Q. P. Code: 5932**1**

SET – VI

ANSWER KEY

Q.1. **A)** **Select the correct alternative**

(i) b. $\dfrac{Y}{2\eta} - 1$ 　　　　2

(ii) c. velocity of fluid

(iii) b. 10cm 　　　　2

(iv) b.Chromatic aberrations 　　　　2

(v) a. Random motion of gas molecules. 　　　　2

(vi) c. $V - b$ 　　　　2

　　　　2

B) **Answer in one sentence**

(i) A streamline flow or laminar flow is defined as one in which there are no turbulent velocity fluctuations. 　　　　1

(ii) linear magnification = size of image / size of object 　　　　1

(iii) Maximum temperature at which a gas can be liquefied by increasing pressure alone. 　　　　1

C) **Fill in the blanks**

(i) Modulus of rigidity

(ii) Upward direction 　　　　1

(iii) odd 　　　　1

(iv) mean 　　　　1

(v) Path Dependent 　　　　1

Q. 2 **A)** **Attempt ANY ONE** 　　　　1

(i) Diagram and description 　　　　2

Description and equation: $A_1\delta x_1 = m / \rho = A_1\delta x_1 = m / \rho$ 　　　　1

Total workdone = change in potential and kinetic energy.

$W = \frac{1}{2} m_2 v_2^2 - \frac{1}{2} m_2 v_2^2 + mgh_2 - mgh_1$

$W = P_1 A_1 \delta x_1 - P_1 A_1 \delta x_1$ equating and simplifying : $P + \rho g h + 1/2 \rho v^2 = $ constant. 　　　　2

(ii) figure and description 　　　　3

Modulus of rigidity , $\eta = \dfrac{Tangential.stress}{Shear.strain} = \dfrac{T}{\varphi} = \dfrac{F}{2\pi r dr} \times \dfrac{L}{r\theta}$ 　　　　2

Torque = $dT = \dfrac{2\pi\eta\theta}{L} r^3 . dr$, Couple required = $\dfrac{\pi\eta\theta}{2L}(a_2^4 - a_1^4)$ 　　　　1

　　　　5

B) **Attempt ANY ONE**

(i) Applications: Explaination of any two like: Lift of an airplane, Aspirator pump, Spinning ball (4 mark each) 　　　　8

(ii) Description and diagram

$Y = 2\eta (1 + \sigma)$, η = shear stress / shear strain = F / θ. 　　　　2

Shear strain = $\theta = 2F/Y(1 + \sigma)$, $Y = 2\eta (1 + \sigma)$ 　　　　3

　　　　3

C) **Attempt ANY ONE**

(i) Accn $= m2 /(m1+m2) = [5 / 15] * 9.8 = 3.26\ m/s^2$
$T = m^2 * accn = 12 * 3.25 = 39.2\ N$ 2

(ii) $\sigma = \dfrac{1}{2}\left(1 - \dfrac{Y}{3K}\right)$ $= \dfrac{1}{2}\left(1 - \dfrac{7.3 \times 10^{10}}{3 \times 1.2 \times 10^{11}}\right) = 0.39$ 2   4

Q. 3 **A)**

(i) **Attempt ANY ONE**
Transmitted light interference through thin film
Ray diagram & Description
Derive expression for Optical path difference Δ
$\Delta = 2\mu t \cos r$ 4   4

(ii) Wedge shaped film
Diagram   2
Assume exp O.P.D $= 2\mu t \pm \lambda/2$ & Condition for CI/DI , derive
expression for position of nth bright or dark band $x_n = n\lambda / 2\mu\theta$ 4
Hence Fringe Width of bright/dark band $\beta = \lambda/2\mu\theta$ 2

B)

(i) **Attempt ANY ONE**
Ray Diagram showing cardinal pts
Derive $-1/F = 1/f1 + 1/f2 - d/f1.f2$ 3
$P = P_1 + P_2 - dP_1 P_2$ 4

(ii) Ray Diagram of Huygen's Eyepiece showing images   1
Description & Working   3
Expression of equivalent focal length: $F = 3f/2$ 3   2

C)

(i) **Attempt ANY ONE**
$\lambda = \dfrac{D^2_{15} - D^2_5}{4(10)R} = 6497 \times 10^{-10}\ m = 6500 A.U.$ 4

