B I (Three Year H)
Under 1+1+1 System

2007

PHYSICS (Honours)

First Paper

(Revised New Syllabus)

Time : Four Hours Full Marks : 70

The figures in the margin indicate full marks.

Answer question No.1 and *five* other from the rest, taking at least *one* from each Group.

1. (a) If A is a Hermitian matrix, show that e^{iA} is unitary. 2½

(b) The surface tension of water at 27°C is 65 dyne/cm, and for water rate of change of surface tension with temperature is — 0.15 dyne $cm^{-1}k^{-1}$. Find the surface energy of water. 2½

(c) If the radius of the earth shrinks by 2%, its mass remaining unchanged, what is the percentage change in its rotational kinetic energy. 2½

(d) The co-ordinates of a moving point mass are given by $\gamma = 2t + 3$ and $\theta = 3t - t^2$ at any instant t. Calculate the instantaneous radial and transverse components of velocity of the point mass. 2½

P.T.O.

Group - A

(Mathematical Methods)

2. (a) Explain the physical significance of gradient, divergence and curl of a vector field $\vec{A}$. 5

(b) Time evolution of a vector $\vec{A}$ is given by $\frac{d\vec{A}}{dt} = \vec{A} \times \vec{B}$, $\vec{B}$ is a constant vector.

Show that —

(i) the magnitude of $\vec{A}$ and

(ii) the angle between $\vec{A}$ and $\vec{B}$, do not change with time. 4

(c) $\vec{E} = \vec{E}_0 e^{i\vec{k}\cdot\vec{r}}$ and $\vec{B} = \vec{\nabla} \times \vec{E}$ are two vector fields with $\vec{E}_0$ and $\vec{K}$ constant vectors. Show that $\vec{B}$ is perpendicular to both $\vec{E}$ and $\vec{K}$. 3

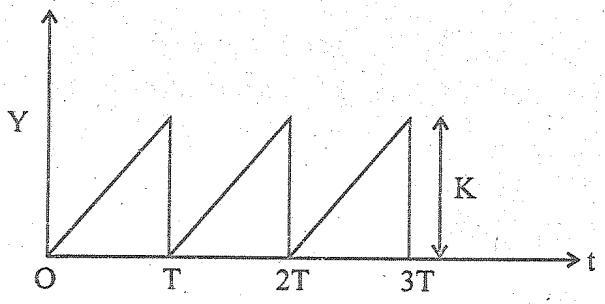
3. (a) Show that

(i) the eigen values of a Hermitian matrice are real and

(ii) eigen matrices corresponding to distinct eigen values are mutually orthogonal. (2+2)

(b) Find the eigen values and eigen vectors of the matrix $\begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$ 4

(c) Find the Fourier Series for the function shown graphically.



4

4. (a) Solve the heat flow equation $\frac{\partial Q}{\partial t} = h^2 \frac{\partial^2 Q}{\partial x^2}$ by the method of separation of variables. 5

(b) Prove that $\int_{-1}^{+1} xP_n(x)P_{n-1}(x)dx = \frac{2n}{4n^2-1}$ 4

(c) Three unbiased coins are tossed. Find the probabilities of getting Zero head, one head, two heads and three heads. 3

Group - B

(Classical Mechanics)

5. (a) Verify that the law of conservation of linear momentum is invariant under Galilean transformation. 4

(b) Determine the components of acceleration (a_r, a_θ, a_ϕ) in spherical polar co-ordinate system. 5

P.T.O.

(c) A particle moves in a field of force given by

$F_x = yz(1-2xyz), F_y = zx(1-2xyz),$

$F_z = xy(1-2xyz)$, verify that the force is conservative and find the potential function from which it is derivable. 3

6. (a) Find out the gravitational potential and intensity at a point located within the material of a thick spherical shell of radii a and b ($b > a$). 5

(b) Graphically plot the variation of potential and intensity with the radial distance from the centre of the thick spherical shell to a region outside the spherical shell. 2+2

(c) If a planet were suddenly stopped in its orbit, prove that it will fall into the Sun within a time $\left(\frac{1}{4\sqrt{2}}\right)^T$ where T is the time period of precessional motion of the planet and the orbit is circular. 3

7. (a) Explain the terms principal moments of inertia and ellipsoid of inertia. 3

(b) Determine the moment of inertia of a triangular lamina of uniform thickness about one of its sides. 4

(c) Assuming the inverse square force to be $f(r) = -\mu/r^2 (\mu > 0)$, prove that the speed of the particle

moving an elliptical path in the above force field is given by $V^2 = \frac{k}{m}\left(\frac{2}{r} - \frac{1}{a}\right)$ where k and a are constants. 5

Group - C

(General properties of Matter)

8. (a) Obtain the expression for the excess pressure on the concave side of a general curved membrane. 4

(b) Two soap bubbles of radii a and b coalesce isothermally to form a single bubble of radius C.

If the external pressure is P, show that the surface tension of the soap solution is given by

$$\frac{P\left(c^3 - a^3 - b^3\right)}{4\left(a^2 + b^2 - c^2\right)}$$ 3

(c) A vertical steel column 10 metres high supports a load of 80 metric tons. Taking the Young's modulus for steel to be 2×10^6 kg wt/cm^2, area of cross-section to be 100 cm^2 and Poisson's ratio to be 0.2, find the decrease in length and the decrease in volume of the column when load is applied. 5

9. (a) Set up the differential equation of motion of a body falling under gravity in a viscous medium and solve the equation to find out the terminal velocity of the body. 6

(b) A capillary tube of radius a and length l is fitted horizontally at the bottom of a cylindrical flask of cross-section

P.T.O.

A. Initially, there is water in the flask upto a height h_1. What time would be required for the height to reduce to h_2, where $h_2 = \frac{1}{2}h_1$, and η be the co-efficient of viscosity of water. 4

(c) A liquid rises to a height h in a capillary tube made of glass under the influence of surface tension. What will happen to the liquid within the capillary tube if the tube is broken at a height less than h. 2

B I (Three Year H)
Under 1+1+1 System

2007

PHYSICS (Honours)

Second Paper

(Revised New Syllabus)

Time : Four Hours | Full Marks : 70

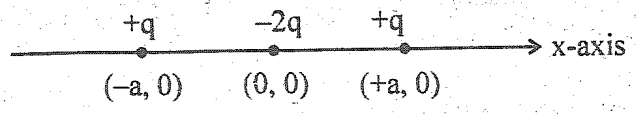
The figures in the margin indicate full marks.

Answer question no.1 and *five* other from the rest taking at least *one* from each Group.

1. (a) If the most probable speed is taken as the unit of speed for gas molecules then show that, the probability for the speed to be within v and $v + dv$ is independent of temperature.

(b) The intensity level of a conversation is $70\,dB$ above the threshold of 10^{-12} w/m^2. Calculate the amplitude of vibration of the air particles due to the conversation. Given velocity of sound = 350 m/s, density of air = 1.25 gm/lt, mean frequency = 500 Hz.

(c) Find out the dipole and quadrupole moments of the following charge distribution.



$3\frac{1}{2}+3+3\frac{1}{2}$

P.T.O.

Group - A

(Heat)

2. (a) Assuming Maxwell's velocity distribution of molecules of gas, derive the corresponding energy distribution law. Hence find out the average energy, root mean square energy and most probable energy of gas molecules. 5+(1+2+2)

(b) What is the importance of Brownian Motion in the kinetic theory of molecules. 2

3. (a) Find the rate of radial heat flow through a cylindrical shell having internal radius r_1, temperature θ_1 and external radius r_2, temperature θ_2, when the system has reached its steady state. 4

(b) The temperature gradient in the earth's crust is 42°C per km and the mean conductivity of the rock is 3.36 w/m/°k. Taking the radius of the earth as 6000 km, calculate the daily loss of heat by the earth. 3

(c) A radio station operating at a frequency of 105 MHz has a power of 100 kW. Determine the rate of emission of quanta from the station. 2

(d) Deduce the relation between power of diffused radiation and energy density. 3

4. (a) Define coefficient of viscosity and thermal conductivity of a gas. Establish the relation between them for a perfect gas. 6+2

(b) Define Boyle temperature of a gas molecule.

Using Berthelot's equation of state $p = \frac{RT}{V-b} - \frac{q}{TV^v}$, calculate the Boyle temperature T_B. 1+3

Group - B

(Sound)

5. (a) Determine the velocity of longitudinal waves in a solid medium (linear) in terms of Young's modulus and the density of the material of the medium. Is the formula valid for an extended solid medium ? 4+1

(b) For propagation of sound waves, distinguish between a dispersive and a non-dispersive medium. 2

(c) Define 'Phase velocity' (c) and 'Group velocity (cg)' of waves. Prove the relation, $C = w/k$ and $C_g = \frac{dw}{dk}$

$C_g = -\lambda \frac{dc}{d\lambda}$. 2+1+1+1

6. (a) Distinguish between energy current and energy density at a point.

Derive the expression of intensity of sound wave at a point in terms of acoustic pressure. 1+4

(b) A locomotive engine continuously sounds a whistle of frequency 200 Hz while approaching a tunnel. The tunnel reflects the sound so that the driver of the engine hears 5 beats per sound. If the speed of sound in air is 350 m/s, calculate the speed of the locomotive engine. 3

P.T.O.

(c) How ultrasonic sound waves can be generated ? Mention some of its practical applications. 2+2

Group - C

(Electricity)

7. (a) Show that $\vec{P}\cdot\hat{n}=\sigma'$ where σ' is surface density of polarised charge and $\nabla\cdot\vec{\rho}=-\rho'$ where ρ' is volume density of potential charge. 4

(b) Eight identical charges each of value $+q$ are fixed at the eight corners of a cube of side 'a'. Calculate the electrostatic potential at the centre of a face. 4

(c) The separation between the two plates of area A, of a parallel plates is filled with material whose dielectric constant varies linearly from k_1 at one plate to k_2 $(k_2 > k_1)$ at the other. Show that the capacity of the capacitor is given by $C=\frac{2\epsilon_0 A}{d}\left(\frac{k_1-k_2}{\ln(k_1/k_2)}\right)$ where ϵ_0 is the permitibility of the free space. 4

8. (a) Show that the energy of a spherical charge distribution of uniform charge density is given by $U=\frac{3}{5}\frac{Q^2}{4\pi\epsilon_0 a}$, where '$Q$' is the total charge and 'a' the radius of the distribution. 3

(b) What is the significance of displacement vector $\vec{D}$?

Obtain the boundary conditions for electric field

$\vec{E}$ and Electric displacement Vector $\vec{D}$ at the interface of two dielectric media. 1+3

(c) Show that the field due to a dipole of moment.

$\vec{P}$ at a distance $\vec{r}$ is given by

$$\vec{E}(r)=\frac{1}{4\pi\varepsilon_0}\left[\frac{3(\vec{P}\cdot\vec{r})\vec{r}}{r^5}-\frac{\vec{P}}{r^3}\right]$$ 5

9. (a) State Kirchoff's laws and obtain an expression for the current through the galvanometer in an unbalanced Wheatstone bridge. Discuss briefly the sensitivity of the bridge.

Why is Wheatstones' bridge unsuitable for measurement of very low and very high resistances ?

$2+4+1\frac{1}{2}+1\frac{1}{2}$

(b) Two batteries B_1 and B_2 of emfs V_1 and V_2, have resistances R_1 and R_2 respectively. They are connected in parallel to the ends of a Resistance R. Find the condition for zero currerent through B_2. 3

B II (Three Year H)
Under 1+1+1 System

2007

PHYSICS (Honours)

Fourth Paper

(Revised New Syllabus)

Time : Four Hours Full Marks : 70

The figures in the margin indicate full marks.

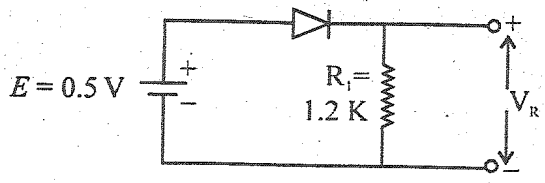
Answer question No.1 and any *five* from the rest taking at least *one* from each Group but not more than *two* from any Group.

1. (a) A thin lens of refractive index μ separates the object-space of refractive index μ_1, from the image-space of refractive index μ_2. Show that the focal lengths are related as, $f'/f = -\mu_2/\mu_1$.

(b) What is the effect of increasing (a) the slit width and (b) the wavelength in Fraunhofer diffraction pattern ?

(c) What happens to the interference pattern if the entire apparatus used in Young's experiment is immersed in water ?

(d) For the series Si-diode configuration shown in the figure, determine V_{D_2}, V_R and I_D



P.T.O.

(e) Convert a decimal number 2895 to a hexadecimal number. 2×5

Group - A

(Geometrical Optics)

2. (a) State and explain Fermat's principle and establish the thin lens formula using this principle. 1+4

(b) Derive Helmholtz's-Lagrange's relation for refraction through a system of co-axial spherical refracting surfaces. How is the relation modified for telescopic system ? 3+1

(c) Obtain the condition for achromatism for two thin lenses separated by a distance. 3

3. (a) For a thick lens show that

(i) the distance between two nodal points is equal to the distance between the two principal points and

(ii) the principal points coincides with the nodal points if the medium on both sides of the system is same. 2+3

(b) Two thin lenses of power D_1 and D_2 are supported by a distance d, show that the power of the equivalent lens is given by

$$D = D_1 + D_2 - dD_1D_2$$ 3

(c) Discuss the operating principle of a Huyghen's eye-piece to find out its cardinal points. 4

Group - B

(Physical Optics)

4. (a) What is a wavefront? State and explain Huyghen's principle. Use this principle to study the reflection of the spherical waves from a concave mirror and establish the corresponding mirror equation.

(b) What is Rayleigh's criterion for resolving power?

(c) Apply the Rayleigh's criterion to deduce the relation, $\lambda/d\lambda = nN$ where N is the total number of lines in a grating and 'n' is the order at which the wavelength is λ and $\lambda + d\lambda$ are just resolved. (1+2+3)+2+4

5. (a) To which class does the interference in Newton's rings and that in the bi-prism experiment belong?

(b) Why an extended source is necessary for Newton's ring experiment, while a narrow source is necessary in Fresnel's biprism experiment?

(c) Deduce the working formula for the determination of the wavelength of a mono-chromatic light source by Newton's rings.

(d) The inclined faces of a biprism $(\mu = 1.5)$ make angles of 1° with the base of the prism. A slit is 10 cms away from the biprism, and it is illuminated with a light source of $\lambda = 5900\text{Å}$. Find out the fringe width observed at a distance of 1 mt. from the biprism. 2+2+6+2

6. (a) Describe the construction of a Michelson's interferrometer and explain its working.

P.T.O.

(b) How the interferrometer is used to obtain circular fringes?

(c) In a Michelson's interferrometer the readings for a pair of maximum indistinctness were found to be 0.6939 mm and 0.9884 mm. If the mean wavelength of the two components of the light source being used in 5893Å, deduce the difference between the wavelengths of the two components. 6+3+3

7. (a) What is a zone plate? Show that it has multiple foci. Compare the zone plate with a convex lens.

