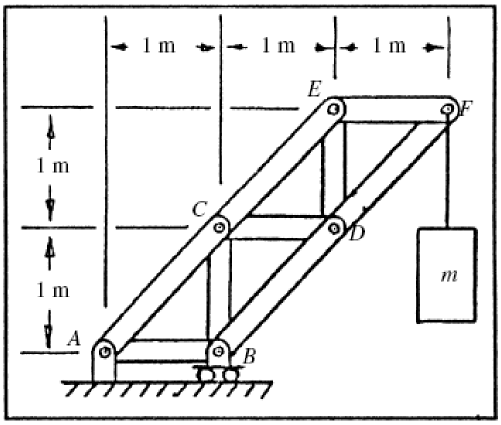
$\Rightarrow \quad x = \frac{250 \times 180}{900} = \boxed{50\text{mm}}$

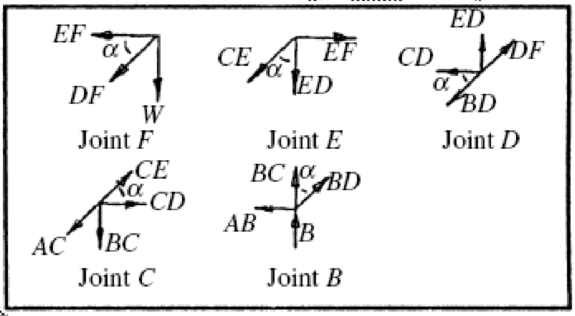


2. 36 kg

The common interior angle BAC = DCE = EFD = CDB is $\alpha = \tan^{-1}$ (A) = 45°.

Note $\cos\alpha = \sin\alpha = \frac{1}{\sqrt{2}}$. Denote the axial force in a member joining two points I, K by IK.





Joint F:

$$\sum F_y = -\frac{DF}{\sqrt{2}} - W = 0,$$

from which DF $= -\sqrt{2}W(C)$.

$$\sum F_x = -EF - \frac{DF}{\sqrt{2}} = 0,$$

from which EF = W(T).

Joint E:

$$\sum F_x = -\frac{CE}{\sqrt{2}} + EF = 0$$

from which CE = $\sqrt{2}W(T)$.

$$\sum F_y = -ED - \frac{CE}{\sqrt{2}} = 0,$$

from which ED = –W(C).

Joint D:

$$\sum F_Y = ED + \frac{DF}{\sqrt{2}} - \frac{BD}{\sqrt{2}} = 0,$$

from which BD = $-2\sqrt{2}W(C)$.

$$\sum F_X = \frac{DF}{\sqrt{2}} - \frac{BD}{\sqrt{2}} - CD = 0,$$

from which CD = W(T)

Joint C:

$$\sum F_x = -\frac{AC}{\sqrt{2}} + \frac{CE}{\sqrt{2}} + CD = 0,$$

from which AC = $2\sqrt{2}W(T)$

$$\sum F_y = -\frac{AC}{\sqrt{2}} + \frac{CE}{\sqrt{2}} - BC = 0,$$

from which BC = –W(C)

Joint B:

$$\sum F_x = -AB + \frac{BD}{\sqrt{2}} = 0,$$

from which AB = –2W(C)

This completes the determination of the axial forces in all nine members. The maximum tensile force occurs in member AC, AC = $2\sqrt{2}W(T)$, from which the safe load is W= $\frac{4}{2\sqrt{2}} = \sqrt{2}$ =1.414 kN. The maximum compression occurs in member BD, BD = $-2\sqrt{2}W$ (C), from which the maximum safe load is W = $\frac{1}{2\sqrt{2}}$ = 0.3536 kN. The largest mass m that can be safely supported is

$$\boxed{m = \frac{353.6}{9.81} = 36.0 \text{ kg}}$$

3. **1/4**

Minimum force with which body will just move=$\mu_s mg$

After the body start moving Frictional force becomes=$\mu_k mg$

So ma=$\mu_s mg - \mu_k mg$

or a=g/4

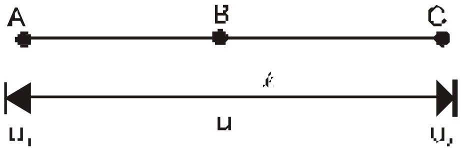
4. **1 : 1**

$v^2 - u^2 = 2as$

or $\upsilon_2^2 - \upsilon_0^2 = 2al$

or $15^2 - 5^2 = 2al$

or $a = \frac{100}{\ell}$



Again $\upsilon_1^2 - u_0^2 = 2a\frac{\ell}{2}$

or $v_1 = 10$ m/sec

The times t_1 and t_2 to cover distance AB and BC are given by :

$$t_1 = \frac{\upsilon_1 - \upsilon_0}{a} = \frac{10-5}{a} = \frac{5}{a}$$

$$t_2 = \frac{\upsilon_2 - \upsilon_1}{a} = \frac{15-10}{a} = \frac{5}{a}$$

∴ Required ratio = $\frac{t_1}{t_2} = 1:1$

5. 0.94

Given: m_{box} 1 = 2.0 kg; m_{box} 2 = 5.0 kg; d_{box} 1 = 1.2 m; t_{box} 1 = 0.50 s; d_{box} 2 = 0.90 m, t_{box} 2 = ???(Let 2-kg box be referred to as Box 1 and the 5-kg box will be referred to as box 2.)

The two boxes are initially at rest. The total system momentum is initially 0. After the cutting of the string and the impulse of the spring, the total system momentum must also be 0. Thus, Box 1's backward momentum must be equal to the Box 2's forward momentum. The distance and time for Box 1 must be used to determine its velocity.

v = d/t = (1.2 m) / (0.5 s) = 2.4 m/s

Now the principle of momentum conservation can be used to determine Box 2's velocity.

m_{box} 1 • v_{box} 1 = m_{box} 2 • v_{box} 2

(2 kg) • (2.4 m/s) = (5 kg) • v_{box} 2

v_{box} 2 = (2 kg) • (2.4 m/s) / (5 kg) = 0.96 m/s

The velocity of Box 2 can be used to determine the time it takes it to move a distance of 0.90 meters.

v_{box} 2 = d_{box} 2 / time

Time = d_{box} 2 / v_{box} 2 = (0.90 m) / (0.96 m/s) = 0.9375 s = ~0.94 s.

6. **11**

$$\Delta = \frac{4PL}{\pi E D_1 D_2}$$

Actually

$$\Delta_1 = \frac{4PL}{\pi(2D^2)E} = \frac{2PL}{\pi D^2 E}$$

Avg. diameter of bar

$$\frac{2D + D}{2} = 1.5\text{ D}$$

Approximate extension =

$$\Delta_2 = \frac{4PL}{\pi(1.5D)^2 E} = \frac{4PL}{2.25 \times \pi D^2 E}$$

$$\therefore \text{Error} \rightarrow \left(1 - \frac{\Delta_1}{\Delta_2}\right) \times 100$$

$$= \left(1 - \frac{2}{2.25}\right) \times 100 = 11\%$$

7.(A) When one of the principal stress at a point is large in comparison to the other the situation resembles axial tension test. Therefore, all theories give nearly same result.

