Roll No. ____________

1(CCE-M)6

PHYSICS-I

[18]

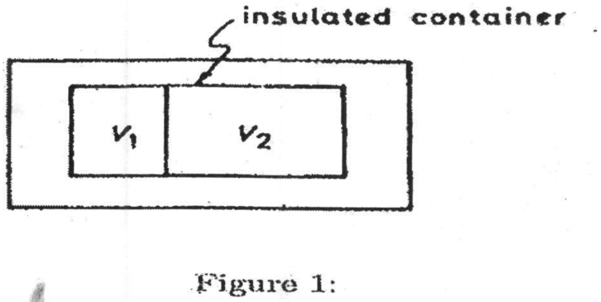
Time Allowed : 3 Hours *Maximum Marks : 300*

INSTRUCTIONS

i) *Answers must be written in English.*
ii) *The number of marks carried by each question is indicated at the end of the question.*
iii) *The answer to each question or part thereof should begin on a fresh page.*
iv) *Your answer should be precise and coherent.*
v) *The part/parts of the same question must be answered together and should not be interposed between answers to other questions.*
vi) *Candidates should attempt* ***FIVE*** *questions.* ***Q.No.1 and 5*** *are compulsory. Attempt any* ***three*** *out of the remaining questions,selecting atleast* ***one*** *questions from each section.*
vii) *If you read any typographical error, please read it as it appears in the text book.*
viii) *Candidates are in their own interest advised to go through the General Instructions on the back side of the title page of the Answer Script for strict adherence.*
ix) *No Continuation sheets shall be provided to any candidates under any circumstances.*
x) *Candidates shall put a cross (X) on the blank pages in the answer Script.*
xi) *No blank page be left in between answer to various questions.*
xii) *No programmable Calculators are allowed.*
xiii) *No stencil (with different markings) is allowed.*
xiv) *Under no circumstances help of scribe will be allowed.*

SECTION-A

1. a) Consider that an ideal gas is originally confined to a volume V_1 in an insulated container of volume V_1+V_2 (see Figure 1). The remainder of the container is evacuated . The partition is then removed and the gas expands to fill the entire container. If the initial temperature of the gas was T, what would be the final temperature. Give reasons in support of your answer.



(12)

Figure 1:

[Turn Over

b) Starting with the first law of thermodynamics, show that $c_p - c_v = \left[p + \left(\frac{\partial U}{\partial V}\right)_T\right]\left(\frac{\partial V}{\partial T}\right)_p$ where c_p and c_v are specific heat capacities per mole at constant pressure and volume, respectively, and U and V are energy and volume of one mole. **(24)**

c) For a Van der Waals gas, the equation of state is given by

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

Using the following expression :

$p + \left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_V$ Find $c_p - c_v$ for a Van der Waals gas. Show that as $V \to \infty$ at constant p, we obtain the ideal gas result for $c_p - c_v$. **(24)**

2. A perfect gas is defined by an equation of state of the form, $pV = Nk_BT$ and whose internal energy is only a function of temperature . For a perfect gas,

a) Show that $c_p = c_v + k_B$, *where* c_p *and* c_v are the heat capacities (per molecule) at constant pressure and constant volume respectively. **(17.5)**

b) Show that the quantity pV^γ is constant during an adiabatic expansion.

(Assume $\gamma = {}^{c_p}\!/_{c_v}$ is constant). **(17.5)**

c) Show that one mole of ideal gas is carried from temperature T_1 and molar volume V_1 to T_2 and V_2 respectively. Show that the change in entropy is

$$\Delta S = c_v In\frac{T_2}{T_1} + RIn\frac{V_2}{V_1}$$ **(25)**

3. a) The solar constant (radiant flux at the surface of the earth) is about $0.1 W/cm^2$. Assuming the sun to be a black body, find the temperature of the sun. **(25)**

b) Consider an idealised sun and earth, both black bodies, in otherwise empty flat space. The sun is at a temperature of Ts = 6000K and heat transfer by oceans and atmosphere on the earth is so effective as to keep the earth's surface temperature uniform. The radius of the earth is $R_E = 6\times10^8$ cm, the radius of the sun is $R_S=7\times10^{10}$ cm, and the earth -sun distance is $d=1.5\times10^{13}$ cm. Find the temperature of the earth. **(35)**

4. a) Monochromatic light illuminates two slits separated by 1.2mm, creating fringe pattern on a screen 3.6 m from the slits. The distance between third and sixth dark fringes on the screen is 5.3mm. What is the wavelength of the light? **(25)**

b) The width of each slit in part (a) is a=0.15 mm. What is the width of the central diffraction maximum on the screen , and how many bright fringes (i.e, interference maxima) are contained within it? **(35)**