(b) Distinguish between the dispersive power and the resolving power of a diffraction grating.

Two spectral lines have wavelengths λ and $\lambda + d\lambda\,(d\lambda \ll \lambda)$, respectively. Show that their angular separation in a grating spectrometer is given by,

$$d\theta = d\lambda \Big/ \left[\left(\frac{a+b}{n}\right)^2 - \lambda^2\right]^{1/2}$$

where $(a+b)$ is the grating element, n the order at which the lines are observed. (2+4)+(2+4)

Group - C

(Electronics - I)

8. (a) How does a barrier potential develop across a p-n junction? Calculate the barrier potential across a p-n junction at equilibrium.

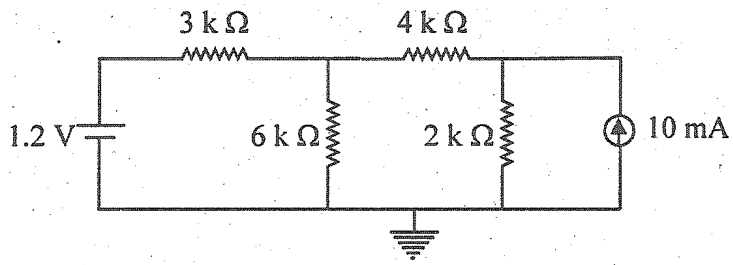
(b) Show that the conductivity of an intrinsic

semiconductor is given by $\sigma = e(n_h\mu_h + n_e\mu_e)$, where n stands for number density and μ stands for mobility. Also show that, at a given temperature the minimum conductivity of an intrinsic semiconductor is given by,

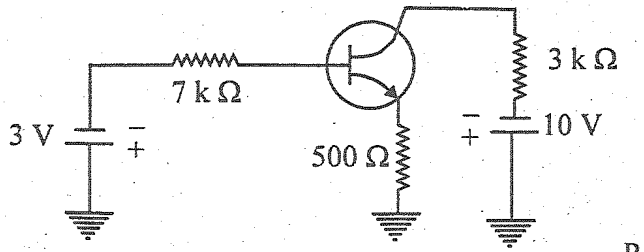
$$\sigma_{min} = 2en(\mu_n\,\mu_e)^{1/2} \quad \text{where} \quad n_h = n_e = n$$

(c) Draw an OR, an AND and a NOT gate using transistors and explain their operation. (2+2)+(2+3)+3

9. (a) Using Thevenins theorem, calculate the current through the 4 kΩ resistor of the given circuit,



(b) For the circuit given below, find whether the transistor is in cut-off, saturation or in the active region. Find the minimum value of emitter resistor R_E for which the transistor operates in the active region. Given $\beta = 100$.



P.T.O.

(c) The Boolean expressions for two variables X and Y in terms of three inputs A, B and C are,

$$X = ABC + A\overline{B}\overline{C} + \overline{A}B\overline{C}$$
$$Y = (\overline{A} + \overline{B} + \overline{C})\cdot(\overline{A} + B + C)\cdot(A + \overline{B} + C)$$

What is the relation between X and Y ? 4+(3+2)+3

B III (Three Year H)
Under 1+1+1 System
&
B II (Three Year H) New
Under 2+1 System

2010

PHYSICS (Honours)

SEVENTH PAPER (1+1+1 System)

(Revised New Syllabus)

SIXTH PAPER (2+1 System)

(New Syllabus)

Time : 4 hours *Full Marks* : 90

The figures in the margin indicate full marks.

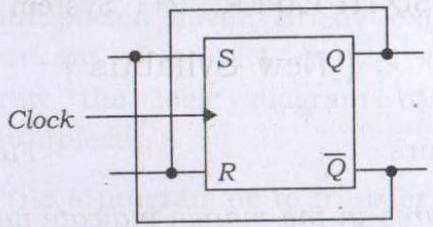
Answer Question No. **1** and **five** from the rest taking at least **one** from Group—A, **one** from Group—B, **two** from Group—C and the rest **one** from any Group.

1. *(a)* The Lagrangian for a relativistic particle of rest mass m_0 and velocity v is given by $L = -m_0c^2\sqrt{1-v^2/c^2}$. Show that the Hermitian is $H = \sqrt{p^2c^2 + m_0^2c^4}$ where p is the momentum.

(b) The centre of mass of two point masses connected by a weightless rigid rod of length l is constrained to move on a circle of radius R. Find the number of degrees of freedom.

(c) Assuming Debye temperature and Einstein characteristic temperature to be equal and is 200 K, calculate the specific heat of silver at 50 K.

(d) Draw the output waveforms along with the clock pulse of the given flip-flop circuit.



(e) Two power supplies A and B, A having no-load and full-load voltages 30 V and 25 V respectively, while that of B it is 30 V and 29 V. Which is better power supply and why? 3×5=15

GROUP—A

(Classical Mechanics II and Fluid Mechanics)

2. *(a)* What are constraints? Classify any two types of constraints with examples. How do the constraints affect the motion of a mechanical system? 1+2+1

(b) What are the advantages of the Lagrangian approach over Newtonian? Of the two approaches, Hamiltonian and Lagrangian, which one will you prefer and why? 1½+1½

(c) Deduce Lagrange's equation of motion from Hamilton's principle. 5

(d) What do you mean by 'cyclic coordinates'? Show that the generalised momentum conjugate to a cyclic coordinate is conserved. 1+2

3. (a) Define Hamiltonian of a system. Stating the required conditions, show that $H = T + V$ = constant, where H, T and V are Hamiltonian, kinetic energy and potential energy of the system respectively. 1+4

(b) What is Poisson's bracket? Prove that $[L_x, L_y] = L_z$, for the components of angular momentum. What is the significance of this result? Show that u is a constant of motion, if $[u, H] = 0$. 1+2+1+2

(c) Use Hamilton's equations to find the differential equation for planetary motion and prove that the areal velocity is constant. 4

4. (a) What is Euler's equation of motion for an ideal fluid? Starting from this equation, derive Bernoulli's equation for the flow of an incompressible irrotational fluid. 2+4

(b) Water stands at a height h in a large open tank with vertical side walls. A hole is made in one of the walls at a depth x below the water surface. Calculate the horizontal distance d from the wall at which the emerging water stream strikes the ground. 3

(c) Determine the *(i)* T and V matrices and *(ii)* normal frequencies for a system of two coupled pendulums of same mass and same length. 3+3

GROUP—B

(Statistical Mechanics)

5. (a) State and explain the principle of a priori probability. 2

(b) Derive an expression for entropy in terms of thermodynamical probability. Explain the physical significance of this relation. 4+1

(c) Show that for MB-distribution of particles of an isolated system in equilibrium, the internal energy is given by $U = NKT^2 \frac{\partial}{\partial T}(\ln Z)$ where all the parameters have their usual significances. 4

(d) Prove that, for a system at $T > 0$ K obeying FD statistics, the probability of unoccupancy of a level lying ΔE below the Fermi level is same as the probability of occupancy of a level lying ΔE above the Fermi level. 4

6. (a) Show that the thermodynamic probability in case of Fermi-Dirac statistics is

$$W = \frac{g_1 ! \, g_2 ! \cdots}{N_1 ! (g_1 - N_1)! \, N_2 ! (g_2 - N_2)! \cdots}$$

and hence, show that

$$N_i = \frac{g_i}{Ae^{-\beta \varepsilon_i} + 1}, \text{ where } \beta = \frac{1}{kT}$$ 4

(b) Derive Planck's formula for black-body radiation using BE-distribution law and hence, derive Wien's displacement law. 5+2

(c) Show from FD distribution that in a metal the average electron energy at $T = 0$ K is $\frac{3}{5} E_F(0)$, where $E_F(0)$ is the Fermi energy at $T = 0$ K. 4

GROUP—C

(Electronics—II)

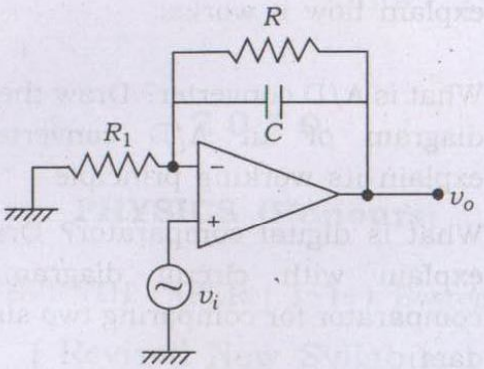
7. (a) Explain the construction and principle of operation of a depletion type MOSFET. 5

(b) What is feedback amplifier? Show that the negative feedback stabilizes the gain of an amplifier. 1+2

(c) Find an expression for the frequency of oscillation of Wien bridge oscillator and show that the voltage gain of the amplifier used in the oscillator must be greater than 3. 5

(d) Calculate the output impedance of an emitter follower. 2

8. *(a)* Find out the output (v_o) of the circuit given below : 3



(b) Draw a circuit diagram of a two-stage *R-C* coupled amplifier and derive the expression for the voltage gain of the amplifier in low frequency range. Draw the frequency response of the amplifier and explain its nature. 4+2

(c) Draw the circuit diagram of an ohm-meter. 2

(d) Define modulation. Draw the wave-forms of AM and FM waves showing signal and carrier waves. 1+3

9. *(a)* What is Master-Slave *J-K* flip-flop? Draw a Master-Slave *J-K* flip-flop system and explain its operation. 1+4

(b) What is meant by shift register? Explain the operation of a 4-bit shift register. 5

(c) Draw the logic diagram, waveforms and truth table to form a Mod-5 counter and explain how it works. 5

10. *(a)* What is A/D converter? Draw the circuit diagram of an A/D converter and explain its working principle. 5

(b) What is digital comparator? Draw and explain with circuit diagram of a comparator for comparing two single-bit data. 3

(c) How many select lines do an 8 : 1 multiplexer have? Briefly explain the working of a 4 : 1 multiplexer. Also, draw the logic diagram of a 4 : 1 multiplexer. 5

(d) Write a programme to transfer one byte of data from the memory location 0010H to 1000 H. 2

★★★

B III (Three Year H)
Under 1+1+1 System
&
B II (Three Year H) New
Under 2+1 System

2010

PHYSICS (Honours)

EIGHTH PAPER (1+1+1 System)

(Revised New Syllabus)

SEVENTH PAPER (2+1 System)

(New Syllabus)

Time : 4 hours *Full Marks* : 90

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group but not more than **two** from a Group.

1. *(a)* Show that every reciprocal lattice is normal to a lattice plane of the direct crystal lattice. 3

(b) What will be the period of 'second' pendulum measured by an observer moving at a speed of $0 \cdot 8\,c$? 3

(c) Write an expression for a linearly polarized wave of angular frequency ω propagating in the positve x-direction with its plane of vibration at 30° to the z-x plane. 3

(d) A step index optical fibre has refractive indices of the core and cladding as 1·44 and 1·40 respectively and is surrounded by air. Calculate the neumerical aperture. 3

(e) An electric field in free space has the components

$$E_x = E_y = 0 \text{ and } E_z = E_0 \cos\left(\frac{2\pi x}{\lambda}\right) \cos \omega t$$

Find the magnetic field $\vec{B}$. 3

GROUP—A

(Physical Optics—II)

2. (a) What is population inversion? With the help of simple energy level diagrams, show how population inversion is achieved in He-Ne laser. 1+5=6

(b) What do you mean by Einstein's A, B coefficients? Show that the ratio

$$\frac{A_{mn}}{B_{nm}} = \frac{8\pi h\nu^3}{c^3}$$

5

(c) What is meant by acceptance angle and numerical aperture of a fibre? Obtain their expressions for a step index fibre. 4

3. (a) Give the construction, theory and principle of operation of a Babinet's compensator to produce and analyse elliptically polarised light. How is it superior to $\lambda/4$ plate? 2+3+3+2=10

(b) A parallel beam of light is incident normally on the plane face of a quartz crystal. Construct both the refracted wavefronts and the refracted rays when the optic axis of the crystal is—

(i) on the plane of the incident and parallel to the refracting surface;

(ii) perpendicular to the plane of incidence. 2½+2½=5

4. (a) Define specific rotation of an optically active substance. Discuss Fresnel's theory of rotation of the plane of polarization by an optically active substance. Derive an expression for the angle by which the plane of polarization of a plane polarized light is rotated in passing through a thickness d of the material. How can you experimentally justify the Fresnel's theory? 1+2+3+2=8

(b) State and explain Brewster's law of polarization. Show that the reflected and refracted components are mutually perpendicular to each other. 2+3=5

(c) What will be the Brewster angle for a glass slab ($\mu = 1 \cdot 5$) immersed in water ($\mu = 1 \cdot 33$)? 2

GROUP—B

(Electromagnetic Theory and Special Theory of Relativity)

5. (a) Write down Maxwell's equation for an electromagnetic field, briefly explaining the physical laws represented by the equations. 5

(b) Obtain the electromagnetic wave equation from Maxwell's equations in a conducting medium. 4

(c) Starting from the wave equation, find the skin depth of a conductor in terms of the conductivity and the frequency of the incident wave. 4

(d) The intensity of sunlight reaching the earth's surface is about 1300 Wm^{-2}. Calculate the strength of electric and magnetic fields of the incoming sunlight. 2

6. (a) Derive an expression for Rayleigh scattering cross-section. Distinguish between Rayleigh scattering and Thomson scattering. 7

(b) For a plane electromagnetic wave, show that the magnitude of the Poynting vector is equal to the product of the phase velocity and the energy density. 4

(c) Write down Cauchy's formula for dispersion and hence show that the dispersive power varies inversely as the cube of wavelength. 2

(d) At what velocity does the total energy of a moving particle become exactly twice its rest mass? 2

7. (a) Derive Lorentz transformation equations based on the fundamental postulates of the special theory of relativity. 5

(b) Explain Lorentz-FitzGerald contraction of length and the dilation of time scales on the basis of Lorentz transformation. 2+3=5

(c) What is Minkowski's space? 2

(d) The kinetic energy of an electron is 0·1 MeV. Find the speed of the electron according to—

(i) classical mechanics;

(ii) relativistic mechanics.

(Given : Rest mass energy of electron = 0·511 MeV) 3

GROUP—C

(Solid-state Physics)

8. (a) Derive Lame's equation and hence deduce Bragg's law of diffraction of X-rays by crystal planes. 6

(b) Define packing fraction and explain its physical significance. 2

(c) Calculate the packing fraction in the case of (i) body-centred and (ii) face-centred cubic lattice. 2+2=4

(d) Electrons are accelerated by 844 volts and are reflected from a crystal. The reflection maximum occurs when the glancing angle is 58°. Determine the spacing of the crystal. 3

9. (a) Show that the electrical conductivity of a semiconductor is given by $\sigma = e(n\mu_n + p\mu_p)$, where the symbols have their usual meaning. 6

(b) Derive Richardson's equation from thermodynamical consideration. 6

(c) An n-type Ge strip 1 mm wide and 1 mm thick, has a Hall coefficient of 10^{-2} m/coulomb. If for a current of 1 mA, the Hall voltage produced inside the strip is 1 mV, calculate the strength of the magnetic field. 3

10. (a) Define polarizability and deduce Clausius-Mossotti equation. 1+6=7

(b) What are paramagnetic materials? Give some examples. Derive the temperature dependence of the magnetic susceptibility of a paramagnetic substance. 1+1+4=6

(c) For argon gas $N = 10^{19}$ cm^{-3}, $z = 18$ and $\gamma = 10^{-8}$ cm, calculate the electronic polarization for an applied field of 10 kV/cm. 2

★★★

B III (Three Year H)
Under 1+1+1 System
&
B II (Three Year H) New
Under 2+1 System

2010

PHYSICS (Honours)

NINTH PAPER (1+1+1 System)

(Revised New Syllabus)

EIGHTH PAPER (2+1 System)

(New Syllabus)

Time : 4 hours *Full Marks* : 90

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group but not more than **two** from a Group.