8.(D) Poisson's ratio = $\frac{\text{Lateral strain}}{\text{Longitudual strain}}$

$$\frac{\text{Lateral strain}}{4 \times \text{Longitudual strain}} = 0.25$$

$$G = \frac{E}{2(1+\mu)} = \frac{2 \times 10^5}{2(1+0.25)} = 0.8 \times 10^5 \text{ N/mm}^2$$

9. **52.44**

$$\frac{1}{K_s} = \frac{1}{K_1} + \frac{1}{K_2} = \frac{1}{1} + \frac{1}{3} = \frac{4}{3} \text{KN/m}$$

combined stiffness

$= K_s = K_3$

$$= \frac{3}{4} + 2 = \frac{11}{4} \text{KN/m}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{11 \times 10^3}{4 \times 1}} = 52.44 \text{ Hz}$$

10.(A) We shall assume a horizontal force component P and a vertical force component Q at pin C so as to permit us to use Castigliano's theorem for the horizontal and vertical displacement components there. Our first step is then to determine the strain energy of the system from the 1-kip load at D, the 2-kip load at B, and the loads P and Q at C. By the method of joints, for the forces in the members of the truss we have **(equilibrium)**

AB = P – 2(1 + Q) tension DE = 1 + Q tension

BC = P – Q tension DB = Q compression (a)

CD = $\frac{Q}{.707}$ tension EB = $\frac{2+Q}{.707}$ tension

We now determine U in the following way (**constitutive law**):

$$U = \sum_i \frac{F_i^2 L_i}{2A_i E_i} \quad \text{(b)}$$

Taking A_i and E_i as having the same value for each member, we get

$$U = \frac{1}{2AE}\left\{[P-2(1+Q)]^2(10) + (P-Q)^2(10) + \left(\frac{Q}{.707}\right)^2\left(\frac{10}{.707}\right)\right.$$

$$\left. +(1+Q)^2(10) + Q^2(10) + \left(\frac{2+Q}{.707}\right)^2\left(\frac{10}{.707}\right)\right\} \quad \text{(c)}$$

We may now compute the horizontal and vertical components of pin C by first taking partial derivatives of U with respect to P and with respect to Q, respectively, and then letting P and Q equal zero. Thus, for the horizontal component Δ_H we have **(compatibility)**

$$\Delta_H = \left(\frac{\partial U}{\partial P}\right)_{P=Q=0} = \frac{1}{2AE}[2(P-2-2Q)(10) + 2(P-Q)10]_{P=Q=0}$$

$$= \frac{1}{2AE}[(2)(-2)(10)] = -\frac{20}{AE}\text{ ft} \quad \text{(d)}$$

Clearly, the horizontal deflection component of the pin is opposite in sense to the direction of the force P shown in Fig. Now we get Δ_V. Thus,

$$\Delta_V = \left(\frac{\partial U}{\partial Q}\right)_{P=Q=0} = \frac{1}{2AE}[2(P-2-2Q)(10)(-2)+2(P-Q)(10)(-1)$$

$$+\frac{2Q}{(.707)^2}\left(\frac{10}{.707}\right)+2(1+Q)(10)+20Q+\frac{2(2+Q)}{(.707)^2}\frac{10}{.707}\Bigg]_{P=Q=0}$$

$$\therefore \Delta_V = \frac{1}{2AE}(80+20+113.2) = \frac{106.6}{AE}\text{ ft} \qquad \text{(e)}$$

The deflection at pin C can then be given as

$$\boxed{\Delta_C = \frac{1}{AE}(-20i-106.6j)\text{ ft}} \qquad \text{(f)}$$

11. **1/2**

Pure shearing strain of magnitude

$= \gamma_{xy}$ radians

$\therefore$ Maximum principal strain

$= \frac{\gamma_{xy}}{2}$

12. **- 0.0440**

It would at first seem that we have a statically indeterminate support system here, but this is not the case. We can take $\overline{AB}$ as free body with the bending moment zero at the pin at B and solve for the supporting force at A. Thus observing Fig.,

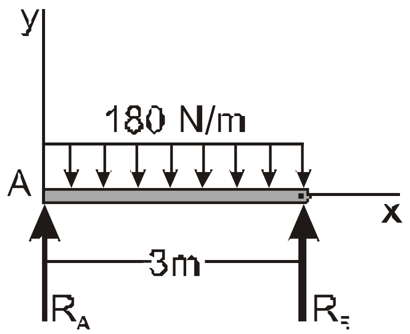


Figure. Free body of AB.

$\sum M_B = 0$:

$$-R_A(C) + (180)(C)\left(\frac{3}{2}\right) = 0$$

$\therefore R_A = 270$ N

We can now proceed with the deflection curve analysis.

$0 \le x < 3$:

$$\frac{d^2v}{dx^2} = \frac{1}{EI}\left[270(x) - 180\left(\frac{x^2}{2}\right)\right]$$

$$\frac{dv}{dx} = \frac{1}{EI}\left[270\left(\frac{x^2}{2}\right) - 180\left(\frac{x^3}{6}\right) + C_1\right] \qquad \text{........(a)}$$

$$v = \frac{1}{EI}\left[270\left(\frac{x^3}{6}\right) - 180\left(\frac{x^4}{24}\right) + C_1x + C_2\right] \qquad \text{.......(b)}$$

$3 < x < 9$:

$$\frac{d^2v}{dx^2} = \frac{1}{EI}\left[270(x) - 180\left(\frac{x^2}{2}\right)\right]$$

$$\frac{dv}{dx} = \frac{1}{EI}\left[270\left(\frac{x^2}{2}\right) - 180\left(\frac{x^3}{6}\right) + C_3\right] \qquad ....(c)$$

$$v = \frac{1}{EI}\left[270\left(\frac{x^3}{6}\right) - 180\left(\frac{x^4}{24}\right) + C_3x + C_4\right] \qquad ....(d)$$

You will note that except for the constants of integration the deflection equations are identical for this simple problem for both domains.

Boundary conditions:

1. When x = 0, v = 0.

$$\therefore\ C_2 = 0$$

2. When x = 9, dv/dx = 0

$$270\left(\frac{9^2}{2}\right) - 180\left(\frac{9^3}{6}\right) + C_3 = 0$$

$$\therefore\ C_3 = 1.094 \times 10^4$$

3. When x = 9, v = 0.

$$270\left(\frac{9^3}{6}\right) - 180\left(\frac{9^4}{24}\right) + (1.094 \times 10^4)(9) + C_4 = 0$$

$$\therefore\ C_4 = -8.206 \times 10^4$$

Patch condition:

$$[v(C)]_{Eq.(b)} = [v(C)]_{Eq.(d)}$$

$$\therefore C_1(C) + C_2 = C_3(C) + C_4$$

Noting that $C_2 = 0$, $C_3 = 1.094 \times 10^4$, and $C_4 = -8.206 \times 10^4$, we can solve for the remaining unknown constant C_1. That is,

$$3C_1 + 0 = (C)(1.094 \times 10^4) - 8.206 \times 10^4$$

$$\therefore C_1 = -1.641 \times 10^4$$

We now look for zero slopes of v in the two domains. Thus for the left domain we have

$$\frac{dv}{dx} = 0 = \frac{1}{EI}\left(270\frac{x^2}{2} - 180\frac{x^3}{6} - 1.641 \times 10^4\right) \qquad \text{..........(e)}$$

We find as a real root for this equation

$$x = -6.92 \text{ m}$$

Clearly, we discard this result, coming as it does outside the domain of Eq. (e). Look next at the remaining domain.

$$\frac{dv}{dx} = 0 = \frac{1}{EI}\left[270\left(\frac{x^2}{2}\right) - 180\left(\frac{x^3}{6}\right) + 1.094 \times 10^4\right]$$

We get as the only zero-slope position,

$$x = 9.00 \text{ m}$$

This corresponds to the base of the cantilever and represents the trivial condition of a minimum deflection of zero.

We should check the pin. Thus, from Eq. (b) we have

$$v(C) = \frac{1}{EI}\left[270\left(\frac{3^3}{6}\right) - 180\left(\frac{3^4}{24}\right) - \left(1.641\times10^4\right)(3)\right]$$

$$= -\frac{4.862\times10^4}{EI}\,m$$

It should now be clear that the maximum deflection must occur at the pin.