SECTION-B

5. a) Solve the one-dimensional wave equation $\frac{\partial^2\psi}{\partial x^2}=\frac{1}{v^2}\frac{\partial^2\psi}{\partial t^2}$ Using the method of separation of variables and show that the solution can indeed be expressed as $\psi(x,t)=a\exp\{\pm i(kx\pm wt+\phi)\}$ **(30)**

b) Obtain a general solution for the wave equation in three dimension in terms of spherical waves and show that their amplitude decay as $1/r$ *where* r is the distance of form the origin. **(30)**

6. a) Consider scattering of alpha particle (carrying charge Z_1e) from a heavy nucleus (carrying charge Z_2e) and derive the expression for Rutherford scattering cross section assuming Coulomb potential , $V(r)=Z_2e/r$ **(30)**

b) Does the cross section remain finite when forward scattering is considered? Give physical justification for your answer. **(15)**

c.) If we use a screened Coulomb potential $V(r)=(Z_2e/r)\exp(-r/a)$, how does the cross section change? Give physical justification for your answer.**(15)**

7. a) A mass M, initially moving at speed v, collides and sticks to a mass m, initially at rest, Assume M >> m. What are the final energies of the two masses, and how much energy is lost to heat, in:(i)The lab frame?(ii) The frame in which M is initially at rest? (Assume M >> m.) **(50)**

b) Find the escape velocity for the sun assuming it to be a sphere of radius R_s and mass M_s. **(10)**

8. a) Consider the formation of a hologram with a point object and a plane reference wave [see figure 2]. Choose the z axis to be along the normal from the point source to the plane of the photograph, assumed to be coincident with the plane z = 0. For simplicity assume the reference wave to fall normally on the photographic plate. Obtain the interference pattern recorded by the hologram. **(45)**

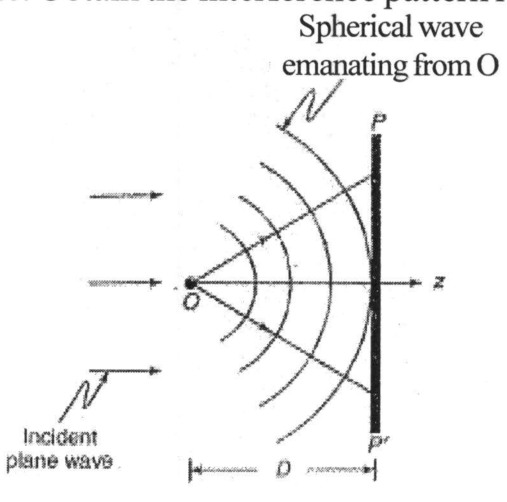


Figure 2:

b) A left circularly polarized beam $\left(\lambda_0 = 5893 A^0\right)$ is incident normally on a calcite crystal (with its optic axis cut parallel to the surface) of thickness 0.005141 mm. What will be the state of polarization of the emergent beam? **(15)**

Physical Constants

Velocity of light in vacuum $c = 3\times10^8$ m/s
Mass of electron $m_e = 9.11\times10^{-31}$kg
Charge of electron $e = 1.602\times10^{-19}$C
Specific charge of electron $e/m_e = 1.76\times10^{11}$ C/kg
1 u = 1 amu = 1.660566×10^{-27} kg = 931.5 MeV/c^2
Rest mass energy of electron $m_e c^2 = 0.511$ MeV
Permittivity in free space $\epsilon_0 = 8.8542\times10^{-12} C^2/N/m^2$

Permeability of free space $\mu_0 = 4\pi\times10^{-7} N/A^2$
Gas constant R = 8.314 J/mol/K
Boltzman constant $k_B = 1.381 \times 10^{-23}$J/K
Planck constant $h = 6.626 \times 10^{-34}$ Js
$\hbar = 1.0546 \times 10^{-34}$ Js

Bohr magneton $\mu_B = 9.274\times10^{-24} J/T$

Nuclear magneton $\mu_N = 5.051\times10^{-27} J/T$
Fine structure constant $\alpha = 1/137.03599$
Mass of proton $M_p = 1.0072766$ u = 1.6726×10^{-27} kg = 938.3MeV
Mass of neutron $M_n = 1.0086652$ u = 1.6749×10^{-27} kg = 939.6 MeV
Mass of deuteron $M_d = 2.013553$ u
Mass of α - particle $M\alpha = 4.001506$ u

Mass of ${}^{12}_{6}C = 12.0000000\ u$

Stefan - Boltzmann constant $\sigma = 5.7\times10^{-8} Watt/m^2/K^4$
Mass of sun $M_s = 1.99 \times10^{30}$ kg
Radius of sun $R_s = 6.96 \times10^8$m
Gravitational constant $G = 6.673\times10^{-11}Nm^2/kg^2$