1. *(a)* Prove that it is not possible for a photon to transfer its entire energy to a free electron.

(b) In the muon decay process

$$\mu^- \rightarrow e^- + \gamma_\mu + \tilde{\gamma}_e$$

Why are two neutrinos emitted?

(c) The series limit of Balmer series is at 3646 Å. Calculate the wavelength of the first line of the series.

(d) Why is the resolving power of an electron microscope much greater than that of an optical microscope?

(e) Three identical particles (fermions), each of mass m, are confined in a one-dimensional box of width l. The potential inside the box is zero. Calculate the energy of the system at ground state. 3×5=15

GROUP—A

(Atomic Physics)

2. (a) Describe Thomson's method for the determination of (e/m) of an electron. What are the drawbacks of this method? 5+1

(b) What is Bohr magneton? What modification is introduced in Bohr's theory due to the finite mass of a nucleus? 2+3

(c) Find out the expressions for magnetic dipole moment due to orbital motion of an electron and its corresponding gyromagnetic ratio. 4

3. (a) What are normal and anomalous Zeeman effects? Give the theory of normal Zeeman effect. Why anomalous Zeeman effect cannot be explained without vector atom model? 4+4+2

(b) Describe the applications of photoelectric effect. How Planck's constant can be determined from photoelectric effect? 2+3

4. (a) What correction did Millikan apply to Stokes' law (formula) and why? 4

(b) Why is non-homogenous magnetic field used in Stern-Gerlach experiment? Explain. 3

(c) What is Faraday effect? Mention its characteristic features. 2+2

(d) Calculate the wavelength separation in the fine structure spectrum due to spin-orbit interaction within the hydrogen atom at $\lambda = 4000$ Å. 4

GROUP—B

(Quantum Mechanics)

5. *(a)* Determine the transmission coefficient of a particle with energy E through a rectangular potential barrier of width a and height V_0 ($V_0 > E$). Apply the above result to find decay constant λ taking the α-decay process. 8+3

(b) An α-particle of energy 4 MeV is accelerated through 500 kV. Compute the fractional change in de Broglie wavelength. 4

6. *(a)* Find out the commutation relation $[e^{ikx}, \hat{p}_x]$, where x and p have their usual meanings. 3

(b) The ground state wave function of hydrogen atom is given by $\psi(r) = \left(\frac{1}{\pi a^3}\right)^{1/2} e^{-r/a}$, where r measures distance from the nucleus and a is a constant. Write down the probability that the electron lies between r and $r + dr$. Hence show that the most probable value of r is a. 2+2

(c) Obtain expression for the probability current density for the wave function

$$\psi = \frac{e^{ikr}}{r}$$ 4

(d) Prove the operator relation

$$\left[\frac{1}{x}\frac{d}{dx}x\right]^2 = \frac{d^2}{dx^2} + \frac{2}{x}\frac{d}{dx}$$ 2

(e) A perfectly monochromatic light source is not possible. Explain on the basis of Heisenberg uncertainty principle. 2

7. *(a)* Set up the Schrödinger equation for a linear harmonic oscillator. Solve it to obtain the energy eigenvalues and eigenfunctions. Highlight the physical significance of asymptotic behaviour of wave function. 2+8

(b) What is zero-point energy? Calculate the zero-point energy of a mass $1{\cdot}67 \times 10^{-24}$ gm connected to a fixed point by a spring with force constant 10^4 dyne/cm. 1+4

GROUP—C

(Nuclear and Particle Physics)

8. *(a)* Describe the theory and construction of a GM counter. How is quenching achieved in it? What are dead time, resolving time and recovery time? 4+2+3

(b) In a radioactive decay process, λ_1 and λ_2 are the decay constants of parent and daughter nuclei respectively. Prove that the time at which the number of daughter nuclei become maximum is given by

$$t_m = \frac{\ln(\lambda_2/\lambda_1)}{(\lambda_2 - \lambda_1)}$$ 4

(c) Explain the straggling of the range of α-particles. 2

9. *(a)* Explain the concept of nuclear reaction cross-section. What is compound nucleus hypothesis? Find expression for the threshold energy of an endoergic reaction. 3+2+2

(Continued)

(b) What is carbon-nitrogen cycle? Estimate the total energy released in a carbon-nitrogen cycle. Given :

$m_H = 1{\cdot}007825$ a.m.u.

$m_{He} = 4{\cdot}002603$ a.m.u.

$m_e = 5{\cdot}4865 \times 10^{-4}$ a.m.u. 2+2

(c) What are primary and secondary cosmic rays? Describe the latitude effect in cosmic rays. 2+2

10. *(a)* Describe, giving schematic diagram, the working principle of a fixed frequency cyclotron. Why cyclotron cannot be used for accelerating an electron? 5+1

(b) Calculate, by shell model, spin and parity of each nucleon : 3

N^{15}, O^{16}, C^{13}

(c) How was neutron discovered? Give a method to determine the mass of neutron. 2+4

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B I (Three Year H)
Under 1+1+1 System

2011

PHYSICS (Honours)

FIRST PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* Find the expression for the critical velocity of fluid motion by dimensional analysis.

(b) Show that if a rigid body be in motion, the curl of its linear velocity is twice its angular velocity, i.e., $\vec{\nabla}\times v = 2\vec{\omega}$; the symbols have their usual meanings.

(c) Prove that the inverse of a matrix is unique.

(d) $I = \int_{-1}^{+1} x^3 P_2(x)$. Evaluate I, without actually performing the integration and justify your answer. 2½×4=10

GROUP—A

(Mathematical Methods)

2. *(a)* Show that the line integral of $\vec{r} = -y\hat{i} + x\hat{j}$ around a continuous closed curve in the x-y plane is twice the area enclosed by the curve.

(b) Show that the vector

$$\vec{A} = (2xy + z^3)\hat{i} + x^2\hat{j} + 3xz^2\hat{k}$$

is irrotational and find a scalar function Φ such that $\vec{A} = \vec{\nabla}\Phi$.

(c) Explain the physical significance of curl of a vector field $\vec{A}$.

(d) Express $\vec{\nabla}\cdot\vec{A}$ in cylindrical coordinate system. 3×4=12

3. *(a)* Show that the modulus of each characteristic root of a unitary matrix is unit.

(b) Show that, if A be a square matrix, then its trace is the sum of its eigenvalues.

(c) If A and B are square matrices of the same type and if B is non-singular, show that the matrices A and $B^{-1}AB$ have same eigenvalues.

(d) If a dice is thrown 5 times, what is the chance that an ace turns up exactly three times? 4+3+3+2

4. *(a)* Write down the 2-D Laplace's equation of a plane in terms of the polar coordinates (r, θ) and solve it by the method of separation of variables.

(b) Expand the function $f(x) = x^2$ in the interval $(0, \pi)$ in series of sine.

(c) Obtain the recurrence relation

$$(2n+1)x\,P_n(x) = nP_{n-1}(x) + (n+1)P_{n+1}(x)$$

(d) Locate and classify the singular points of the following equation :

$$(1-x^2)\frac{d^2y}{dx^2} + 2x\frac{dy}{dx} + 2y = 0$$

4+3+3+2

GROUP—B

(Classical Mechanics—I)

5. *(a)* A particle of mass m is acted on by a central force. If (r, θ) be the polar coordinates of the particle, show that the total energy of the particle is given by

$$E = \frac{L^2}{2m}\left[\left(\frac{du}{d\theta}\right)^2 + u^2\right] + v(r)$$

where $v(r)$ is the potential energy, L is the angular momentum of the particle and $u = \frac{1}{r}$.

(b) Is any work done by a centrifugal force for motion in a circular orbit? Explain.

(c) Find out the radial and transverse component of velocity and acceleration in polar coordinates.

(d) If a planet were suddenly stopped in its orbit, prove that it will fall into the sun within a time $\frac{T}{4\sqrt{2}}$; where T is the time period of precessional motion of the planet and the orbit is circular. 3+2+3+4

6. (a) Why is the gravitational potential always negative?

(b) Find the gravitational potential due to a solid, homogeneous sphere at a point inside it and hence derive the intensity.

(c) A particle moves in a force field derivable from a potential function $v(x) = 6x(x^2 - 3)$. Find the position of the stable equilibrium.

(d) Is a mass situated at any place on the earth's surface attracted exactly towards the centre of the earth?

(e) Show that the total energy of a particle moving in a conservative field of force is constant. 1+4+2+2+3

7. (a) What is ellipsoid of inertia? What is its physical significance? Under what condition the ellipsoid becomes a sphere?

(b) Show that the rotational kinetic energy $T_{rot} = \frac{1}{2}(\vec{L} \cdot \vec{\omega})$, where $\vec{L}$ is the angular momentum vector and $\vec{\omega}$ the angular velocity vector.

(c) A cylinder has a mass M, length l and radius r. Find the ratio of l to r, if the moment of inertia about an axis through the centre perpendicular to its length is minimum. 4+4+4

GROUP—C

(General Properties of Matter)

8. (a) A horizontal bar of length $2l$ and cross-section α is tightly fixed to rigid supports at both ends. A weight W is suspended from the midpoint of the wire. Show the depression d of the

midpoint is given by $d^3 = \frac{Wl^3}{Y\alpha}$, Y is Young's modulus of the material. Cross-section of the bar is rectangular.

(b) Show that $Y = 3k(1-2\sigma) = 2\eta(1+\sigma)$, where the symbols have their usual meanings.

(c) If a liquid neither rises nor depressed in a capillary, can you conclude that the surface tension of the liquid is zero? Explain.

(d) Explain the term coefficient of viscosity and give its dimension. 4+5+1+2

9. (a) Show that in a streamline flow of a liquid through a capillary tube, the velocity profile in a plane of the advancing liquid is a parabola.

(b) What is terminal velocity? Two drops of rain of same size are falling through air with terminal velocity 10 cm/s. If the two drops coalesce to form a single drop, what will be the new terminal velocity?

(c) How does temperature affect the viscosity of a liquid and a gas?

(d) A uniform spring of spring constant K is cut into two halves. What is the spring constant of each half?

4+(1+3)+(1½+1½)+1

★★★

B I (Three Year H)
Under 1+1+1 System

2011

PHYSICS (Honours)

SECOND PAPER

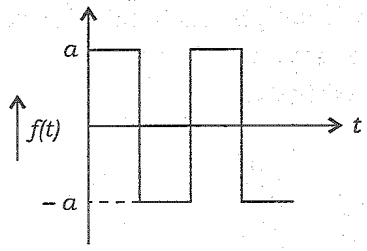
(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* Express the function $f(t)$ as a Fourier series. 3



(b) Calculate the fraction of molecules of a gas possessing speeds within 2% of the most probable speed. 3

(c) In a conducting wire of radius a, current density varies with radial distance as

$$\vec{J} = \left(\frac{r^2}{a}\right)\vec{J}_0$$

where $\vec{J}_0$ is parallel to the axis. Calculate the total current through the wire. 2

(d) What is mechanical reactance? What are its important constituents? 2

GROUP—A

(Heat)

2. (a) Explain qualitatively transport phenomena in gases in the light of kinetic theory. The coefficients of viscosity of two monatomic gases of atomic weight M_1 and M_2 are η_1 and η_2 at room temperature and pressure respectively. Show that their ratio of thermal conductivities is given by

$$\frac{K_1}{K_2} = \frac{\eta_1}{\eta_2} \times \frac{M_2}{M_1}$$ 3+3

(b) Using the Berthelot equation of state

$$p = \frac{RT}{V-b} - \frac{a}{TV^2}$$

show that

$$\frac{RT_c}{P_cV_c} = \frac{8}{3}$$

where the symbols carry their usual meanings. 4

(c) Show that the temperature T of a planet varies inversely as the square root of its distance R from the sun. Consider the sun and planets to be blackbodies in radiative equilibrium. 2

3. (a) Define emissive power and absorptive power for a substance. State the law giving the relation between the two. 2+2

(b) Considering the steady-state condition of a conducting spherical shell, integrate Fourier's equation of heat flow to obtain the temperature distribution along the radial direction. 5

(c) Two slabs of thicknesses d_1 and d_2 and thermal conductivities k_1 and k_2 are placed in contact with each other and heated at the junction. If the steady temperature be θ_1 and θ_2 at the two free surfaces, show that the temperature at the interface between the slabs is

$$\left(\frac{k_1\theta_1}{d_1} + \frac{k_2\theta_2}{d_2}\right) / \left(\frac{k_1}{d_1} + \frac{k_2}{d_2}\right)$$ 3

4. *(a)* Write down Stefan-Boltzmann law of radiation and derive it from Planck's law. 1+3

(b) Discuss the merits and demerits of thermocouple thermometers. 2

(c) Define 'mean free path' and 'collision probability'. What is the relation between them? 2+1

(d) Calculate the mean free path of molecules of H_2 gas at 27 °C at atmospheric pressure. Assume the molecular diameter to be $2{\cdot}00 \times 10^{-8}$ cm. 3

GROUP—B

(Sound)

5. *(a)* The differential equation for one-dimensional damped harmonic oscillator is

$$m\frac{d^2x}{dt^2} + k\frac{dx}{dt} + sx = 0$$

Explain the significance of each term in the equation. Solve the equation in the case of critical damping. 2+2

(b) Distinguish between amplitude resonance and velocity resonance. 2

(c) What do you mean by group velocity and phase velocity of a plane progressive wave? Derive a relation between them. 2+2

(d) Two mutually perpendicular oscillations are represented by $x(t) = a \sin \omega t$ and $y(t) = b \sin (2\omega t + \phi)$. Sketch the Lissajous figure resulting from these oscillations with $\phi = -\pi$. 2

6. *(a)* Define normal modes and normal frequencies of vibration.

Two particles of masses m_1 and m_2 are connected by a massless spring of spring constant S. If the system is free to oscillate along the length of the spring, find the frequency of oscillation. Also find the ratio of the amplitudes of the oscillating particles. 2+2+1

(b) What are ultrasonic waves? How can they be detected in the laboratory? 1+2

(c) What are beats?

Two tuning forks when sounded together form 6 beats per second. They are in unison with 70 cm and 72 cm of the same wire under the same tension. Find the frequencies of the forks. 1+3

GROUP—C

(Electricity—I)

7. *(a)* What is an electric dipole?