The value of EI is next computed.

$$EI = (2\times10^{11})\left[\left(\frac{1}{12}\right)(.075)(.1)^3 - \left(\frac{1}{12}\right)(.040)(.060)^3\right]$$

$$= 1.106\times10^6\ N\text{-}m^2$$

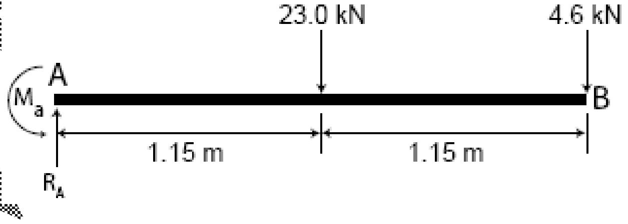
The maximum deflection then is

$$v(3) = -\frac{4.862\times10^4}{1.106\times10^6} = -.0440\ m$$

13. 32.0

We need to calculate the reaction and reacting moment at A. Draw the free body diagram for the forces acting on the beam, converting the distributed load to an equivalent concentrated load:

Find the reaction at A:



$$\sum F_y = R_A - 23.0 - 4.6$$

$$= 0$$

$$R_A = 27.6\,kN$$

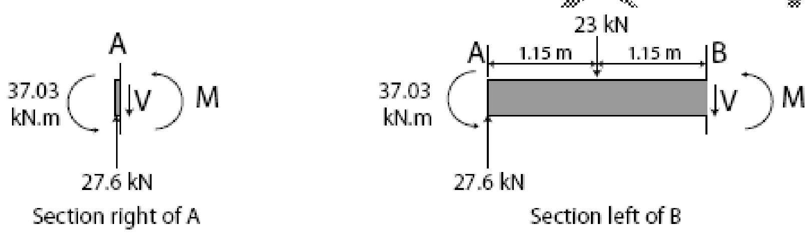
Find the reacting moment at A:

$$\Sigma M_A = M_a - 23.0 \times 1.15 - 4.6 \times 2.3$$

$$= 0$$

$$M_a = 37.03\ kN \cdot m$$

Now, use the method of sections to find the shear forces and bending moments between A and B. The loads are distributed, so the shear force diagram is linear and the bending moment will be quadratic.



Consider a section immediately right of A. Draw the shear force, V, and the bending moment, M, in the positive direction. Then:

$$\Sigma Fy = 27.6 - V = 0$$

$$V = 27.6\,kN$$

$$\Sigma M_{section} = M + 37.03 = 0$$

$$M = -37.03\ kN \cdot m$$

Now repeat the procedure for a section immediately left of B:

$$\Sigma F_y = 27.6 - 23 - V = 0$$

$$V = 4.6\ kN$$

$$\Sigma M_{section} = M + 37.03 + 23 \times 1.15 - 27.6 \times 2.3 = 0$$

$$M = 0$$

The bending moment diagram is a quadratic that passes through (0, -37.03) and (2.3, 0).

One method is to integrate the equation of the shear force diagram. The load along the beam between A and B is uniformly distributed so the shear force diagram is a straight line between (0, 27.6) and (4, 4.6).

The slope of this line is given by:

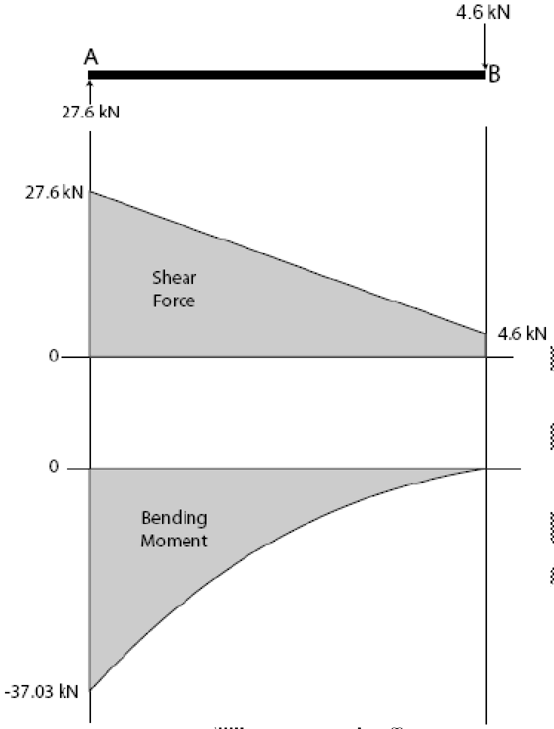
$$m = \frac{y_1 - y_0}{x_1 - x_0} = \frac{4.6 - 27.6}{4 - 0} = -10$$

The equation of the line is y = mx + c = –10x + c and it passes through (0, 27.6). Solving for c, the curve becomes y = –10x + 27.6. The equation of the bending moment diagram is the integral of this line:

$$M(x) = \int (-10x + 27.6)\, dx = -5x^2 + 27.6x + c$$

$$= -5x^2 + 27.6x - 37.03$$

Now sketch the shear force and bending moment diagrams:



The depth of the beam is d = 306 mm and the moment of inertia about the x-centroidal axis is I = 177 × 10^{-6} m4 = 177 × 10^6 mm^4. Maximum stress occurs at the top or at the bottom of the beam, where c = 153 mm. The maximum bending moment is 37.03 kN · m at the left hand end of the beam. Bending stress is given by:

$$\sigma_B = \frac{Mc}{I} = \frac{37.03 \times 10^6 \text{ N} \cdot \text{mm} \times 153 \text{ mm}}{177 \times 10^6 \text{ mm}^4} = 32.0 \text{ MPa}$$

14. **3**

$$\sqrt{M^2 + 4^2} = 5$$

or $M = 3$ kNm

15. **0.5**

Shear stress developed at a point proportional to its centre from centre of shaft.

At distance r, shear stress = $\frac{\tau}{2r}.r = \frac{\tau}{2} = 0.5\tau$

16. 1.25

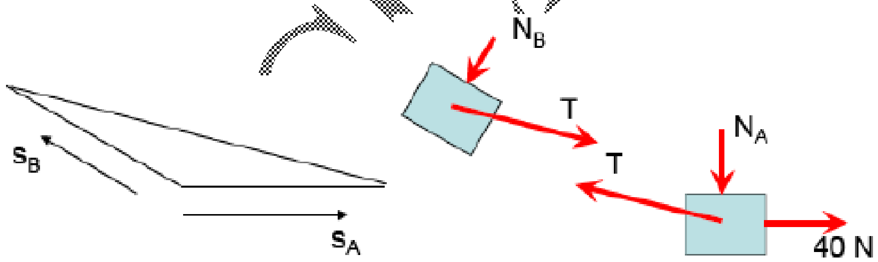
Stiffness of spring $R = \frac{Gd^4}{8D^3n}$

$$R_1 = \frac{c}{25}$$

$$R_2 = \frac{c}{20}$$

$$\frac{R_2}{R_1} = \frac{c}{20} \times \frac{25}{c} = 1.25$$

17.(A) & 18.(C)



Kinematics: triangle OAB

$s_A = s_B$ and $0.5 = s_A \cos 15 + s_B \cos 15$, $s_A = s_B = 0.2588$ m

$$l^2 = s_A^2 + s_B^2 - 2s_A s_B \cos 150$$

diff: $0 = 2s_A v_A + 2s_B v_B - 2\cos 150\,(s_A v_B + s_B v_A)$

given: $v_A = 0.4$ m/s $\rightarrow v_B = -0.4$ m diff: $0 = v_A^2 + s_A a_A + v_B^2 + s_B a_B - \cos 150(s_A a_B + s_B a_A + 2v_A v_B)$

$0 = 0.04287 + 0.4829a_A + 0.4829a_B$ (A)

Kinetics:

$\left[\sum F = ma\right]$ $40 - T\cos 15 = 2a_A$ and $-T\cos 15 = 3a_B$ into (A)

$a_A = 7.95\ m/s^2$, $a_B = -8.04\ m/s^2$, $T = 25.0$ N

19.(A) & 20.(B) The free-body diagram for the entire beam is shown in Fig. We shall consider the supporting force R_1 as the redundant constraint in the ensuing computations. We can here compute the bending moment M in terms of R_1 without the necessity of determining other supporting forces or torques in terms of R_1. Accordingly, we shall employ Eq., for two spans of the beam as follows:

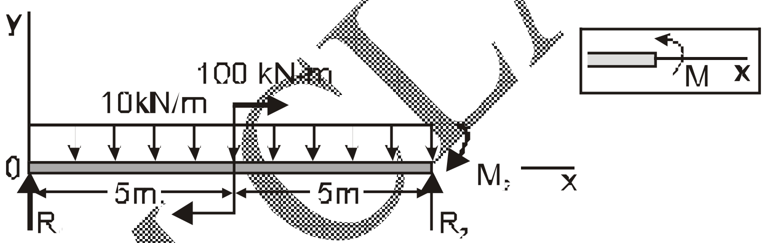


Figure. Free-body diagram of cantilever beam.