(ii) $F = 10.58cm,$
$\alpha = 8.8\ cm,\ \beta = 7.058cm$ 1   3

Q. 4 **A)**

(i) **Attempt ANY ONE**
1. Correction to Pressure:
Consider the molecule of gas well inside the container. It is
attracted by other molecules in all direction with same force and
thus the net force acting on it is zero. But when it strikes the wall it
gets pulled back by the other molecules of the gas. This results in
the decrease in the momentum with which it collides with the wall
and decrease in pressure. This correction to the pressure depends
upon:
(i) Number of molecules striking a unit area per unit time of the
walls of container and
(ii) The resultant inward cohesive force.
Each of these factors is proportional to the density of the gas.   4

$$\therefore Correction\ to\ pressure, p \propto \rho^2 \propto 1/V^2$$
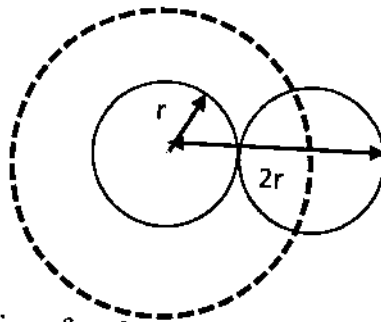
$$p = \frac{a}{V^2}$$

Where a is constant and V is volume of the gas.

$$\therefore Corrected\ or\ real\ pressure = P + p = \left(P + \frac{a}{V^2}\right)$$

2. Correction to Volume:

Due to the finite size of the gas molecules, the actual space available for the molecule is less than the actual volume of the vessel.

4

Here r is the radius of each gas molecule.

$$Volume\ of\ the\ molecule, x = \frac{4}{3}\pi r^3$$

The center of each molecule can approach each other only by a minimum distance of $2r$. Volume of sphere of influence of each molecule, s is

$$s = \frac{4}{3}\pi(2r)^3 = 8\frac{4}{3}\pi r^3 = 8x$$

Volume available for 1st molecule $= V$

Volume available for second molecule $= V - 8x = V - s$

$\therefore$ Volume available for nth molecule $= V - (n-1)s$

$\therefore$ Average space available for each molecule $=$

$$\frac{V + (V - s) + (V - 2s) + \cdots + (V - (n-1)s)}{n}$$

$$= V - \frac{s}{n}(1 + 2 + 3 + \cdots + (n-1)$$

$$= V - \frac{ns}{2} + \frac{s}{2}$$

$s/2$ can be neglected in comparison with $ns/2$.

$$= V - 4nx = V - b$$

Therefore Van der Waals equation for state is given by:

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

(ii)   For adiabatic process, $dQ = 0$

We know from the first law of thermodynamics,
$$dQ = dU + PdV$$
Substituting for dU,

$$dQ = \left(\frac{\partial U}{\partial T}\right)_V dT + \left(\frac{\partial U}{\partial V}\right)_T dV + PdV$$

$$\therefore \frac{dQ}{dT} = \left(\frac{\partial U}{\partial T}\right)_V + \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right]\frac{dV}{dT} \quad \cdots\cdots (i)$$

$$C_V dT = -\left[P + \left(\frac{\partial U}{\partial V}\right)_T\right]\frac{dV}{dT}$$

$$C_V \frac{\partial T}{\partial V} = -\left[P + \left(\frac{\partial U}{\partial V}\right)_T\right]$$

The isobaric volume coefficient of expansion

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$$

We have $C_P - C_V = P\left(\frac{\partial V}{\partial T}\right)_P$

$$\therefore P = \frac{C_P - C_V}{\alpha V}$$

$$\left(\frac{\partial U}{\partial V}\right)_T = 0 = P - P \text{ or } \frac{C_P - C_V}{\alpha V} = \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right]$$

$$\therefore C_V \frac{\partial T}{\partial V} = \frac{C_P - C_V}{\alpha V}$$

$$\left(\frac{\partial T}{\partial V}\right) = \frac{C_P - C_V}{\alpha V}$$

4

4

B)