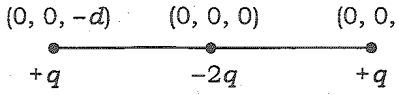
Calculate the potential and field at a point (r, θ) due to a dipole. What approximations are used in this derivation? 1+3+1

(b) Define susceptibility (χ_e), permittivity and dielectric constant (K). Hence prove the relation $K = 1 + \chi_e$. 3+1

(c) Show that Kirchhoff's current law is consistent with the principle of charge conservation, and the voltage law is consistent with the principle of conservation of energy. 3

8. *(a)* Obtain Laplace's equation from Coulomb's law. Use Laplace's equation to find the capacitance of a spherical capacitor where the inner sphere is grounded and the outer shell is charged. 2+3

(b) What is the significance of quadrupole term in the multipole expansion of potential? Show that at large distances the approximate potential due to the linear quadrupole given below varies inversely as the cube of the distance. 1+3



(c) A point charge q is placed at a distance d from an infinite earthed conducting plane. Let O be the foot of the perpendicular from q on the plane. Show that the circle on the plane centred on O which contains half of the total induced charge will have the radius $\sqrt{3}d$. 3

9. *(a)* Explain with necessary theory the working of Callender and Griffith's bridge in the case of platinum resistance thermometer. 4

(b) State and prove the boundary conditions on $\vec{E}$ and $\vec{D}$ prevailing at the interface of two dielectric media. 4

(c) Write down Ohm's law in microscopic form explaining the meaning of the symbols used.

Two batteries B_1 and B_2 of e.m.f.'s E_1 and E_2 have resistances r_1 and r_2 respectively. They are connected in parallel to the ends of a resistance R. Find the condition for zero current through B_2. 1+3

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B II (Three Year H)
Under 1+1+1 System

2011

PHYSICS (Honours)

FOURTH PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* Explain the role of minority carriers on the barrier potential across a *p-n* junction.

(b) Convert $(2F9A \cdot A8)_{16}$ into equivalent decimal number.

(c) A zone plate is to be constructed with focal length 45 cm for wavelength 5893 Å. Calculate the radius of the first-order zone.

(d) Show that for a coaxial lens system $xx' = ff'$, where x and x' are respectively the distances of the object and image from the first and second focal points; f and f' are two focal lengths. 3+2+2+3=10

GROUP—A

(Geometrical Optics)

2. *(a)* What is the usefulness of considering cardinal points of an optical system? Show that when a lens system is surrounded by air, the nodal points coincide with principal points.

(b) Discuss the operating principle of a Huygens' eye-piece and find out its cardinal points.

(c) Obtain the condition for achromatism for two lenses placed in contact.

(1+4)+4+3=12

3. *(a)* State and explain Fermat's principle. Hence show that when light goes from one point to another via a plane mirror, the path followed by the light is the one which takes the least time.

(b) Obtain Abbe's sine condition for a single-refracting surface.

(c) The eye can be regarded as a single spherical refracting surface of radius of curvature of cornea 7·8 mm, separating two media of indices 1·00 and 1·34. Calculate the distance from the refracting surface at which a parallel beam of light will come to focus.

(d) The refractive index of a flint glass for red and violet light are 1·613 and 1·632 respectively. What will be the angular dispersion produced by a thin prism of refracting angle 5° of flint glass?

(2+3)+3+2+2=12

GROUP—B

(Physical Optics)

4. *(a)* State and explain Huygens' principle. Using the principle, prove the relation

$$\frac{1}{v}-\frac{1}{u}=(n-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$

for the refraction through lenses. Symbols have their usual significance.

(b) Show that in two dimensions, the shape of the fringes in Young's experiment is hyperbolic. Why are these fringes called non-localised?

(c) What will be the nature of fringes in Fresnel's biprism experiment when white light is used? (2+4)+(4+1)+1=12

5. *(a)* Describe the principle of production of interference fringes in a Fabry-Perot interferometer. Show that the ratio of

maximum to minimum intensity is given by

$$\frac{I_{max}}{I_{min}} = \frac{(1+r^2)^2}{(1-r^2)^2}$$

where r is the reflection coefficient.

(b) Light containing two wavelengths λ_1 and λ_2 falls normally on a plano-convex lens of radius of curvature R resting on a glass plate. If the nth dark ring due to λ_1 coincides with the $(n+1)$th dark ring due to λ_2, prove that the radius of nth dark ring of λ_1 is $\{\lambda_1\lambda_2 R/(\lambda_1-\lambda_2)\}^{1/2}$.

(c) Suppose that in a microscope the space between the object and objective is filled with an oil of refractive index n. Show that the limit of resolution in this case is $\lambda/2n \sin\theta$. 6+3+3=12

6. *(a)* Explain half-period zone in relation to a plane wavefront. Show that it acts as a convergent lens having multiple focii.

(b) The refractive index of a prism depends upon the wavelength according to Cauchy's formula

$$n(\lambda) = A + \frac{B}{\lambda^2}$$

where A and B are constants.

(i) Find how resolving power of prism varies with wavelength.

(ii) Determine the thickness of the base if the prism is to be used to resolve sodium D-lines (λ = 5890 Å and 5896 Å).

(c) Discuss the differences between prism and grating spectrum. (2+3)+(2+2)+3=12

7. *(a)* Discuss the phenomenon of Fraunhofer diffraction at a single slit with detailed calculation and show that the intensities of successive maxima are nearly in the ratio

$$\frac{4}{9\pi^2} : \frac{4}{25\pi^2} : \frac{4}{49\pi^2}$$

(b) A quasi-monochromatic source emits radiations of mean wavelength λ = 5461 Å and has a bandwidth $\Delta\nu = 10^9$ Hz. Calculate *(i)* coherence time and *(ii)* coherence length.

(c) Examine if two spectral lines of wavelengths 5890 Å and 5896 Å can be clearly resolved in the *(i)* first order and *(ii)* second order by a diffraction grating of width 2 cm and having 425 lines/cm. (5+2)+2+3=12

GROUP—C

(Electronics—I)

8. *(a)* Derive the condition for transfer of maximum power from a source to a load.

(b) State Norton's theorem. Using Norton's theorem, find the current in 8 Ω register in a network as given in Fig 1 :

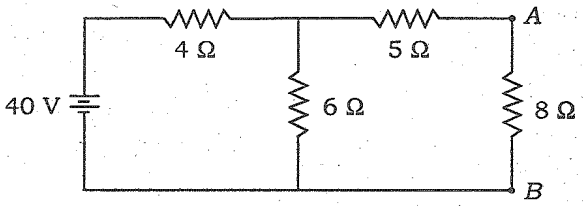

Fig. 1

(c) Explain what you mean by ideal current source and ideal voltage source.

(d) Find the Thevenin's voltage, Thevenin's impedance and load current for the circuit shown in Fig. 2 (where $\omega = 100\pi$ rad/sec).

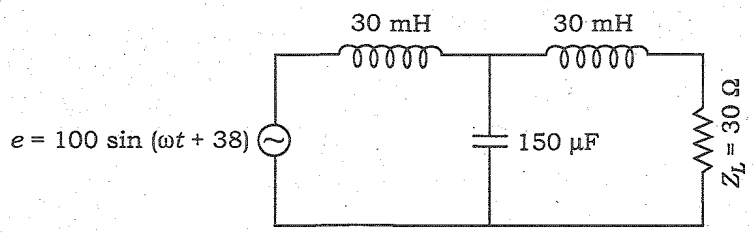

Fig. 2 3+(1+2)+2+4=12

(Continued)

9. *(a)* Draw AND and NOT gate using diodes and explain their operation.

(b) The Boolean expression for two variables Y_1 and Y_2 in terms of inputs A, B and C are

$$Y_1 = (A+B)\cdot(B+C)\cdot(C+A)$$
$$Y_2 = AB + BC + CA$$

Find the relation between Y_1 and Y_2.

(c) Draw with explanation the space-charge density, barrier field, barrier potential and barrier potential energy across an unbiased *p-n* junction.

(d) For the circuit given in Fig. 3, the d.c. operating points (*Q*-point) are given by $I_B = 60\ \mu A$, $V_{BE} = 0{\cdot}52$ V, $V_{CE} = 7$ V, $I_C = 3{\cdot}5$ mA. Draw the a.c. load line on the V_{CE}-I_C characteristic curve, explaining the procedure. (The reactance of C_1 and C_2 are negligible at the used frequency.)

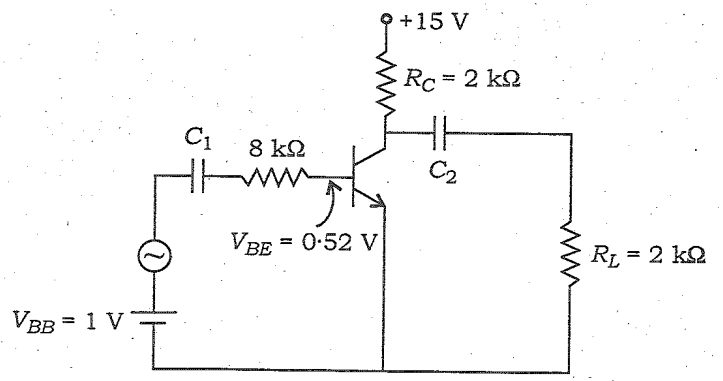

Fig. 3 3+2+4+3=12

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B II (Three Year H)
Under 1+1+1 System

2011

PHYSICS (Honours)

FIFTH PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* An inventor claims to have developed an engine working between 600 K and 300 K capable of having an efficiency of 52%. Comment on his claim.

(b) Out of the two instruments, a voltmeter and a potentiometer, which one is preferred to measure the EMF of a cell and why?

(c) An inductor is connected to a battery through a switch. Explain why the EMF induced in the inductor is much larger when the switch is opened as compared to the EMF when the switch is closed.

(d) Why and how does the condition of balance in an a.c. bridge differ from that in a d.c. bridge?

(e) Do all substances get cooled on adiabatic expansion? Explain. 2×5=10

GROUP—A

(Thermodynamics)

2. (a) State the essential difference between the 1st law and the 2nd law of thermodynamics.

(b) Prove that the adiabatic curve is steeper than isothermal curve in (P-V) indicator diagram.

(c) A Carnot engine operates between T and T' with a gas as working substance whose equation of state (EOS) is given by $P(V-b)=RT$.

Work out expressions for the heat absorbed and the work done in each part of the cycle and show that the efficiency of the cycle is $\left(1-\frac{T'}{T}\right)$.

(d) Two identical bodies of constant heat capacity at temperatures T_1 and T_2 are used as the source and sink respectively

of a heat engine. If the bodies remain at constant pressure and there is no change in phase, show that the maximum possible work done by the heat engine is $C_P(\sqrt{T_1}-\sqrt{T_2})^2$.

1+2+6+3=12

3. (a) State and establish the Clausius theorem for cyclic process. Show that this theorem leads to a 'state function' called 'entropy'.

(b) Show that the entropy is a measure of the so-called unavailable energy.

(c) Two globes of volume V_1 and V_2 contain n_1 and n_2 moles respectively of two ideal gases at the same temperature. A valve connecting the two is opened and the gases mix without any reaction. Show that

$$\Delta S = n_1 R \ln\frac{V_1+V_2}{V_1} + n_2 R \ln\frac{V_1+V_2}{V_2}$$

(5+2)+2+3=12

4. (a) Explain the principle of cooling of a paramagnetic substance by adiabatic demagnetization. Deduce the expression for the amount of cooling.

(b) Show that

(i) $TdS = C_V dT + T\left(\frac{\partial P}{\partial T}\right)_V dV$

(ii) $C_P - C_V = \frac{TV\alpha^2}{K_T}$

where α is the volume coefficient of expansion and K_T the isothermal compressibility and others have their usual significances. (2+4)+(3+3)=12

5. (a) Write down the relation between Helmholtz free energy, enthalpy and Gibbs free energy. Prove that

$$G = H + T\left(\frac{\partial F}{\partial T}\right)_V$$

The symbols have their usual meanings.

(b) What is the significance of Joule-Thomson coefficient? Prove that Joule-Thomson effect is the result from the deviation of Joule's law and Boyle's law.

(c) What are inversion line and the temperature of inversion T_i? Show that for van der Waals gas the temperature of inversion is

$$T_i = \frac{2a(V-b)^2}{RV^2 b}$$

where symbols used are having usual meaning. (2+2)+(1+3)+(1+3)=12

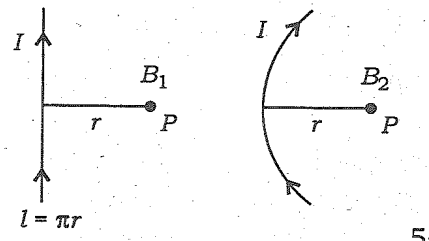
GROUP—B

(Electricity—II)

6. (a) Find an expression for vector potential due to an arbitrary current element and hence deduce Biot-Savart law.

(b) Using Biot-Savart law, prove that $\vec{\nabla}\cdot\vec{B} = 0$.

(c) A current I passes through a straight conductor of length = πr. The magnetic induction at a perpendicular distance r from the centre of that wire is B_1. The same conductor is now bent in the form of a semicircular arc of the same radius r. The magnetic induction at the same point is now B_2. Find the relation between B_1 and B_2.

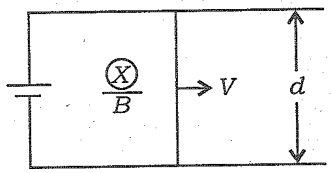


5+3+4=12

7. (a) How does a ballistic galvanometer differ from a deadbeat galvanometer?

Work out the theory of working of a suspended coil type ballistic galvanometer. Explain the meaning of external critical damping resistance.

(b) Consider two long parallel rails of negligible resistance separated by a distance d and connected to a cell of EMF E at one end. A jumper of mass m and resistance R slides without friction along the rails. An external uniform magnetic field B is applied normal to the plane of the rails. Find the velocity of the jumper as a function of time. Find its terminal velocity and also current through it when it attains the terminal velocity.



(1+6+1)+4=12

8. (a) What is series resonance in an electric circuit? What are the resonant frequency, bandwidth and Q-factor of this circuit? How are they related? Why is the circuit called acceptor circuit?

(b) In an ideal transformer, show that the ratio of output voltage to the input voltage is equal to the ratio of the number of secondary turns to the number of primary turns.

(c) A single-phase 50 kVA transformer has primary voltage of 6600 V and secondary voltage of 256 V and has 32 secondary turns. Calculate the number of primary turns and primary and secondary currents.

[1+(1+2+1)+1+1]+2+3=12

9. (a) Discuss the principle of measurement of the frequency of an a.c. source by using Wien's parallel bridge.

(b) Explain how a rotating magnetic field can be produced. Derive an expression for the torque acting on a coil placed in a rotating magnetic field and hence find out the maximum value of the torque.

(c) In a material, the magnetization is $\vec{M} = (2z\hat{i} - 3x\hat{j})$ A/m. What is the bound current density? 5+4+3=12

★★★

B III (Three Year H)
Under 1+1+1 System
&
B II (Three Year H) New
Under 2+1 System

2011

PHYSICS (Honours)

SEVENTH PAPER (1+1+1 System)

(Revised New Syllabus)

SIXTH PAPER (2+1 System)

(New Syllabus)

Time : 4 hours *Full Marks* : 90

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group but not more than **two** from a Group.