$0 \le x < 5$:

$$\frac{d^2v}{dx^2} = \frac{1}{EI}\left(R_1 x - \frac{10x^2}{2}\right) \qquad \text{(a)}$$

$5 < x < 10$:

$$\frac{d^2v}{dx^2} = \frac{1}{EI}\left(R_1 x - 10\frac{x^2}{2} + 100\right) \qquad \text{(b)}$$

Integrating twice, for the spans we get

$0 \le x < 5$

$$\frac{dv}{dx} = \frac{1}{EI}\left(R_1\frac{x^2}{2} - \frac{10x^3}{6} + C_1\right) \quad (c)$$

$$v = \frac{1}{EI}\left(R_1\frac{x^3}{6} - \frac{10x^4}{24} + C_1x + C_2\right) \quad (d)$$

$5 < x < 10$:

$$\frac{dv}{dx} = \frac{1}{EI}\left(R_1\frac{x^2}{2} - \frac{10x^3}{6} + 100x + C_3\right) \quad (e)$$

$$v = \frac{1}{EI}\left(R_1\frac{x^3}{6} - \frac{10x^4}{24} + 100\frac{x^2}{2} + C_3x + C_4\right) \quad (f)$$

We have four constants of integration plus the unknown R_1 to be determined. We can note that

at $x = 0$, $v = 0$

at $x = L$, $\frac{dv}{dx} = v = 0$

Applying these conditions, we have

$C_2 = 0$ (g)

$$C_3 = -\frac{R_1(10)^2}{2} + \frac{(10)(10)^3}{6} - (100)(10) = -50R_1 + 667 \quad (h)$$

$$C_4 = -\frac{R_1(10)^3}{6} + \frac{(10)(10^4)}{24} - (100)\frac{(10^2)}{2} - (-50R_1 + 667)(10) \quad (i)$$

$= 333R_1 - 7.51 \times 10^3$

Next we apply the patch conditions **(compatibility)** at x = 5. Thus

$$\left[\frac{dv(5^-)}{dx}\right]_{Eq.(c)} = \left[\frac{dv(5^+)}{dx}\right]_{Eq.(e)}$$

$$R_1\left(\frac{5^2}{2}\right) - 10\frac{(5^3)}{6} + C_1 = R_1\left(\frac{5^2}{2}\right) - 10\frac{(5^3)}{6} + (100)(5) + C_3$$

$$\therefore C_1 = 500 + C_3 \qquad \text{(j)}$$

Also,

$$[v(5^-)]_{Eq.(d)} = [v(5^+)]_{Eq.(f)}$$

$$R_1\left(\frac{5^3}{6}\right) - \frac{(10)(5^4)}{24} + C_1(5) = R_1\left(\frac{5^3}{6}\right) - \frac{(10)(5^4)}{24} + 100\frac{(5^2)}{2} + C_3(5) + C_4$$

$$\therefore 5C_1 = 1250 + 5C_3 + C_4 \qquad \text{(k)}$$

Replacing C_3 and C_4 using Eqs. (h) and (i) in Eqs. (j) and (k), we get the following simultaneous equations for C_1 and R_1

$$C_1 = 1167 - 50R_1$$

$$5C_1 = 83R_1 - 2.92 \times 10^3$$

Solving for R_1, we get

$$R_1 = 26.3\,\text{kN}$$

The other supporting forces are now readily available from rigid-body mechanics. Thus,

$\sum F_y = 0:$

$$R_1 - (10)(10) + R_2 = 0$$

$$\therefore \; R_2 = 73.7 \text{ kN}$$

$\sum M_0 = 0:$

$$-(100)(5) - 100 + R_2(10) - M_2 = 0$$

$$\therefore \; M_2 = 137 \text{ kN m}$$

We have accordingly determined both the deflection equation and the supporting forces simultaneously.

21.(B) (a) $M_o = Fd = 100\text{lb} \times \underbrace{24\cos 60°}_{12}$

$= 1200$ lb in (clock wise)

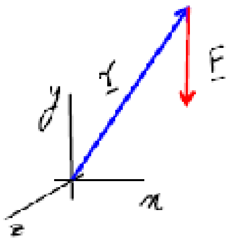
Alternatively

$\underline{M}_o = \underline{r} \times \underline{F}$

$\underline{r} = 12\,\underline{i} + 12\sqrt{3}\,\underline{j}$

$\underline{F} = -100\,\underline{j}$ lb

$\Rightarrow$ $\boxed{\underline{M}_o = -1200\underline{k} \text{ lbin}}$



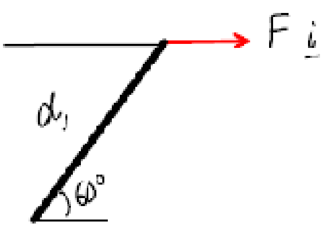
22.(B)

(b) $d_1 = 24 \sin 60°$

$= 12\sqrt{3} = 20.8$ in

$Fd_1 = M_o$

$\Rightarrow f = \frac{M_0}{d_n} = \boxed{57.7 \text{ lb}}$



E: THERMODYNAMICS

1.(B) (i) Vessel is of fixed volume, hence $\Delta V = 0$. No work is done, $W = 0$.

(ii) The gas drives back the atmosphere hence.

$W = -P_{ext} \cdot \Delta V$

Also $\Delta V = V_{final} \simeq V_{initial} V_{final}$ $(\because V_{initial} = 0)$

$\therefore \qquad \Delta V = \frac{nRT}{P_{ext}}$

or $\qquad W = -P_{ext} \cdot \frac{nRT}{P_{ext}} = -nRT$

where n is the number of mole of H_2 gas obtained from n mole of $Fe_{(s)}$.

$$Fe_{(s)} + 2HCl_{(aq)} \longrightarrow FeCl_{2(aq)} + H_{2(g)}$$

1 mole $\qquad\qquad\qquad\qquad$ 1 mole

$\therefore \qquad n = \frac{50}{56} = 0.8929 \text{ mole}$

$\therefore \qquad W = -0.8929 \times 8.314 \times 298$

$= -2212.22 J$

2.(B) (i) Work done during the process from A to B (expansion)

$W_{AB} = +$ area ABKLA

$=$ area of ΔABC + area of rectangle BCLK

$$W_{AB} = \frac{1}{2} BC \times AC + KL \times LC$$

Now, BC = KL $= 4 - 1 = 3$ litre

$= 3 \times 10^{-3} m^3$

$AC = 4 - 2 = 2 \; Nm^{-2}$

$LC = 2 - 0 = 2 \; Nm^{-2}$

$$\therefore \qquad W_{AB} = \frac{1}{2}\times 3\times 10^{-3}\times 2 + 3\times 10^{-3}\times 2$$

$W_{AB} = 9 \times 10^{-3}$ J

(ii) Work done during the process from B to C (Compression) is

W_{BC} = – area BCLK

= – KL × LC

$= -3 \times 10^{-3} \times 2$

$= -6 \times 10^{-3}$ J

(iii) Work done during the process from C to A As there is no change in volume of the gas in this process, therefore, $W_{CA} = 0$

Net work done in the complete cycle

$W = W_{AB} + W_{BC} + W_{CA}$

$= 9 \times 10^{-3} + (-6 + 10^{-3}) + 0$

$= 3 \times 10^{-3}$ J

3.(A) Total heat supplied = Work done + Change in internal energy

So work done = 2140 – 1580 =560 J

Let s be the distance moved then

the work done is given by = Fs

Fs = 560

s = 560/F

= 560/102*10

s =.54 m

4.(D) If the temperature increases, then the internal energy, which depends on temperature, will certainly rise. But adding heat to a system need not result in an increase in bulk energy of the system. For example, consider a pot of water sitting on a hot-plate. If we take the water as our system, then clearly heat is being added to the system, but since the pot is not moving, its potential and kinetic energy are not changing.

Since the boundary of the system is not moving, there is no work being done to, or by the system.