(i) **Attempt ANY ONE**

Work done, $W = \int_{V_1}^{V_2} PdV$

Considering one gram molecule of the gas,

$$PV = RT$$

$$\therefore P = \frac{RT}{V}$$

$$W = \int_{V_1}^{V_2} \frac{RT}{V} dV$$

$$W = RT \times 2.303 \log_{10}\frac{V_2}{V_1}$$

$$P_1 V_1 = P_2 V_2$$

$$\therefore \frac{V_2}{V_1} = \frac{P_1}{P_2}$$

$$\therefore W = RT \times 2.303 \log_{10}\frac{P_1}{P_2}$$

$$W = RT \times 2.303 \log_{10}\frac{V_2}{V_1}$$

6

$$W = 1274.4 J$$

2

(ii)   From the first law of thermodynamics,

$$dQ = dU + PdV$$

Substituting for dU,

$$dQ = \left(\frac{\partial U}{\partial T}\right)_V dT + \left(\frac{\partial U}{\partial V}\right)_T dV + PdV$$

$$\therefore \frac{dQ}{dT} = \left(\frac{\partial U}{\partial T}\right)_V + \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right]\frac{dV}{dT} \cdots \cdots (ii)$$

If the gas is heated at constant volume,

$$\frac{dQ}{dT} = C_V$$

And

$$\frac{dV}{dT} = 0$$

$$\left(\frac{\partial U}{\partial V}\right)_T = C_V \cdots \cdots \cdots (iii)$$

When the gas is heated at constant pressure,

$$\frac{dQ}{dT} = C_P$$

$$\therefore C_P = \left(\frac{\partial U}{\partial T}\right)_V + \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right]\left(\frac{\partial V}{\partial T}\right)_P$$

$$\therefore C_P = C_V + \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right]\left(\frac{\partial V}{\partial T}\right)_P$$

$$C_P - C_V = \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right]\left(\frac{\partial V}{\partial T}\right)_P$$

Since internal energy depends only on temperature,

$$\left(\frac{\partial U}{\partial V}\right)_T = 0$$

Using $PV = RT$ we can show,

$$P\left(\frac{\partial V}{\partial T}\right)_P = R$$

$$\therefore C_P - C_V = R$$

4

C)   Attempt ANY ONE   4
   (i)

$$\text{Work done}, W = \int_{V_1}^{V_2} pdV \cdots \cdots \cdots (i)$$

From the given equation,

$$pV = AT - BT^2$$

$$\therefore pdV + Vdp = AdT - 2BTdT$$

2

But since pressure is constant, $dp = 0$

$$\therefore W = \int_{V_1}^{V_2} pdV = \int_{T_1}^{T_2}(A - 2BT)dT$$

$$W = A(T_2 - T_1) - B(T_2^2 - T_1^2)$$

2

   (ii)

$$W = \int_{V_1}^{V_2} PdV$$

2

⟨6⟩

But $PV^\gamma = constant = K$

$$W = K \int_{V_1}^{V_2} \frac{dV}{V^\gamma} = \frac{1}{1-\gamma} (P_2 V_2 - P_1 V_1)$$

$$P_1 V_1 = RT_1 \ and \ P_2 V_2 = RT_2$$ 　　　　2

$$\therefore W = \frac{R}{\gamma - 1} (T_1 - T_2)$$

Q5

Attempt any four

(i) The **Poisson's ratio** of a stable, isotropic, linear elastic material 　3
will be greater than -1.0 or less than 0.5 because of the
requirement for Young's modulus, the shear modulus and bulk
modulus to have positive **values**.
Most materials have **Poisson's ratio values** ranging between 0.0 　2
and 0.5.

(ii) Diagram and explanation 　5

(iii) Achromatic combination of lens in contact:
Definition : Achromatic combination / Achromatism 　1
Derive : $1/f = (\mu - 1)(K)$, $1/f = 1/f_1 + 1/f_2$,

$$\frac{f_1}{f_2} = -\frac{w_1}{w_2}$$ 　　4

(iv) Newton's lens equation :
Ray Diagram using convex lens & Description 　2
Derive the relation $x_1 x_2 = f_1 f_2$ 　3

(v) Values of constants a and b differ significantly when determined 　5
by different methods.
According to theory, $V_C = 3b$ but it is found to depend on the
nature of the gas.
Experimentally It is found that $V_c \cong 2b$.
The theoretical value of critical coefficient $\frac{RT_c}{P_c V_c}$ is 2.667 for all

gases. However it varies from gas to gas with an average value of
3.7.

(vi) If $T_c = 132K$, $P_c = 32.7$ atm and $R = 82.07$ cm^3 atoms K^{-1},
calculate b.
Solution:

$$T_c = \frac{8a}{27bR}$$

$$P_c = \frac{a}{27b^2}$$

$$\therefore b = \frac{RT_c}{8P_c} = 36.41 \ cm^3$$