1. *(a)* A Hamiltonian of one degree of freedom is given by

$$H(x,\ p) = \frac{1}{2}\frac{p^2}{(1+2\beta x)} + \frac{\omega^2 x^2}{2} + \alpha x^3$$

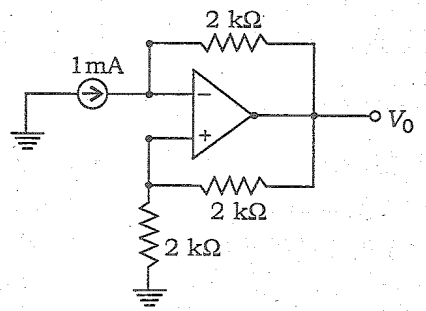
where ω, α, β are constants. Show that the corresponding Lagrangian is

$$L(x,\ \dot{x}) = \frac{1}{2}\dot{x}^2 - \frac{1}{2}\omega^2 x^2 - \alpha x^3 + \beta x \dot{x}^2$$ 3

(b) Show that rotational symmetry of a system in space leads to conservation of angular momentum. 3

(c) What is the resolution of an 8-bit D/A converter expressed as a percent? If the full-scale voltage is 5 V, what is the resolution in volts? 2+1=3

(d) Find the output voltage in the circuit shown in the figure below : 3



(e) The point of suspension of a simple pendulum is attached to a moving lift which falls vertically with an acceleration f. Set up the Lagrangian for the system. 3

GROUP—A

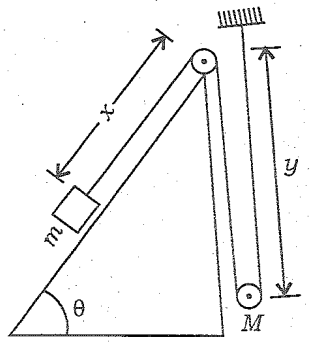
(Classical Mechanics—II and Fluid Mechanics)

2. (a) What do you mean by generalised coordinates? Why are they called generalised? Give a suitable set of generalised coordinates for the dynamical systems described in the following and indicate the coordinates in diagrams : 1+1+(2½+1½)=6

(i) A disc rolling without slipping on a table

(ii) A coplanar double pendulum

(b) State and explain d'Alembert's principle. A block of mass m is pulled up as the mass M moves down as shown in the figure below. Assume the pulley and the incline both are frictionless. Using d'Alembert's principle, show that the acceleration of m is $\ddot{x} = \dfrac{mg\sin\theta - \frac{1}{2}Mg}{\left(m + \frac{M}{4}\right)}$. 5

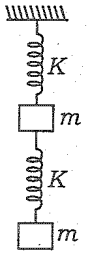


(c) What are transformation equations? If the transformation equations do not contain time explicitly, then show that the kinetic energy can be expressed as a homogeneous quadratic function of generalised velocities. 1+3=4

3. (a) State and prove the principle of least action. 5

(b) Use Hamiltonian formulation to show that the path of a projectile is a parabola. 4

(c) Define normal modes of vibration. Two equal masses m are connected to each other with the help of spring of force constant K and the upper mass is connected to a rigid support by an identical spring as shown in the figure below :



If the system is allowed to oscillate in the vertical direction, show that the frequencies of two normal modes are

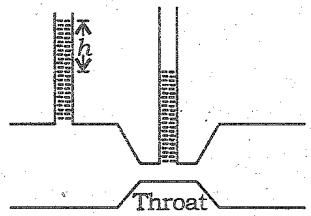
$$\frac{(3 \pm \sqrt{5})K}{2m}$$ 2+4=6

4. (a) Define cyclic coordinates. What is the significance of a cyclic coordinate in relation to the symmetry properties of the system? 1+2=3

(b) Deduce the fundamental Poisson's brackets. Show that $[t, H] = 1$, where time is a dynamical variable and H is Hamiltonian. 2+2=4

(c) Derive the expression for equation of continuity of a fluid. Hence show that for irrotational flow of incompressible fluid, the velocity potential satisfies the Laplace's equation. 3+2=5

(d) Liquid is flowing through a pipeline with a throat as shown in the figure below :



If A_1 and A_2 are the cross-sectional areas of the pipe and the throat respectively, then show that the rate of flow is given by

$$V = A_1 A_2 \sqrt{\frac{2gh}{(A_1^2 - A_2^2)}}$$ 3

GROUP—B

(Statistical Mechanics)

5. *(a)* Explain the terms μ-space and Γ-space. 2

(b) What do you mean by ensemble? Distinguish between canonical and microcanonical ensemble. 1+3=4

(c) Prove that the number of molecules of an ideal gas in equilibrium temperature T, whose momentums lie between p and $p+dp$ is given by

$$n(p)\,dp = \frac{4\pi}{(2\pi mkT)^{3/2}}\, p^2 e^{-\frac{p^2}{2mkT}}\, dp$$ 4

(d) Show that M-B statistics is the limiting case of quantum statistics. 3

(e) Explain the significance of partition function. 2

6. *(a)* Derive the Richardson-Dushman equation of thermionic emission. 5

(b) What are the essential differences between the postulates of Debye and Einstein to explain the specific heat of solids at low temperature? Deduce Einstein's formula for specific heat of solids. Hence show that the atomic heat at constant volume C_v tends to zero as $T \to 0$. 2+3+2=7

(c) Derive Planck's formula for blackbody radiation using BE-distribution law. 3

GROUP—C

(Electronics—II)

7. *(a)* Explain the meaning of field-effect transistor. Derive the expressions for voltage gain and output impedance for a source follower. 1+5=6

(b) How does a small-signal high-frequency model of transistor differ from a small-signal low-frequency model? Explain. 2

(c) What are the disadvantages of asynchronous counter? Construct a decade ripple counter where all the disadvantages of asynchronous counter are completely eliminated. Give the limiting diagram of that counter. 1+3+1=5

(d) Compare between L-section filter and π-section filter. 2

8. *(a)* Explain the construction and principle of operation of enhancement type of MOSFET. 5

(b) Obtain the condition for sustained oscillation and frequency of oscillation of Colpitts oscillator. 6

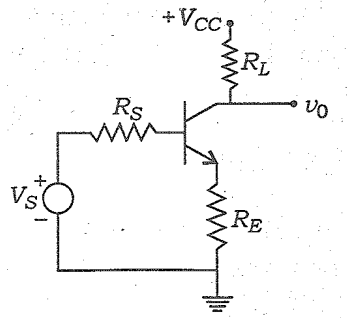
(c) Show that the total power dissipated in case of 100% AM modulation is 1·5 P_c, where P_c is the power of the carrier wave. 4

9. *(a)* What are the advantages of FM over AM? A frequency modulated wave is represented by

$$v = v_0 \cos(\omega_0 t + m_f \sin \omega_m t)$$

where the parameters have their usual meanings. Show that if modulation index $m_f << 1$, then the bandwidth of the FM is approximately $2\omega_m$. 2+5=7

(b) The following figure shows a transistor feedback amplifier. What type of feedback (topology) is used here? Justify your answer. Calculate feedback factor β and voltage gain with feedback A_{vf} for the circuit. 2+3=5



(c) What are the meanings of the following instructions of an 8085 µp? 3

(i) MOV B, M

(ii) STA 2400H

(iii) MVI C, 09H

10. *(a)* What is the essential difference between a sequential logic system and a combinational logic system? What is read only memory? Show that a ROM may be considered as a decoder for the input code followed by an encoder for the output code. 1+1+3=5

(b) Explain the functions of the operations in microprocessor *(i)* MOV A, B and *(ii)* LDA. 2+2=4

(c) Explain how a CRO can be used to measure phase of an a.c. voltage. 4

(d) Why is an electronic voltmeter superior than an ordinary voltmeter? 2

★★★

B III (Three Year H)
Under 1+1+1 System
&
B II (Three Year H) New
Under 2+1 System

2011

PHYSICS (Honours)

EIGHTH PAPER (1+1+1 System)

(Revised New Syllabus)

SEVENTH PAPER (2+1 System)

(New Syllabus)

Time : 4 hours *Full Marks* : 90

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group but not more than **two** from a Group.

1. *(a)* NaCl crystallizes as cubic structure. Taking the molecular weight of NaCl as 58·46 and the density at room temperature as $2 \cdot 167\ gm/cm^3$, calculate the lattice constant *a*. 3

(b) Calculate the Fermi energy and Fermi temperature of liquid He^3 whose density near 0 K is $81\ kg\text{-}m^{-3}$. 3

(c) Calculate the thickness of a half-wave plate for sodium light (given, $n_0 = 1 \cdot 54$ and the ratio of the velocity of *O*-component and *E*-component is 1·007). Is the crystal positive or negative? Give reasons. 3

(d) Show that the rest mass of a particle of momentum p and kinetic energy T is

$$m_0 = \frac{p^2c^2 - T^2}{2Tc^2}$$ 3

(e) The spacing of the planes in a crystal is 1·2 AU and the angle for the first-order Bragg's reflection is 30°. Determine the energy of the X-rays in eV. 3

GROUP—A

(Physical Optics—II)

2. (a) What is an optical fibre? Explain the working principle of optical fibre as a waveguide for light. 5

(b) Explain the temporal and spatial coherence of a beam of light. What are spontaneous and stimulated emissions? 3+4=7

(c) Can two independent laser beams produce an interference patterns? Justify your answer. 3

3. (a) Explain the functions of various parts of Laurent's half-shade polarimeter. 6

(b) How would you use it to determine the specific rotation of sugar solution? 4

(c) A quartz plate, cut with its surface perpendicular to the optic axis, is required to annual completely the rotation of the plane of polarization of red light ($\lambda = 7600$ AU) by a 26·7 cm length of lactose solution (specific rotation = 52·5°) containing 100 gm of an active substance per litre of the solution. What should be the thickness of the plate? For quartz plate with light $\lambda = 7600$ AU, $\mu_L = 1 \cdot 53920$ and $\mu_R = 1 \cdot 53914$. 5

4. (a) How can you convert an elliptically polarized light into a circularly polarized light? 4

(b) Find the state of polarization when the *X* and *Y* components of an electric field are given by—

(i) $E_x = E_0 \sin(\omega t + kz)$,
$E_y = E_0 \cos(\omega t + kz)$

(ii) $E_x = E_0 \cos(\omega t + kz)$,
$E_y = \frac{E_0}{\sqrt{2}} \cos(\omega t + kz + \pi)$

1½+1½=3

(c) Explain why the colour of the sky during the daytime is blue. If the earth had no atmosphere, what would have been the change? 3

(d) Two Nicol prisms are so arranged that the amount of light transmitted through them is maximum. What will be the percentage reduction in the intensity of the incident light when the analyser is rotated through 45°? 3

(e) Describe the theory of a quarter-wave plate. 2

GROUP—B

(Electromagnetic Theory and Special Theory of Relativity)

5. (a) A plane polarised electromagnetic wave is incident on an interface between two dielectric media. Find the relation among the angles of incidence, reflection and refraction. 5

(b) Starting from Maxwell's electromagnetic field equation, show that for a plane wave propagating in an isotropic, homogeneous dielectric medium, the electric and magnetic field vectors are normal to the direction of propagation and also perpendicular to each other. Also find an expression for the velocity of propagation of a plane electromagnetic wave in the medium. 6+4=10

6. (a) Explain the terms 'normal' and 'anomalous dispersion'. Develop a theory to explain anomalous dispersion. Where does the range of anomalous dispersion lie and why? 2+6+2=10

(b) Define scattering cross-section. Show that in Rayleigh scattering, the cross-sections are inversely proportional to the fourth power of wavelength of the incident radiation. 2+3=5

7. (a) What is Minkowski's space? Show that in such a space, the Lorentz transformation amounts to a simple rotation about the origin. 1+4=5

(b) Prove the relation

$$m = \frac{m_0}{\sqrt{1 - v^2 / c^2}}$$

where the symbols have their usual meanings. 5

(c) Derive the relativistic expressions of kinetic energy and show that it reduces to the usual expression $\frac{1}{2} m_0 v^2$, where $v / c << 1$. 3

(d) A particle with a mean proper life time of 2×10^{-6} sec, moves through laboratory with a speed of 0·9 *c*. Calculate its life time as measured by an observer in laboratory. 2

GROUP—C

(Solid-state Physics)

8. *(a)* Derive an expression for the interplaner spacing d of the set of (hkl) planes of a cubic lattice. 3

(b) Define Miller indices of a plane in a crystal. Find the Miller indices of a plane having intercepts $6a$, $4b$ and $2c$ on the X, Y and Z axes respectively. 1+2=3

(c) Define packing fraction of a crystal and estimate its values in b.c.c. and f.c.c. lattices. 1+2+2=5

(d) Define cohesive energy of a crystal. Describe the differences between ionic and covalent binding in solids. 2+2=4

9. *(a)* Establish the relationship among the electric displacement, field strength and polarization vectors. 4

(b) What are the characteristics of a ferromagnetic substance? Derive the Currie-Weiss law of ferromagnetism and obtain an expression for critical temperature. 1+4+1=6

(c) What are ferrites? Name some of their applications. 2

(d) Silicon has the dielectric constant 12 and the edge length of the conventional cubic cell of silicon lattice is 5·43 AU. Calculate the electronic polarizability of silicon atom.
[Given, $\varepsilon_0 = 8 \cdot 854 \times 10^{-12}$ F/m] 3

10. *(a)* State the basic assumptions of the classical Drude theory of metals and deduce the expression for the electrical conductivity of metal. 1+5=6

(b) What is Hall effect? How would you experimentally determine the Hall coefficient? Mention the uses of Hall effect. 1+3+2=6

(c) Calculate the conductivity of intrinsic germanium at room temperature (300 K). Given that at 300 K the intrinsic carrier concentration, electron mobility and hole mobility are $2 \cdot 4 \times 10^{19}$ m^{-3}, $0 \cdot 38$ $m^2 v^{-1} s^{-1}$ and $0 \cdot 19$ $m^2 v^{-1} s^{-1}$ respectively. 3

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B III (Three Year H)
Under 1+1+1 System
&
B II (Three Year H) New
Under 2+1 System

2011

PHYSICS (Honours)

NINTH PAPER (1+1+1 System)

(Revised New Syllabus)

EIGHTH PAPER (2+1 System)

(New Syllabus)

Time : 4 hours *Full Marks* : 90

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group but not more than **two** from a Group.