5.(D)

$$\dot{m} = \rho \dot{V}$$

$$\sum_{Inlets} \dot{m}_{in} = \sum_{Outlets} \dot{m}_{out}$$

$$\rho \dot{V}_1 = \rho \dot{V}_2$$

$$\dot{V}_1 = \dot{V}_2$$

$$A_1 \vec{V}_1 = A_2 \vec{V}_2$$

$$\vec{V}_2 = \frac{A_1}{A_2}\vec{V}_1 = \frac{\pi D_1^2/4}{\pi D_2^2/4}\vec{V}_1$$

$$\vec{V}_2 = \left(\frac{D_1}{D_2}\right)^2 \vec{V}_1 = \left(\frac{2D}{D}\right)^2 \vec{V}_1$$

$$\vec{V}_2 = 4\vec{V}_1$$

6.(C)

$$\oint \frac{\delta Q_{net}}{T} \le 0$$

$$\int\left(\frac{\delta Q_{net}}{T}\right)_{in} + \int\left(\frac{\delta Q_{net}}{T}\right)_{out} \le 0$$

$$\left(\frac{Q_{in}}{T_{in}}\right) + \left(-\frac{Q_{out}}{T_{out}}\right) \le 0$$

$$\left(\frac{3150\text{kJ}}{(440+273)\text{K}}\right)+\left(\frac{-1294.46\text{ kJ}}{(20+273)\text{K}}\right)\le 0$$

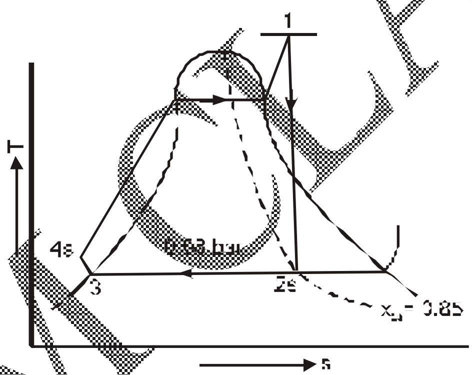
$$(4.418-4.418)\frac{\text{kJ}}{\text{K}}=0$$

The Clausius inequality is satisfied here. Since the cyclic integral is equal to zero, the cycle is made of reversible processes.

$$W_{net}=Q_{in}-Q_{out}=(3150-1294.46)\text{kJ}=1855.4\text{ kJ}$$

$$\eta_{th}=\frac{W_{net}}{Q_{in}}=\frac{1855.54\text{ kJ}}{3150\text{ kJ}}=0.589 \quad \text{or} \quad 58.9\%$$

7.(D) As state 2s (Fig.) the quality and pressure are known.



$\therefore \quad s_{2s}=s_f+x_2 s_{fg}=0.5926+0.85(8.2287-0.5926)$

Since $\quad =7.0833\text{kJ/kg K}$

$\therefore \quad s_1=7.0833\text{kJ/kgK}$

At state, I the temperature and entropy are thus known. At 360^0C, s_g = 5.0526 kJ/kg K, which is less than s_1. So from the table of superheated steam, at $t_1 = 360^0$C and s_1 = 7.0833 kJ/kg K, the pressure is found to be 16.832 bar (interpolation).

∴ The greatest allowable steam pressure is :

$p_1 = 16.831$ bar

$h_1 = 3165.54$ kJ/kg

$h_{2s} = 173.88 + 0.85 \times 2403.1 = 2216.52$ kJ/ kg

$h_3 = 173.88$ kJ/kg

$h_{4s} - h_3 = 0.001 \times (16.83 - 0.08) \times 100 = 1.675$ kJ/kg

$h_{4s} = 175.56$ kJ/kg

$Q_1 = h_1 - h_{4s} = 3165.54 - 175.56 = 2990$ kJ/kg

$W_T = h_1 - h_{2s} = 3165.54 - 175.56 = 2990$ kJ/kg

$W_P = 1.675$ kJ/kg

$$\eta_{cycle} = \frac{W_{net}}{Q_1} = \frac{947.32}{2990} = 0.3168 \text{ or } 31.68\%$$

Mean temperature of heat addition.

$$T_{m1} = \frac{h_1 - h_{4s}}{s_1 - s_{4s}} = \frac{2990}{7.0833 - 0.5926}$$

$$= 460.66K = 187.51^0C \ .$$

8. **75**

The efficiency of a heat engine is the ratio of the work done per cycle W to the heat absorbed from the high-temperature reservoir Q_h.

The percentage of the heat of combustion (heat absorbed from the high temperature reservoir) is the ratio of Q_c to Q_h. We can use the relationship between W, Q_h, and Q_c ($W = Q_h - Q_c$) to find Q_c/Q_h.

Use the definition of efficiency and the relationship between W, Q_h, and Q_c to obtain:

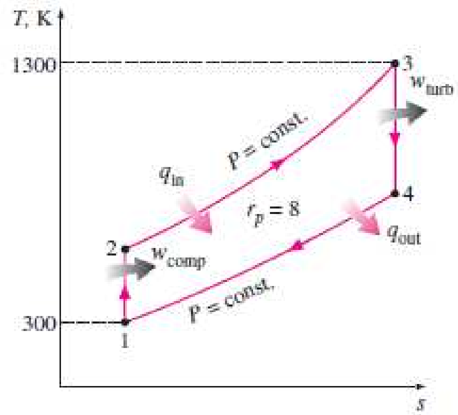
$$\varepsilon = \frac{W}{Q_h} = \frac{Q_h - Q_c}{Q_h} = 1 - \frac{Q_c}{Q_h}$$

Solving for Qc/Qh yields: $\frac{Q_c}{Q_h} = 1 - \varepsilon$

Substitute for ε to obtain: $\frac{Q_c}{Q_h} = 1 - 0.25 = 0.75$

9.(C) The *T-s* diagram of the ideal Brayton cycle described is shown in Fig. We note that the components involved in the Brayton cycle are steady-flow devices. The air temperatures at the compressor and turbine exits are determined from isentropic relations:

Process 1-2 (isentropic compression of an ideal gas):



$$T_1 = 300\text{ K} \to h_1 = 300.19\text{ kJ/kg}$$
$$P_{r1} = 1.386$$
$$P_{r2} = \frac{P_2}{P_1}P_{r1} = (8)(1.386) = 11.09$$

$T_2 = 540$ K

Process 3-4 (isentropic expansion of an ideal gas):

$$T_3 = 1300\text{ K} \to h_3 = 1395.97\text{ kJ/kg}$$
$$P_{r3} = 330.9$$
$$P_{r4} = \frac{P_4}{P_3}P_{r3} = \left(\frac{1}{8}\right)(330.9) = 41.36$$

$T_4 = 770$ K

10.(D) $\Delta H^0_{Reaction} = \Sigma H^0_{Products} - \Sigma H^0_{Reactants} = [2 \times H^0_{HF_{(g)}} + H^0_{O_{2(g)}}] - [H^0_{OF_{2(g)}} + H^0_{H_2O_{(g)}}]$

$\because$ H^0 of free elements = 0 $\quad \therefore H^0_{O_2} = 0$

$\because$ $\Delta H^0_f = H^0$, i.e., standard heat of formation = standard heat enthalpy of a compound

Also, ΔH^0_f for F_2O is +ve; ΔH^0_f for H_2O is –ve, because heats of combustion are exothermic.