1. *(a)* Show that the momentum operator $-i\hbar\nabla$ is a Hermitian operator. 3

(b) Obtain the expression for the probability current density for the wave function $\psi(r) = e^{ikr}/r$. 3

(c) Explain why pair production cannot take place in vacuum. 3

(d) Energy required to remove an electron from sodium is 2·3 eV. Does sodium show photoelectric effect for orange light with wavelength 6800 Å? 3

(e) Fission is not a prominent decay mode for light mass nuclei. Explain. 3

GROUP—A

(Atomic Physics)

2. (a) Describe Franck-Hertz experiment. What conclusion can be drawn from that experiment? 4+1

(b) An electron circles a nucleus of charge Ze. Assume, there are two orbits 1 and 2 with radii r_1 and r_2 respectively. Total energy of the electron is greater while it is in orbit 1. Prove that $r_1 > r_2$. Also show that the velocity and acceleration in orbit 2 are greater than those in orbit 1. 2+3

(c) Show that

$$m / M = \frac{R_{He} - R_H}{R_H - \frac{1}{4}R_{He}}$$

where m and M are the electron and the proton masses respectively and R_H and R_{He} are the Rydberg constant for H and He^+ respectively. 5

3. (a) Does the concept of Bohr's orbit obey the Heisenberg uncertainty principle? Explain. 4

(b) Explain why Lyman series can be observed in absorption spectra while the Balmer series cannot be observed. 3

(c) Derive the expression for Lande's splitting factor and explain the anomalous Zeeman effect of sodium doublet line D_1 and D_2. 2+2

(d) What are the L-S and the j-j coupling? 4

4. (a) What is a mass spectrograph? 2

(b) Describe the Bainbridge mass spectrograph and explain how it is used to identify positive ions of different masses. 3+2

(c) The distance between the tracks corresponding to masses 12 and 16 in an Aston's mass spectrograph is 4·8 cm. Calculate the mass of the particle whose trace is at a distance of 8·4 cm from the trace of mass 16. 4

(d) What is a spectrometer and how does it differ from a spectrograph? 2+2

GROUP—B

(Quantum Mechanics)

5. *(a)* What do you mean by phase velocity and group velocity? 1½+1½

(b) Define probability density. From the time-dependent Schrödinger equation, obtain the equation of continuity. 5

(c) What do you understand by wave particle duality? Show that the de Broglie wavelength associated with a particle of rest mass m_0 and kinetic energy E is given by

$$\lambda = \frac{hc}{(E^2 + 2Em_0c^2)^{1/2}}$$ 3+4

6. *(a)* What are the basic postulates of quantum mechanics? 4

(b) Find the normalized wave function for a particle trapped in an one-dimensional box and calculate the expectation values of $\hat{P}_x$ and $\hat{x}$ of the particle. 4+4

(c) How can Bohr's postulate of angular momentum be explained by wave mechanics? 3

7. *(a)* Derive the expression for the rotational energy levels of a diatomic molecule. (Assume, the atoms are connected by a rigid rod.) How the energy levels get modified if the atoms are connected by a flexible spring? 5+3

(b) What is Raman effect? Discuss the selection rules in Raman spectroscopy. 4

(c) Give the quantum theory of Raman effect in connection with the Stokes' and anti-Stokes' lines. 3

GROUP—C

(Nuclear and Elementary Particle Physics)

8. *(a)* Give a rough estimate of the α-decay constant of a radioactive element. 7

(b) In a radioactive decay process, λ_1 and λ_2 are the decay constants of parent and daughter nuclei respectively. Show that the time at which the number of daughter nuclei become maximum is given by

$$t_m = \frac{\ln(\lambda_2 / \lambda_1)}{(\lambda_2 - \lambda_1)}$$ 4

(c) Discuss the β-energy and momentum spectra obtained from a β-active heavy element. 2+2

9. (a) Give your arguments against the proton-electron hypothesis for the structure of nuclei. 4

(b) Which of the following isobars would you expect to be β-active and how would it decay and why?

$_{28}Ni^{64}$ and $_{29}Cu^{64}$

Given,

m_{Ni} = 63·9280 a.m.u.

m_{Cu} = 63·9298 a.m.u. 3

(c) What are β-rays? How does β-decay differ from α-decay? 2+2

(d) Write down the selection rules of β-decay. What are the Pauli's hypotheses of β-decay? 2+2

10. (a) Describe the liquid drop model of the nucleus. Write down the Bethe-Weizacker mass formula and explain different terms. 3+5

(b) Show that for light nuclei, the atomic number of the most stable isotope is $z \approx A/2$ for a given A. 3

(c) Show that the elementary particle pion has odd (negative) parity. 4

★★★

B I (Three Year H)
Under 1+1+1 System

2012

PHYSICS (Honours)

FIRST PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* Show that Newton's second law remains invariant under Galilean transformation.

(b) If you are given two beams made of same material and having same length and weight, with only difference being that one has a circular cross-section while the other is square in nature, show that the ratio of loads required to produce equal depression for the two beams is $\pi/3$.

(c) If a matrix A satisfies a relation $A^2 + A - I = 0$, prove that A^{-1} exists and find A^{-1}.

(d) If F is a differentiable function of x, y, z, t; where x, y, z are differentiable functions of t, prove that

$$\frac{dF}{dt} = \frac{\partial F}{\partial t} + (\vec{\nabla} F) \cdot \frac{d\vec{r}}{dt}$$ 2½×4=10

GROUP—A

(Mathematical Methods)

2. *(a)* Find the constants a and b so that the surface $ax^2 - byz = (a+2)x$ will be orthogonal to the surface $4x^2y + z^3 = 4$ at the point $(1, -1, 2)$.

(b) Find the directional derivative of $f = 3e^{2x-y-z}$ at the point $A(1, 1, -1)$ in the direction $\overrightarrow{AB}$, where B is the point $(-3, 5, -6)$.

(c) Evaluate

$$\iint_S \vec{F} \cdot \hat{n}\, dS$$

where $\vec{F} = 4xz\hat{i} - y^2\hat{j} + yz\hat{k}$ and S is the surface of the cube bounded by $x = 0$, $x = 1$; $y = 0$, $y = 1$; $z = 0$, $z = 1$.

(d) Explain the physical significance of divergence of a vector field $\vec{A}$. 3+4+3+2

3. *(a)* Show that all the eigenvalues of a Hermitian matrix are real.

(b) Find the eigenvalues and eigenvectors of the matrix

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

Is this matrix unitary?

(c) Expand in a Fourier series, the function

$$f(x) = \begin{cases} \sin x & 0 \le x \le \pi \\ -\sin x & -\pi \le x \le 0 \end{cases}$$

3+(4+1)+4

4. *(a)* Locate the singular points of the following equation and solve it :

$$(1-x^2)\frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + 2y = 0$$

(b) Prove that

$$\int_{-1}^{+1} [P_n(x)]^2 dx = \frac{2}{2n+1}, \quad \text{for } n = 0, 1, 2, \text{ etc.}$$

where $P_n(x)$ is Legendre polynomial.

(c) Prove that for Hermite polynomial

$$H_n(-x) = (-1)^n H_n(x)$$

4+4+4

GROUP—B

(Classical Mechanics—I)

5. *(a)* Explain the terms principal moments of inertia and ellipsoid of inertia.

(b) Determine the moment of inertia of a solid cone rotating about an axis passing through its vertex and parallel to its base.

(c) Obtain Euler's equations of motion for a rotating rigid body.

(1½+1½)+4+5

6. *(a)* What are gravitational potential and intensity? Find a relation between them.

(b) Find the gravitational potential and intensity at a point inside the material of the hollow sphere.

(c) State Keplar's laws of planetary motion and deduce the third law from the law of gravitation.

(d) Using the conservation of energy principle, show that angular speed of a simple pendulum is

$$\dot{\theta} = \left[\frac{2}{ml^2}\{E - mgl(1-\cos\theta)\}\right]^{1/2}$$

where the symbols have their usual meanings.

(2+1)+4+3+2

7. *(a)* *(i)* Show that work done by Coriolis force is always zero.

(ii) What will be the direction of the Coriolis force in the northern and the southern hemispheres?

(b) A cylindrical vessel containing liquid is rotating with a constant angular velocity ω about its own axis. Prove that the surface of the rotating liquid is parabola.

(c) A particle moves along the curve

$$\vec{r} = (t^3 - 4t)\hat{i} + (t^2 + 4t)\hat{j} + (8t^2 - 3t^3)\hat{k}$$

where t is the time. Find the magnitude of the tangential and normal components of its acceleration when $t = 2$. 4+4+4

GROUP—C

(General Properties of Matter)

8. *(a)* Prove that the axial modulus of elasticity is related to other elastic constants by

$$\chi = K + \frac{4}{3}\eta$$

where the symbols have their usual meanings.

(b) Define flexural rigidity and internal bending moment of a beam. How are they related to each other?

(c) Find an expression for the electric charge q required to expand a soap bubble to twice its radius, say from r to $2r$, in terms of the atmospheric pressure P and surface tension S. 4+4+4

9. *(a)* Derive Poiseuille's formula for the steady flow of a incompressible viscous liquid through a horizontal capillary tube of uniform cross-section. What are the chief corrections to be applied to the formula?

(b) A capillary tube of radius a and length l is fitted horizontally at the bottom of a cylindrical flask of cross-section A. Initially, there is water in the flask up to a height h_1. What time would be required for the height to reduce to h_2, if η be the coefficient of viscosity of water?

(c) Calculate the torque required to produce a unit twist in a wire of length l and radius a. (3+2)+3+4

★★★

B I (Three Year H)
Under 1+1+1 System

2012

PHYSICS (Honours)

SECOND PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* Two sinusoidal waves

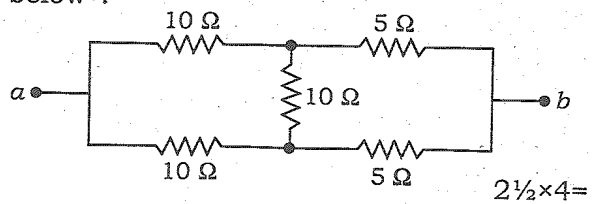
$$y_1 = 0\cdot03\sin(7t-10x)$$
and $$y_2 = 0\cdot03\sin(5t-8x)$$

were superimposed. Calculate the group velocity.

(b) Three charges $(+q, +q, +2q)$ are placed at the corners of an equatorial triangle of side L. What is the force on $2q$?

(c) Show that the ratio of the speed of sound in an ideal gas to the average speed of the molecules is $\sqrt{\frac{\gamma\pi}{8}}$, where $\gamma = C_p / C_v$.

(d) Find the equivalent resistance between the points a and b of the circuit shown below :



2½×4=10

GROUP—A

(Heat)

2. (a) Obtain Maxwell's expression for mean free path, $\lambda = \frac{1}{\sqrt{2}\pi\sigma^2 n}$, where σ is the molecular diameter and n is the number of molecules per unit volume on the basis of kinetic theory of gases.

(b) The mean free path of molecules of a certain gas at pressure P and temperature T is 2×10^{-5} cm. Deduce the mean free path under the following conditions :

(i) Pressure $P\times10^{-6}$, temperature T

(ii) Pressure $P/2$, temperature $2T$

(c) If the mean free path of the molecules of a certain gas is 10^{-6} cm and the mean speed is 500 m/sec, estimate the average number of collisions made by a molecule in a second. 6+3+3=12

(Continued)

3. (a) When steam is passed through a cylindrical tube of length l having internal and external radii a and b respectively, prove that the rate of outward flow of heat is given by

$$Q = \frac{2\pi kl(\theta_1 - \theta_2)}{\ln(b/a)}$$

where θ_1 and θ_2 are steady temperatures of inner and outer surfaces respectively.

(b) State virial theorem of Clausius. Use it to obtain ideal gas equation.

(c) What is Boyle temperature? Derive the expression for Boyle temperature from van der Waals' equation. 4+4+4=12

4. (a) State and deduce Wiedemann-Franz law relating thermal and electrical conductivities.

(b) Prove that diffuse radiation exerts pressure on the walls of the container equal to 1/3 of its total energy.

(c) A pond is covered with ice 20 cm thick and the temperature of the air is –20 °C. How long will it take for the thickness to double? Given that, $K = 0\cdot004$ CGS unit, $\rho = 0\cdot92$ gm/cc, $L = 80$ cal/gm. 4+4+4=12

(Turn Over)

GROUP—B

(Sound)

5. *(a)* A uniform flexible string of length L is stretched between its ends. The string is plucked with an amplitude h at a distance $L/3$ from one end and then released. Investigate the subsequent motion of the string. Discuss Young's law for missing harmonics.

(b) Show that the intensity of the wave at a point is given by $I = \frac{P_{rms}^2}{\rho V}$, where P_{rms} is the root-mean-square value of the excess pressure. (6+2)+4=12

6. *(a)* Set up the differential equation of motion of a simple harmonic oscillator subjected to a damping force and an external simple harmonic force. Obtain the expressions for the amplitude and the phase angle of the displacement in the steady state.

(b) Show that at the steady state of forced vibration, the power supplied by the forcing system is equal to the rate of work done by the dissipative force.

(c) Two trains approach each other in an adjacent parallel track, the engine of one of them sounding continuously its whistle of frequency 500 Hz. Find the drop of frequency of the sound heard by a passenger in the other train as the whistling engine crosses him. The velocity of each train is 75 km/hr and the velocity of sound in air is 340 m/sec. (2+3+1)+3+3=12

GROUP—C

(Electricity—I)

7. *(a)* Derive an expression for Gauss' law in presence of dielectric. Prove that divergence of displacement vector is equal to the density of free charge $\vec{\nabla} \cdot \vec{D} = \rho_{free}$.

(b) Derive the relation for the energy of an electric field due to a continuous charge distribution and show that electric energy per unit volume in a dielectric is $\frac{1}{2}\vec{D} \cdot \vec{E}$, where the symbols have their usual meanings.

(c) Prove that $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$.

(d) How does a material get polarized? Define polarization. (2+2)+3+2+3=12

8. *(a)* What is electric dipole? Show that the field due to a dipole of moment $\vec{P}$ and a distance $\vec{r}$ is given by

$$\vec{E}(r) = \frac{1}{4\pi\varepsilon_0}\left[\frac{3(\vec{P}\cdot\vec{r})\vec{r}}{r^5} - \frac{\vec{P}}{r^3}\right]$$

(b) State and explain Kirchhoff's laws in current electricity. Obtain the expression for current through the galvanometer in an unbalanced Wheatstone bridge. (1+5)+(2+4)=12

9. *(a)* Use the method of image to find the potential due to a point charge in front of a spherical conductor. Why is the method so named?

(b) Two isotropic dielectrics meet on $z=0$ plane. For $z \geq 0$, $\varepsilon_{r_1} = 4$ and for $z \leq 0$, $\varepsilon_{r_2} = 3$. A uniform electric field $\vec{E}_1 = 5\hat{i} - 2\hat{j} + 3\hat{k}$ exists for $z \geq 0$. Find $\vec{E}_2$ for $z \leq 0$.

(c) Obtain an expression for the capacitance of a parallel-plate capacitor where the space between them is filled with a composite dielectric media.

(d) Show that the energy of a spherical charge distribution of uniform charge density is given by

$$U = \frac{3}{5}\frac{Q^2}{4\pi\varepsilon_0 a}$$

where Q is the total charge and a the radius of distribution. 3+3+3+3=12

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B I (Three Year H)
Under 1+1+1 System

2013

PHYSICS (Honours)

FIRST PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* For any scalar function ϕ and vector function $\vec{A}$, prove that

$$\vec{\nabla}\cdot(\phi\vec{A}) = (\vec{\nabla}\phi)\cdot\vec{A} + \phi(\vec{\nabla}\cdot\vec{A})$$

(b) The equation of the orbit of a particle of mass m, moving under the action of a central force field about a fixed centre is $r = \frac{1}{2\theta}$. Find the force law.