$\Delta H^0_R = [2 \times (-270)] + 0 - [20 + (-250)] = -310$ kJ

Now $\quad \Delta H^0 = \Delta E^0 + \Delta nRT$

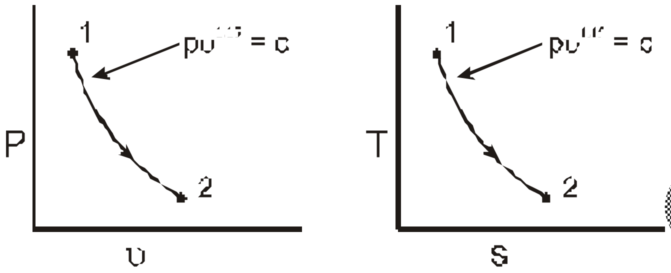
$\because \quad \Delta H^0_R = -310 \times 10^3$ J; $\quad \Delta n = 3 - 2 = 1$

R = 8.314 J; T = 298 K

$\therefore \quad -310 \times 10^3 = \Delta E^0 + 1 \times 8.314 \times 298$

$\therefore \quad \Delta E^0 = -312477.5 \text{ joule}$

$\therefore \quad \Delta E^0 = \mathbf{-312.4775\ kJ}$



11.(A)

The fluid is air (Fig.)

$$\upsilon_2 = \upsilon_2\left(\frac{P_1}{P_2}\right)\frac{RT_1}{P_1}\left(\frac{P_1}{P_2}\right)^{\frac{1}{n}} = \frac{0.287\times 473}{1000}(10)^{1/1.15}$$

$u_2 = 0.13575 \times 7.406 = 1.0054 m^3/kg$

$$\frac{P_1\upsilon_1}{T_1} = \frac{P_2\upsilon_2}{T_2}$$

$$\therefore \quad T_2 = 473\times\frac{1}{10}\times\frac{1.0054}{0.13575} = 350.306K = 77.3°C$$

$$Q = \Delta u + W = C\upsilon\Delta T + \frac{p_2\upsilon_2 - p_1\upsilon_1}{1-n}$$

$$= \left(c_\upsilon + \frac{R}{1-n}\right)(T_2 - T_1)$$

$$= \left(0.716 + \frac{0.287}{-0.15}\right)(350.306 - 473)$$

= (– 1.195)(– 123.306) = 147.35kJ

12. **125**

We can find the entropy change of the universe from the entropy changes of the high- and low-temperature reservoirs. The maximum amount of the 500 J of heat that could be converted into work can be found from the maximum efficiency of an engine operating between the two reservoirs.

The entropy change of the universe is the sum of the entropy changes of the two reservoirs:

$$\Delta S_u = \Delta S_h + \Delta S_c = -\frac{Q}{T_h} + \frac{Q}{T_c} \quad = -Q\left(\frac{1}{T_h} - \frac{1}{T_c}\right)$$

Substitute numerical values and evaluate ΔS_u:

$$\Delta S_u = (-500\,\text{J})\left(\frac{1}{400\,\text{K}} - \frac{1}{300\,\text{K}}\right)$$

$= 0.42$ J/K

Relate the heat that could have been converted into work to the maximum efficiency of an engine operating between the two reservoirs:

$W = \varepsilon_{max} Q_h$

The maximum efficiency of an engine operating between the two reservoir temperatures is the efficiency of a Carnot device operating between the reservoir temperatures:

$$\varepsilon_{max} = \varepsilon_C = 1 - \frac{T_c}{T_h}$$

Substitute for ε_{max} to obtain:

$$W = \left(1 - \frac{T_c}{T_h}\right) Q_h$$

Substitute numerical values and evaluate W:

$$W = \left(1 - \frac{300\,\mathrm{K}}{400\,\mathrm{K}}\right)(500\,\mathrm{J})$$

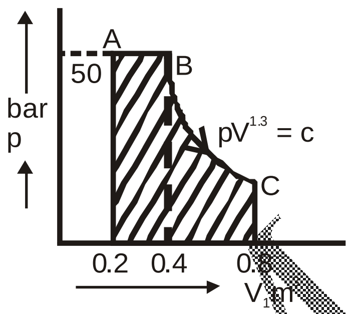
$= 125\,\mathrm{J}$

13.(B) Area under AB

$= (0.4 - 0.2) \times 50 \times 10^5$ J

$= 10^6$ J = 1 MJ

Area under BC



$= \frac{p_1V_1 - p_2V_2}{n-1} = \frac{50\times10^5\times0.4 - 20.31\times10^5\times0.8}{1.3-1}$

= 1.251MJ

Total work = 2.251MJ

14. **2087.83**

Here, mass of water, m = 1g

$\therefore$ Initial volume of water, $V_1 = 1\ \mathrm{cm}^3$

Volume of steam, $V_2 = 1671\ cm^3$

$\therefore$ Change in volume, $dV = V_2 - V_1 = 1671 - 1 = 1670\ cm^3 = 1670 \times 10^{-6}\ m^3$

Standard atmospheric pressure,

$P = 1.013 \times 10^5\ Nm^{-2}$

As change of state is involved,

$\therefore$ $dQ = mL = 1 \times 540 \times 4.18\ J = 2257\ J$

Change in internal energy, $dU = ?$

$dW = PdV = 1.013 \times 10^5 \times 1670 \times 10^{-6} = 169.17\ J$

From $dQ = dU + dW$

$dU = dQ - dW = 2257 - 169.17$

$dU = 2087.83\ J$

15. 0.369, 342

Firstly we calculate the mass of air in the tire

$$PV = mRT \Rightarrow m = \left[\frac{PV}{RT}\right] = \frac{310\ [kPa]\ 0.1\ [m^3]}{0.287\left[{}^{kJ}\!/\!{}_{kg\ K}\right] 293\ [K]}$$

$m = 0.369\ kg$

The temperature in the tire increases to 50°C (323K), however the volume and mass of air in the tire remains constant, thus:

$$PV = mRT \Rightarrow m = \left[\frac{PV}{RT}\right]$$

$$\left[\frac{P_1}{T_1}\right] = \left[\frac{P_2}{T_2}\right] \Rightarrow P_2 = P_1\left[\frac{T_2}{T_1}\right] = 310\ kPa\left[\frac{323\ K}{293\ K}\right] = 342\ kPa$$

$$P_{2,gage} = 342 \text{ kPa}$$

16. 276.7

Here, initial temperature,

$T_1 = 27°C = 273 + 27 = 300$ K

final temperature, $T_2 = 97°C = 273 + 97 = 370$ K

When a gas is compressed adiabatically, work done on the gas is given by

$$W = \frac{R}{(1-\gamma)}(T_2 - T_1) = \frac{8.3 \times (370-300)}{1-1.5}$$

or $W = -11.62 \times 10^2$ J

∴ Heat produced,

$$H = \frac{W}{J} = \frac{11.62 \times 10^2}{4.2} = 276.7 \text{ cal.}$$

17. 60

Because this is a constant pressure process, $\Delta H = q_P = 60$ kJ.

$\Delta U = \Delta H . P\Delta V = \Delta H + w$

18. 35

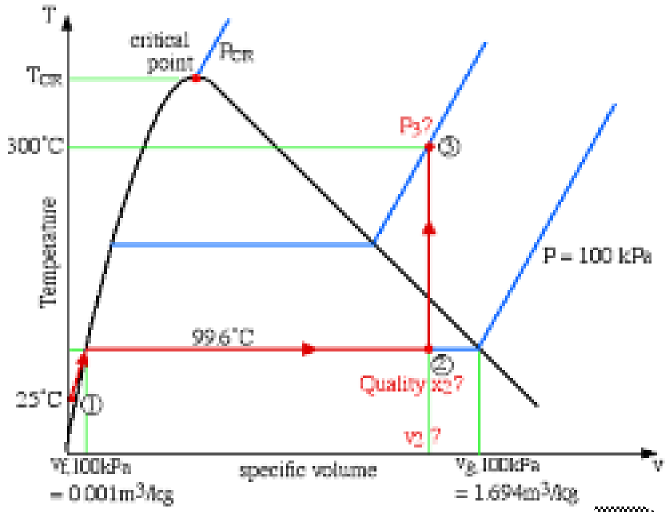
$w = -25$ kJ (work done by the system is negative)

$\Delta U = 60$ kJ – 25 kJ = 35 kJ.

19. 0.118, 0.235

We need to first evaluate the specific volume v_2, which can then be compared to the saturation values v_f and v_g at the pressure of 100 kPa.

Thus $v_2 = V / m = 0.4\ [m^3] / 2\ [kg] = 0.2\ [m^3/kg]$



$$\text{Quality } x_2 = \left[\frac{v_2 - v_f}{v_g - v_f}\right]_{100kPa} = \left[\frac{0.2 - 0.001}{1.694 - 0.001}\right] = 0.118$$

mass of water vapor at state 2:

$x = m_g/m \quad \Rightarrow \quad m_g = xm = 0.118\ (2\ kg) = 0.235\ kg$

20. 129

Concerning state (C), the problem statement did not specify that it is in the superheat region. We needed to first determine the saturated vapor specific volume v_g at 300°C. This value is 0.0216 m^3 / kg, which is much less than the specific volume v_3 of 0.2 m^3 /kg, thus placing state (C) well into the superheated region. Thus the two intensive properties which we use to determine the pressure at state (C) are T_3 = 300°C, and v_3 = 0.2 m^3 / kg. On scanning the superheat tables we find that the closest values lie somewhere between 1.2 MPa and 1.4 MPa, thus we use linear interpolation techniques to determine the actual pressure P_3 as shown below:

Superheat Vapor Tables at 300°C

v	0.2139	v3 = 0.2	0.1823	m³/kg
P	1.2	P3 ?	1.4	MPa

$$\frac{P_3 - 1.2}{1.4 - 1.2} = \frac{0.2 - 0.2139}{0.1823 - 0.2139} = 0.440$$

$$\Rightarrow P_3 = 1.29 \text{ MPa}$$

21. 0.658

$p_1V_1 = mRT_1$

$$R = \frac{300 \times 0.07}{0.25(273 \times 80)} = 0.238 \text{ kJ/kgK}$$

Final temperature

$$T_2 = \frac{p_2V_2}{mR} = \frac{300 \times 0.1}{0.25 \times 0.238} = 505\text{K}$$

Now

$$Q = (U_2 - U_1) + W = (T_2 - T_1) + W$$

$$0 = 0.25\ c_v (505 - 353) - 25$$

$$c_v = \frac{25}{0.25 \times 152} = 0.658 \text{kJ/kg K}$$

22. 0.896

Now $c_p - c_v = R$

$$c_p = 0.658 + 0.238 = 0.896 \text{ kJ/kgK}$$

F: POLYMER SCIENCE AND ENGINEERING

1.(A) Cyanoacrylate

Other/examples of die hardness

- Cyanoacrylate
- Acrylic resin lacquer
- Polystyrene solution

→ Die-hardners → do not increase the actual hardness of die stone but only increase the abrasion resistance

Gypsum disadvantage is the relatively poor resistance to abrasion.

Volatile relief agents and nail polish are die spacers.

2.(A) → Answer should have been as ormocers are organically modified ceramics.

→ Its an acronym for organically modified ceramic

→ Composed of a polymer of multifunctional urethane and thioether, alkoxysilianes.

The silicanes provide for rigid 3 dimensional structure, while methacrylate group are available for photochemical polymerization.

→ Supplied as a tube and cured by light curing

Filler Particle size	1-15 µm
Filler weight	17%
Filler volume	61%

→ COTE is close to that of tooth → less thermal expansion is seen

Other modification of ceramics and composites Smart compositions → Composed of paste of Barium Aluminum or Floride silicates glass-fillers (1 µm) with YbF_3, SiO_2 and alkaline $Casio_4$ glass in dimethacrylate monomers → introduced by Arostion in 1998 k Fluoride releasing other composites (less than GIC more than other composites) – releases Ca^{++} and OH^- ions also

→ Ceromers → Ceramic Optimized polymers-introduced by IV Oclar → Composition; Barium glass, spheriodal mixed oxide ytterium trifluride and silicon dioxide in imethylacrylate monomers (Bis-GMA and UDEMA).

3.(D) Fiber reinforced composite.

Materials used for prosthesis

1. Acrylic copolymer
2. Polyvinyl chloride
3. Chlorinated polyethylene
4. Polyrethone elathomare
5. Silicones
6. Polyphosphozires

4.(C) **0.2 to 0.5%**

Excess of monomer leads to increased polymerization shrinkage

5.(A) Polycrylic acid

Exp. Composition proter	Liquid
• ZnO - Bulk ingredient	Polycrylic acid
• MgO - Modifier	Itaconic acid
• Biomuth/Al oxide- Improves smoothness of the mix	Maleic acid
• SnF_2 - Anticariogenic	Tricarboxyllic acid

6.(D) **Free radical polymerization** is a method of polymerization by which a polymer forms by the successive addition of free radical building blocks. **Emulsion polymerization** is a type of radical polymerization that usually starts with an emulsion incorporating water, monomer, and surfactant. The most common type of emulsion polymerization is an oil-in-water emulsion, in which droplets of monomer (the oil) are emulsified (with surfactants) in a continuous phase of water. Emulsion polymerization permits simultaneous increase in rate of polymerization and polymer weight.

7.(B) A reinforced polymer composite is made by the incorporation of fibers into the polymer. The composite produced from these types of materials are low density, low cost, comparable specific properties, and most importantly they are environmental friendly. Its advantages over traditional construction materials are its high tensile strength to weight ratio, ability to be molded into various shapes, and potential resistance to environmental conditions, resulting in potentially low maintenance cost. It greatly affects the physical as well as mechanical properties of the composite materials. These properties make FRP composite a good alternative for innovative construction.

8.(A) Natural rubber is used extensively in many applications and products, either alone or in combination with other materials. In most of its useful forms, it has a large stretch ratio, high resilience, and is extremely waterproof. Out of all the elastomers, natural rubber has the longest elongation range & flexibility of the order of 1000-1500 percent.

9.(A) Butyl rubber is a synthetic rubber, a copolymer of isobutylene with isoprene. A synthetic rubber, or elastomer, butyl rubber is impermeable to air and used in many applications requiring an airtight rubber. Polyisobutylene and butyl rubber are used in the manufacture of adhesives, agricultural chemicals, fiber optic compounds, ball bladders, caulks and sealants, cling film, electrical fluids, lubricants (2 cycle engine oil), paper and pulp, personal care products, pigment concentrates, for rubber and polymer modification, for protecting and sealing certain equipment for use in areas where chemical weapons are present, as a gasoline/diesel fuel additive, and even in chewing gum. The first major application of butyl rubber was tire innertubes. This remains an important segment of its market even today.

10.(A) MW_{av}(polymer) = DP x MW_{av}(mer)

= (10,000 mers)(28 g/(mol*mer))

= **280,000 g/mol**

11.(C)

$$DP = \frac{molecular\_weight\_of\_polymer(g/mol)}{molecular\_weight\_of\_mer(g/mol/mer)} = \frac{12{,}000\,g/mol}{226\,g/mol/mer} = 53mers$$

12.(D) Raw rubber obtained from milky sap (latex) of the rubber tree does not possess the characteristics of the rubber with which we are familiar. In order to give it strength and elasticity it is vulcanized. In the vulcanization process, raw rubber is mixed with small amount of sulphur and heated. The sulphur reacts with the polymer molecules forming a cross-linked network.

This cross-linking gives mechanical strength to the rubber. In addition, fillers such as carbon black and zinc oxide are usually added to the crude rubber before vulcanization in order to improve its wearing characteristics.

13.(B) Teflon is used as a non-stick coating for pans and other cookware. It is very non-reactive, partly because of the strength of carbon–fluorine bonds and so it is often used in containers and pipework for reactive and corrosive chemicals. Where used as a lubricant, Teflon reduces friction, wear and energy consumption of machinery. It is also commonly used as a graft material in surgical interventions.

14.(C) Plasticizers or dispersants are additives that increase the plasticity or fluidity of a material. The dominant applications are for plastics, especially polyvinyl chloride (PVC). Plasticizers work by embedding themselves between the chains of polymers, spacing them apart (increasing the "free volume"), and thus significantly lowering the glass transition temperature for the plastic and making it softer. For plastics such as PVC, the more plasticizer added, the lower its cold flex temperature will be. This means that it will be more flexible and its durability will increase as a result of it.

15.(B) Bakelite

Bakelite is thermosetting polymer. It becomes infusible on heating and can not be remoulded

16.(B) Resins

Resins are amorphous organic solids or semisolids which usually have a typical lustre and are often transparent or translucent.