(c) If A is a Hermitian matrix, then show that $B^{\dagger}AB$ is Hermitian for every matrix B.

(d) Why is it difficult to bend a hollow cylinder than a solid cylinder of same material, length and mass? 2+3+2+3=10

GROUP—A

(Mathematical Methods)

2. *(a)* Show that $\oint_S \vec{r} \cdot d\vec{S} = 3V$, where V is the volume enclosed by the closed surface S.

(b) Consider the following transformation equations :

$$x' = x\cos\theta + y\sin\theta$$
$$y' = -x\sin\theta + y\cos\theta$$
$$z' = z$$

(i) Write the transformation matrix $[A]$.

(ii) Show that

$$[A(\theta_1)] \times [A(\theta_2)] = [A(\theta_1 + \theta_2)]$$

(iii) Check whether $[A(\theta)]$ is orthogonal or not.

(iv) What are the eigenvalues of $[A(\theta)]$?

(c) Verify divergence theorem for a vector

$$\vec{A} = \frac{\vec{r}}{r}$$

bounded by a region of a sphere of radius R with its centre at the origin, where $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. 2+(1+2+2+2)+3=12

3. *(a)* Show that the force $\vec{F}$ is given by

$$\vec{F} = \hat{i}yz(1-2xyz) + \hat{j}zx(1-2xyz) + \hat{k}xy(1-2xyz)$$

is conservative. Hence determine the potential function from which this force is derived.

(b) Obtain the expression for the Laplacian operator ∇^2 in spherical polar co-ordinate (r, θ, ϕ) system.

(c) Show that the mean of Gaussian distribution

$$\phi(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad \text{for } -\infty < x < \infty$$

is μ. 4+4+4=12

4. *(a)* If

$$f(x) = x \quad \text{for} \quad 0 < x < \pi/2$$
$$= \pi - x \quad \text{for} \quad \pi/2 < x < \pi$$

express the function in terms of a sine and a cosine series. Hence show that

$$\frac{\pi^2}{8} = 1 - \frac{1}{3^2} + \frac{1}{5^2} - \frac{1}{7^2} + \cdots$$

(b) What are Dirichlet conditions?

(c) Use the power series solution method to solve the Legendre differential equation

$$(1-x^2)\frac{d^2y}{dx^2} + 2x\frac{dy}{dx} + \lambda y = 0$$

(4+1)+2+5=12

GROUP—B

(Classical Mechanics—I)

5. *(a)* A body of mass m is moving under the influence of an inverse square attractive central force. Show that the speed of the particle in the above force field is given by

$$v^2 = \frac{k}{m}\left(\frac{2}{r} - \frac{1}{a}\right)$$

where k and a are constants.

(b) Find the centre of mass of a semicircular uniform lamina of radius r.

(c) A satellite of mass 100 kg moves in an elliptical orbit around the earth such that its perigee and apogee are 300 km and 4300 km respectively, above the earth's surface. Find the equation of the orbit. Mass of the earth $= 6\times10^{24}$ kg, and mean radius of the earth = 5700 km. 5+3+4=12

6. *(a)* Show that the angular momentum of a system of particles is given as

$$\vec{L} = \vec{L}_{CM} + \vec{R}\times\vec{p}$$

where $\vec{L}_{CM}$ is the angular momentum of the system about the centre of mass, $\vec{R}$ is the position vector of the centre of man about the origin and $\vec{p}$ is the total linear momentum of the system of particles.

(b) Prove that the velocity of a rocket at any time t is given by

$$v = -gt + v_0 \ln\left(\frac{M_0}{M_0 - \alpha t}\right)$$

where M_0 is the mass of the rocket at time $t=0$, v_0 is the velocity of the ejected gas relative to the rocket and $\alpha = -\frac{dM}{dt}$.

(c) Derive the expressions of the pseudoforces acting on a particle moving in a rotating frame and explain the different terms appearing in it. 4+4+4=12

7. *(a)* Find the expression for the moment of inertia of a solid cylinder about an axis perpendicular to its length and passing through its centre.

(b) What is ellipsoid of inertia of a rigid body? What is its physical significance? Under what condition the ellipsoid becomes a sphere?

(c) A sphere of mass M and radius R is constituted by bringing the particles which are initially infinetely separated. Show that the total work done in this process is $W = -\frac{3}{5}\frac{GM^2}{R}$. 4+4+4=12

GROUP—C

(General Properties of Matter)

8. *(a)* A uniform beam of length l and weight W_0 is clamped at one end on a vertical wall. If the free end is loaded with a weight W, find the expression for the depression of the free end in terms of the Young's modulus of the material and the moment of inertia of the beam.

(b) Find the ratio of depression at the free end of a cantilever with rectangular cross-section of breadth b which equals twice its depth d, when—

(i) d is vertical;

(ii) b is vertical.

(c) Show that the depression of a cantilever at any point P due to a load at Q is the same as that at Q when the load is at P.

5+4+3=12

9. *(a)* Write down the differential equation for a ball falling through a viscous medium. Solve it and estimate the distance within which the ball will attain its terminal velocity.

(Continued)

(b) Two soap bubbles coalesce to form a bigger bubble. If V be the change in volume and S be the change in surface area, then show that

$$3PV + 4ST = 0$$

where, P is the external pressure and T is the surface tension.

(c) With what terminal velocity will an air bubble of 1 mm diameter rise in a liquid of viscosity 0·015 poise and density 0·90 g/cm^3?

(d) Three capillaries of lengths $8l$, $0{\cdot}2l$ and $2l$, and of radii r, $0{\cdot}2r$ and $0{\cdot}5r$ respectively, are connected in series. If the total pressure across the system is P, calculate the pressure across the shortest capillary tube. (1+4)+3+2+2=12

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B I (Three Year H)
Under 1+1+1 System

2013

PHYSICS (Honours)

SECOND PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* The temperature of a body falls from 30 °C to 20 °C in 5 minutes. The air temperature is 13 °C. Find the temperature of the body after another 5 minutes.

(b) A uniformly stretched string of length 1 m and mass 1 g vibrates in three segments at a frequency of 600 Hz. Find the tension in the string.

(c) Explain 'sharpness of resonance' and 'quality factor'.

(d) Find the dimension of the quantity CR when C is the capacitance and R is the electrical resistance of a conductor.

3+2+3+2=10

GROUP—A

(Heat)

2. *(a)* What do you mean by 'degrees of freedom' of a dynamical system? State the law of equipartition of energy. How can the Dulong and Petit's law on specific heat of solids be explained with the help of equipartition theory?

(b) Derive Einstein's equation for the Brownian motion of suspended particles in a fluid.

(c) In an experiment on Brownian motion, the r.m.s. displacement in the horizontal direction of a minute spherical particle suspended in water was found to be $1{\cdot}1\times10^{-3}$ cm over a 30 s interval at 27 °C when the viscosity of water is 10^{-2} c.g.s. unit. If the gas constant $R = 8{\cdot}32\times10^{7}$ erg/K/mole and the Avogadro number $N = 6{\cdot}02\times10^{23}$, calculate the radius of the particle.

(1+1+2)+5+3=12

3. *(a)* Let λdt be the probability of a gas molecule making a collision in the time interval dt. Find—

(i) the probability that a molecule experiences no collision during a time interval t;

(ii) the mean time interval between successive collisions.

(b) Define 'Boyle temperature' and 'critical temperature' of a gas. How are these related to a van der Waals gas?

(c) Find the values of critical constants for a non-ideal gas from the equation of state

$$P = \frac{RT}{(V-b)}e^{-\frac{a}{RTV}}$$

(2+2)+(2+2)+4=12

4. *(a)* For an ideal gas, show that the thermal conductivity $K = \eta C_V$, where η is the co-efficient of viscosity of the gas and C_V is its specific heat at constant volume.

(b) Three slabs of thicknesses x_1, x_2 and x_3 and made of materials of thermal conductivities k_1, k_2 and k_3 respectively, are placed in contact with each other in the order 1, 2 and 3. Show that in the steady state the combination behaves as a single material of conductivity k given by

$$\frac{x_1+x_2+x_3}{k} = \frac{x_1}{k_1}+\frac{x_2}{k_2}+\frac{x_3}{k_3}$$

(c) Write down Stefan-Boltzmann law of radiation and obtain the law from Planck's law of radiation. 5+3+(1+3)=12

GROUP—B

(Sound)

5. (a) A particle is simultaneously subjected to two SHMs at right angles to each other. Their frequencies are in the ratio 1 : 3. Obtain the locus of that particle when the SHMs are in phase difference 0° and 90°.

(b) If ω_1 and ω_2 are the half-power frequencies and ω_0 is the resonance frequency of a particle under forced vibration, then show that $\omega_0^2 = \omega_1\omega_2$.

(c) The equations of motion of two coupled oscillators are

$\ddot{q}_1 + \sqrt{2}q_2 + 4q_1 = 0$ and $\ddot{q}_2 + \sqrt{2}q_1 + 5q_2 = 0$

Find the normal frequencies and the ratios of the amplitude of the normal modes.

(d) Mention two important applications of ultrasonic waves. 4+3+3+2=12

6. (a) A uniform stretched string, fixed at the two ends is struck over a small region at a distance a from one end. Assume that the struck region starts motion with initial velocity u. Obtain the general expression for the displacement of the string $y(x, t)$. Prove that the harmonics which have a node at the struck point will be absent in the resultant vibration. Explain why the sound produced by a struck string is more melodious than that produced by plucking.

(b) Deduce Sabine's formula for reverberation time. (5+2+1)+4=12

GROUP—C

(Electricity—I)

7. (a) Define susceptibility, permittivity and dielectric constant.

(b) The dielectric constant of a monatomic gas at NTP is 1·000538. Calculate the dipole moment induced in each atom when the gas is placed in an external electric field of 30 kV/m.

(c) A dielectric sphere of radius a and permittivity ε_1 is placed in a uniform electric field $\vec{E}_0$ in a medium of permittivity ε_2. Using Laplace's equation, show that the polarization induced in the sphere is given by

$$\vec{P} = 3\varepsilon_2 \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + 2\varepsilon_2} \vec{E}_0$$ 3+3+6=12

8. (a) Consider a dielectric sphere of radius a with uniform polarization $\vec{P} = p\vec{k}$. Find the electric potential at any external point.

(b) Explain the working principle of Kelvin's double bridge with necessary circuit diagram and theory.

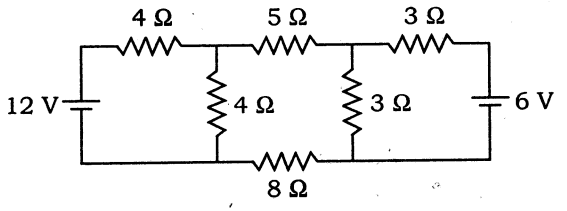
(c) Show that the Kirchhoff's current law is consistent with the principle of charge conservation and the voltage law is consistent with the principle of conservation of energy. 4+4+4=12

9. (a) Deduce Laplace's equation from Coulomb's law. Use Laplace's equation to find out the capacitance of a spherical capacitor where the outer shell is grounded and the inner sphere is charged.

(Continued)

(b) If ϕ_1 and ϕ_2 are two solutions of Laplace's equation, show that $C_1\phi_1 + C_2\phi_2$ is also a solution, where C_1 and C_2 are constants.

(c) Consider the following circuit diagram :



Find out the current through the resistor 5Ω. 4+4+4=12

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B II (Three Year H)
Under 1+1+1 System

2013

PHYSICS (Honours)

FOURTH PAPER

(Revised New Syllabus)

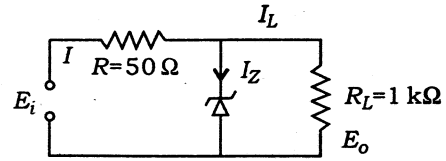
Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* A plano-convex lens ($\mu = 3/2$) is of thickness 3 cm. If the radius of curvature of curved surface be 8 cm, calculate the minimum distance between an object and its real image. 3

(b) Over what range of input voltage will the Zener circuit shown in the figure below maintain 10 volt across 1 kΩ, assuming the series resistance $R = 50\ \Omega$ and Zener current = 100 mA? 3



(c) Explain why the diffraction of sound is more easily observable than the diffraction of light. 2

(d) Draw a circuit diagram of AND gate using transistor only. 2

GROUP—A

(Geometrical Optics)

2. (a) Describe the condition of Huygens' eyepiece and locate its cardinal points. 4

(b) Find the condition for minimum spherical aberration in a lens system. 3

(c) Two thin lenses (convex) of focal lengths f_1 and f_2 are coaxially separated by a distance d apart. Show that the focal length of the equivalent lens is given by

$$f = \frac{f_1 f_2}{f_1 + f_2 - d}$$ 3

(d) Calculate the values of Cauchy's constants A and B for dispersion through crown glass. Given $\mu_c = 1{\cdot}541$; $\lambda_c = 6563$ Å; $\mu_F = 1{\cdot}524$ and $\lambda_F = 4862$ Å. 2

3. (a) State and explain Fermat's principle. 3

(b) Apply Fermat's principle to prove the laws of refraction in case of a plane surface. 3

(c) Explain how two narrow-angled prisms of different dispersive powers may combine to produce dispersion without deviation. 3

(d) A compound microscope has an objective and eyepiece of focal lengths 1 cm and 5 cm respectively. An object is placed at a distance of 11 mm from the objective and the final image is seen at a distance of 25 cm from the eyepiece. Calculate the magnification and the separation of lenses. 3

GROUP—B

(Physical Optics—I)

4. (a) Apply Huygens' principle to deduce the laws of refraction of plane waves at plane surface. Hence on the basis of wave theory, explain the phenomena of total internal reflection and obtain the value of critical angle. 3+3

(b) What is coherent source of light? How are they realised in practise? 1+2

(c) When a film of transparent material of refractive index 1·2 is put behind one of the slits of a two-slit Young's experiment, the zeroth order fringe moves to the position previously occupied by the 4th order bright fringe. Given that the wavelength λ of the light used 5000 Å. Find the thickness of the film. 3

5. (a) State the conditions to be fulfilled for the production of interference fringes. 2

(b) With a neat diagram, explain the formation of fringes by Lloyd's mirror and explain why the central fringe is dark. 4+1

(c) In a Lloyd's mirror experiment, calculate the ratio of the intensities of the interference maxima and minima if the mirror reflects only 75% of light incident on it. Calculate the visibility of the fringes. 3

(d) If in a Newton's rings experiment, the air in the interspace is replaced by a liquid of refractive index 1·5. In what proportion would the diameter of the rings change? 2

6. (a) Find the intensity expression for the Fraunhofer diffraction pattern of a single slit. Deduce the conditions for maxima and minima. 5

(b) A zone plate has radius of the first ring 0·06 cm. If plane waves of $\lambda = 6000$ Å fall on the plate, where should the screen be placed so that light is focussed to a bright spot? 3