17.(B) $$\frac{1.07 \times 10^{11} \text{ lb plastic}}{2.90 \times 10^{8} \text{ people}} = 370 \text{ lb/person in 2003}$$

18.(C) $$\frac{370 \text{ lb/person} - 330 \text{ lb/person}}{330 \text{ lb/person}} \times 100 = 12\% \text{ change}$$

19.(A) When two monomers of ethylene join, they release 228 kJ of energy in an exothermic reaction. The heat released is therefore 114 kJ per monomer. With 1000 monomers joining, the heat released will be 114,000 kJ or 1.14×10^5 kJ.

20.(B) The reaction is so exothermic that, in the early days of polymer manufacture, polymerization vessels exploded. Finally, manufacturers realized that heat had to be removed from the polymerization vessels to avoid this.

21.(B) Two equations: (A) $160 = C(12)^m$ and (B) $300 = C(250)^m$

(A) $\ln 160 = \ln C + m \ln 12$ or $\ln 160 - m \ln 12 = \ln C$

(B) $\ln 300 = \ln C + m \ln 250$ or $\ln 300 - m \ln 250 = \ln C$

(A) and (B): $\ln 160 - m \ln 12 = \ln 300 - m \ln 250$

$5.0752 - 2.4849\, m = 5.7038 - 5.5215\, m$

$(5.5215 - 2.4849)m = 5.7038 - 5.0752$

$3.0366\, m = 0.6286$

m = 0.2

22.(A) (A) $C = 160/(12)^{0.207} = 160/1.6726 = 95.658$

(B) $C = 300/(250)^{0.207} = 300/3.1361 = 95.660$

Averaging these values, **C = 95.7**

G: FOOD PRESERVATION

1.(C) Pasteurization or pasteurisation is a process of heating food, which is usually a liquid, to a specific temperature for a predefined length of time and then immediately cooling it after it is removed from the heat.

2.(B) Clostridium perfingens poison is an enterotoxin produced during sporulation.Clostridium is a genus of Gram-positive bacteria, belonging to the Firmicutes. They are obligate anaerobes capable of producingendospores. Individual cells are rod-shaped, which gives them their name, from the Greek kloster or spindle. These characteristics traditionally defined the genus; however, many species originally classified as Clostridium have been reclassified in other genera.

3.(D) Temperature is not an intrinsic factor in food spoilage.

Intrinsic factor of food spoilage are:

1. Moisture Content.

2.Ph activity and acidity.

3.Nutrient content

4.Biological structure

5. Redox potential

6. Naturally occurring and added antimicrobials

7. Competitive microflora

4.(C) The major function of carbohydrates include structural framework and storage. Carbohydrates are sugar that provide the body with energy. Carbohydrates rich foods in their natural state are low in calories and high in fibers.

5.(C) Polysaccharides are polymeric carbohydrate molecules composed of long chains of monosaccharide units bound together by glycosidic bonds. They range in structure from linear to highly branched. S

6.(A) They may include the following:

• Abdominal pain, especially after a meal on the lower left side of the abdomen

• Either painless rectal bleeding or passing of blood in stool

• Fever

• Nausea

- Vomiting
- Irregular bowel movements, including constipation or diarrhea
- Gas
- Bloating

7.(C) Dextrinization is the browning of starch goods when subjected to dry heat. On dry heating, the starch in the food goes through a chemical reaction.Churning cream to make butter , this process involves dextrinisation.

8.(D) Fats consist of a wide group of compounds that are generally soluble in organic solvents and generally insoluble in water. Fats and oils have an important function in food preparation. They can contribute to the aeration of food products.

9.(D) Developing criteria for evaluation is a stage in the design process in Food and Technology.

It involves creating a set of questions that focus on the specifications found within the design brief.

10.(A) Government agencies are responsible for setting food safety standards, conducting inspections, ensuring that standards are met, and maintaining a strong enforcement program to deal with those who do not comply with standards.

11.(D) Spoilage is the process in which food deteriorates to the point in which it is not edible to humans or its quality of edibility becomes reduced. Bacteria that cause food spoilage needs a moist, damp environment in which to grow.

12.(B) 'Reverse osmosis' is a form of membrane technology that is used to produce some fruit juices.

Reverse osmosis (RO) is a water purification technology that uses a semipermeable membrane. This membrane-technology is not properly a filtration method.

13.(A) Plant sterols (or phytosterols) are a naturally occurring part of all plants. They are mainly found in vegetable oils but are also present in smaller amounts in nuts, legumes, grains, cereals, wood pulp and leaves. Plant sterols are a functional ingredient or naturally occurring plant molecules that are very similar to cholesterol.

14.(C) Test for jelly : Put a plate in the freezer. When you think the jam or jelly is nearly ready, drip a few drops onto the cold plate and let cool, then push the smudge with your finger. If it wrinkles when you push it, your jam or jelly is ready. If you push it with your finger and it looks like you're parting a mini Red Sea but there are no wrinkles, cook a few minutes longer and try again.

15.(A) Aseptic processing is the process by which a sterile (aseptic) product (typically food or pharmaceutical) is packaged in a sterile container in a way that maintains sterility. Bag-In-Box technology is commonly used because it provides strong containers that are light weight and easy to handle prior to being filled. Other common package types are drink boxes and pouches.

16.(B) With oven drying, the sample is heated under specified conditions, and the loss of weight is used to calculate the moisture content of the sample. The operating principle behind oven drying is that the weight lost represents the loss of water.

17.(A) The probability of incorporating an incorrect amino acid is 1 in 10^5. Therefore, the frequency of defective complexes would be $8 \times 10^3 \times 10^{-5}$, i.e., eight of every 100 complexes are defective.

18.(B) Because defective polypeptides will be rejected as being unable to form trimers and any faulty trimers will not assemble further, the frequency of defective complexes will be related only to the seven steps required for the final assembly of the trimers to form the complex, and this would be equal to 7×10^{-2}. Thus, the three-step process produced about 1,000 times fewer defective complexes than the single-step process and, incidentally, requires one-eight as much genetic information.

19.(A) Trypsin hydrolyses peptides at the carboxyl side of lysine and arginine residues. The resulting peptides would be Ala-Ser-Thr-Lys, Gly-Arg, and Ser-Gly.

20.(D) Treatment with FDNB and hydrolysis will liberate DNP derivatives of the N-terminal amino acids: DNP-Ala, DNP-Gly, and DNP-Ser. Note that the ε-amino group of lysine can also react with FDNB; however, the ε-DNP derivative of lysine can be distinguished from the α-DNP derivative by its chromatographic behavior.

21.(A) It is important to convert all units to a consistent set. Here, it is most convenient to use the mol L^{-1} scale. Thus, the molar concentrations are $[A] = c_A/M$ and $[A_2] = c_{A_2}/2M$, where c_A and c_{A_2} are the concentrations in gL^{-1} of A and A_2 respectively, and M is the molar weight of A.

Now, the total concentration of A is

$$c_T = c_A + c_{A_2}$$

Hence $$c_{A_2} = c_T - c_A$$

By substituting in Equation $K_2 = [A_2]/[A]^2$, we get

$$K = \frac{[A_2]}{[A]^2} = \frac{(c_T - c_A)/2M}{(c_A/M)^2}$$

Rearranging and then solving the quadratic in c_A gives two roots, one negative, and thus physically meaningless, and the other positive. The positive root is given by

$$c_A = \frac{-1 + (1 + 8Kc_T/M)^{1/2}}{4K/M}$$

Substituting for K, c_T, and M, we get

$$c_A = 0.13 \text{ g } L^{-1}$$

Therefore, the percentage by weight of monomer is 13, and that of the dimer is 87.

22.(D) Using the same procedure as in Prob. 5.3 and substituting into the expression for c_A, we get

$$c_A = \frac{-1 + [1 + (8 \times 10^6 \times 10)/(4 \times 10^4)]^{1/2}}{4 \times 10^6 / 4 \times 10^4} \text{ g } L^{-1}$$

$$\frac{-1 + (2{,}001)^{1/2}}{100} = \text{g } L^{-1} = 0.437 \text{ g } L^{-1}$$

This represents only 4.4 percent of the total at this new concentration, and thus the percentage by weight of the dimer is 95.6 percent.