(c) State Rayleigh's criterion of limit of resolution of an optical instrument. Determine the resolving power of a telescope. 1+3

7. (a) What is interferometer? Explain the formation of fringe in a Fabry-Perot interferometer. 1+3

(b) Explain how Fabry-Perot interferometer can be used for the study of hyperfine structure. 3

(c) A thin transparent plate of refractive index 1·5 is introduced in one arm of Michelson interferometer. It causes 12 fringe shift. Find the thickness of the plate, take the wavelength of the light as 600 nm. 3

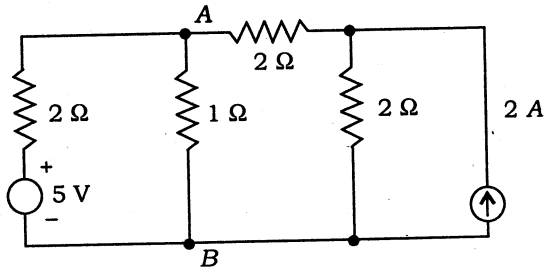
(d) Show that the interference patterns in the reflected and transmitted lights in thin film are complementary to each other. 2

GROUP—C

(Electronics—I)

8. *(a)* Derive the condition for transfer of maximum power from a source to a load. 3

(b) Show that the current through 1 Ω resistor is 2 amp. 4



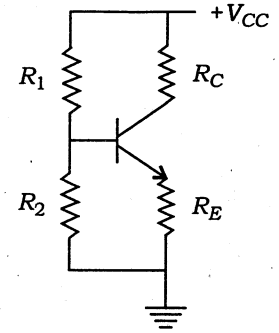
(c) Sketch the variation of electric field and potential as a function of distance across the junction of an unbiased *p-n* junction. 2

(d) Obtain the expression for the barrier potential for a *p-n* junction diode. 3

9. *(a)* Explain how a transistor can be used as a current source. 2

(*Continued*)

(b) What do you mean by biasing of a transistor? For the circuit shown in the figure below, given that $V_{CC} = 20$ V, $R_C = 5$ kΩ, $R_E = 1$ kΩ, $R_1 = 20$ kΩ and $R_2 = 3$ kΩ. The transistor parameters are $\beta = 100$, $V_{BE} = 0{\cdot}7$ V. Assume $I_{CO} << I_C$. Determine the *Q*-point. 1+4



(c) Use 2's complement method to perform the subtraction 48 – 24. 2

(d) Implement the logic circuit of the Boolean function $Y = \overline{A\bar{B} + \bar{A}B}$ using NOR gates only. 3

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B II (Three Year H)
Under 1+1+1 System

2013

PHYSICS (Honours)

FIFTH PAPER

(Revised New Syllabus)

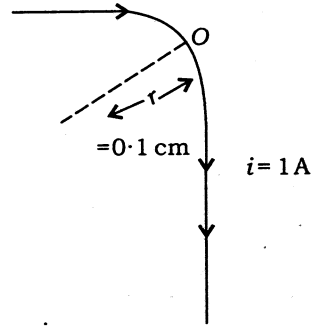
Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

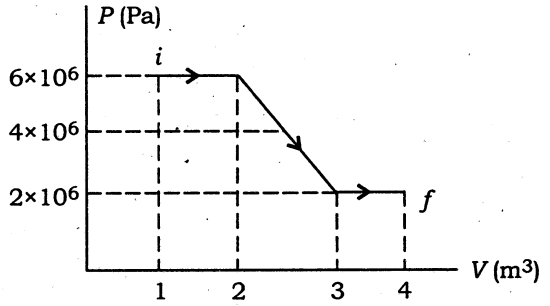
Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* Entropy of the universe is ever-increasing. Explain. 2

(b) A long wire carrying a current $i = 1$ A is bent at its midpoint around one quarter of circle of radius $r = 0 \cdot 1$ cm, the straight parts of the wire being perpendicular to each other. Find the magnetic field at the point *O*. 3



(c) Determine the work done on a fluid that expands from i to f as indicated in the figure below. How much work is done on the fluid if it is compressed from f to i along the same path? 3



(d) Why is capacitance used in an AC bridge for measurement of inductance? 2

GROUP—A

(Thermodynamics)

2. (a) State the physical significance and limitations of the first law of thermodynamics. 2

(b) Show that for a real van der Waals' gas

$$C_P - C_V = R\left\{1 + \frac{2a}{RTV^3}(V-b)^2\right\}$$ 4

(c) Prove that the adiabatic elasticity of a gas is γ times the isothermal elasticity. 3

(d) Explain what is meant by internal energy of a system. Is it a state function? 2+1=3

3. (a) A Carnot engine operates between T_1 and T_2 with a gas as working substance whose equation of state is given by $P(V-b) = RT$. Work out the expression for the heat absorbed and the work done in each part of the cycle and show that the efficiency of the cycle is

$$\left(1 - \frac{T_2}{T_1}\right)$$ 6

(b) Show that the entropy is a measure of the so-called unavailable energy. 2

(c) Using Clausius theorem, show that for any process

$$S_f - S_i \geq \int_i^f \frac{dQ}{T}$$

where the symbols have their usual meanings. 4

4. (a) What is Gibbs potential? How is it related to the first-order phase transition? Establish Clapeyron's equation for a system that can have a first-order phase transition. 1+2+2=5

(b) Prove the following relations : 2+2=4

(i) $\left(\frac{\partial C_P}{\partial P}\right)_T = -T\left(\frac{\partial^2 V}{\partial T^2}\right)_P$

(ii) $\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$

(c) Calculate the increase in entropy when 10 gm of ice at −20 °C is converted into steam at 100 °C. Specific heat of ice = 0·5 cal / gm, latent heat of ice = 80 cal/gm, latent heat of steam = 540 cal/gm. 3

5. (a) What is the significance of Joule-Thomson coefficient? Prove that Joule-Thomson effect is the result from the deviation of Joule's law and Boyle's law. 1+3=4

(b) Draw *P-V* diagram for Otto cycle. Using *P-V* diagram, determine the efficiency. 1+3=4

(c) A certain liquid boils at 400 K at a pressure of 80 cm of Hg. It has a latent heat of vaporisation of 1000 cal/mole. At what temperature will it boil if the pressure is raised to 81 cm of Hg? 4

GROUP—B

(Electricity—II)

6. (a) State Biot-Savart law for the magnetic field due to a current element. A wire is shaped to form a regular hexagonal of side *a*. If a current *i* flows through the wire, calculate the magnetic field at the centre of the hexagon. 1+3=4

(b) Calculate the force between two parallel circular coaxial coils of nearly the same size and carrying currents, being separated by a small distance in free space. For what distance between the coils is this force a maximum? 4

(c) Find the magnetic vector potential of an infinite solenoid with *n* turns per unit length, radius *R* and current *I*. 4

7. (a) How does a ballistic galvanometer defer from a deadbeat galvanometer? Work out the theory of working of a suspended coil-type ballistic galvanometer. Explain the meaning of external critical damping resistance. 1+6+1=8

(b) Show that when a ferromagnetic material undergoes a cycle of magnetisation, the energy dissipated as heat per cycle is proportional to the area enclosed by B-H loop. 4

8. *(a)* A d.c. source of e.m.f. is suddenly applied to a circuit consisting of a resistor R, a capacitor C and an inductor L in series. Calculate the frequency of oscillating growth of the charge. 4

(b) How does Peltier heating differ from Joule heating? "The Thompson co-efficient of a metal is negative." What do you mean by it?

2+2=4

(c) The charge on a lossless capacitor of value 1 μF falls to 50% of its initial value in 5 minutes when the two plates of the capacitor are joined by an unknown resistance. What is the value of the resistance? 2

(d) In a region, the electric field is given by

$$\vec{E} = \hat{j}E_0 \cos(\omega t - kx)$$

Find the corresponding magnetic field. 2

9. *(a)* What do you mean by resonance? In a series L-C-R circuit, find the resonance frequency. A series resonance circuit is called an acceptor circuit. Explain.

1+3+1=5

(b) Two refrigerators are supplied from the same a.c. main. The first one draws a current of 3 A at a power factor 0·6 and the second one draws a current of 2 A at a power factor of 0·7. Assuming that the current lags behind the e.m.f. in both the cases, calculate the total current drawn by the two refrigerators and the corresponding power factors. 4

(c) Self-inductance of two coils are L_1 and L_2 respectively and their mutual inductance is M. Show from energy consideration that in general $M^2 \leq L_1 L_2$. 3

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B I (Three Year H)
Under 1+1+1 System

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PHYSICS (Honours)

FIRST PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* Time evolution of a vector $\vec{A}$ is given by

$$\frac{d\vec{A}}{dt} = \vec{A} \times \vec{B}$$

where $\vec{B}$ is a constant vector. Show that the magnitude of $\vec{A}$ and the angle between $\vec{A}$ and $\vec{B}$ do not change with time. 3

(b) Obtain the Fourier series of the function $f(x) = \exp(\alpha x)$ in the interval $[-\pi, \pi]$. 3

(c) The motion of a particle under the influence of a central force is described by $r = a\sin\theta$. Find an expression for the force. 2

(d) Bulk modulus of water is $2 \cdot 3 \times 10^5$ dyne/cm^2. How much pressure is needed to compress a sample of water by 0·1%? 2

GROUP—A

(Mathematical Methods)

2. (a) Locate and classify the singular points of the following equation : 2

$$(1-x^2)\frac{d^2y}{dx^2}+2x\frac{dy}{dx}+2y=0$$

(b) Prove that for Hermite polynomial, $H_n(-x)=(-1)^n H_n(x)$. 4

(c) Obtain the recurrence relation

$$(2n+1)P_n(x)=nP_{n-1}(x)+(n+1)P_{n+1}(x)$$ 4

(d) Prove that the angular momentum is a constant of motion under central force. 2

3. (a) Prove that

$$(\vec{\sigma}\cdot\vec{a})(\vec{\sigma}\cdot\vec{b})=\vec{a}\cdot\vec{b}+i\sigma\cdot(\vec{a}\times\vec{b})$$

where $\vec{a}$ and $\vec{b}$ are ordinary vectors and $\vec{\sigma}=\sigma_x\hat{i}+\sigma_y\hat{j}+\sigma_z\hat{k}$. Given

$$\sigma_x=\begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix},\ \sigma_y=\begin{bmatrix}0 & -i\\ i & 0\end{bmatrix} \text{ and } \sigma_z=\begin{bmatrix}1 & 0\\ 0 & -1\end{bmatrix}$$ 4

(b) Find the eigenvalues and eigenvectors of the matrix

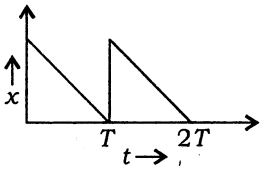
$$\begin{bmatrix}1 & 0 & 0\\ 0 & 0 & 1\\ 0 & 1 & 0\end{bmatrix}$$ 4

(c) A periodic sawtooth wave is given as

$$x=f(t)=C\left(1-\frac{t}{T}\right)$$

$$(0<t<T)$$

$$f(t)=f(t+T)$$



Expand $x=f(t)$ in Fourier series. 4

4. (a) Evaluate $\oiint \vec{r}\cdot\hat{n}\,ds$ over the unit cube, defined by $x=0$, $y=0$, $z=0$; $x=1$, $y=1$ and $z=1$. 3

(b) Write down 3-dimensional Laplace's equation in Cartesian coordinate system and solve it. 1+4=5

(c) What do you mean by 'mean' and 'standard deviation' of a distribution? Find 'mean' and 'standard deviation' of Poisson's distribution

$$p(x)=\frac{m^x e^{-m}}{x,!}$$ (½×2)+(1½×2)=4

GROUP—B

(Classical Mechanics—I)

5. *(a)* Define conservative force field. Hence, show that (*i*) $\vec{F} = -\vec{\nabla}\phi$, $\phi = \phi(x, y, z)$ and $\vec{\nabla} \times \vec{F} = 0$. 4

(b) Prove that the total kinetic energy of a system of particles is equal to the kinetic energy of the centre of mass plus the kinetic energy of the particles with respect to CM. 4

(c) A projectile is ejected with an angle 45° with horizontal direction. Find the range R, if its velocity is 1500 m/s initially. Also find the maximum height H it will rise. 2+2=4

6. *(a)* Obtain Euler's equation of motion related to the rotation of a rigid body with one point of it fixed. 4

(b) A flywheel of mass 100 kg and radius of gyration 0·5 m is rotating with a speed of 90 revolution per minute. Calculate the torque required to bring it to rest in 4 minutes. 3

(c) A cylinder rolls without slipping down a plane inclined at an angle θ to the horizontal. Find the acceleration of its centre of mass. 2½

(d) Explain the action of Coriolis force on a body freely falling towards earth. 2½

7. *(a)* Discuss briefly the principle of determination of G by Heyl's method. 3

(b) Calculate the gravitational self-energy of a homogeneous sphere of mass M. 4

(c) Show that length of semimajor axis of the elliptical orbit of a planet is given by $a = \frac{-K}{2E}$, where K is the force constant and E is the total energy of the planet. 3

(d) Consider an elastic collision between two particles of masses m_1 and m_2 in centre of mass frame (Fig. 1). Show that after collision m_1 and m_2 move off in opposite directions with equal linear momentum and all values of θ are permissible (Fig 2). 2

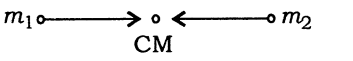


Fig. : 1

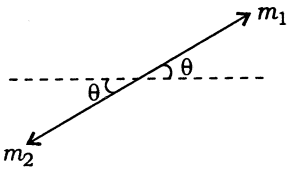


Fig. : 2

GROUP—C

(General Properties of Matter)

8. *(a)* Derive an expression for the height h through which a liquid of surface tension T will rise in a capillary tube of radius r. Explain clearly from where the energy comes, when the liquid rises against gravity in the capillary tube. 3+2=5

(b) If two capillaries of radii r_1 and r_2 and lengths l_1 and l_2 are joined in series, derive an expression for the rate of flow of the liquid through the arrangement using Poiseuille's formula. 4

(c) Establish the relation, $E = S - T\frac{dS}{dT}$, where the symbols carry their usual meaning. 3

9. *(a)* Show that the couple per unit twist of a rod of length l, modulus of rigidity η, radius of cross-section r is given by

$$\tau = \frac{\pi \eta r^4}{2l}$$ 4

(b) State Newton's law regarding viscosity and define coefficient of viscosity. 3

(c) Calculate the excess pressure inside a soap bubble of radius 3×10^{-3} m. Surface tension of soap solution is 20×10^{-3} N/m. Also calculate the surface energy. 3

(d) Find the terminal velocity of an iron ball of radius 3 mm, density 8 gm/cm^3, in a liquid of density 1·8 gm/cm^3 and viscosity at temperature 35 °C is $\eta = 2\cdot3$ poise. 2

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B I (Three Year H)
Under 1+1+1 System

2014

PHYSICS (Honours)

SECOND PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

1. *(a)* Three charges $-q$, $-q$ and $+2q$ are placed at the vertices of an equilateral triangle. Find the dipole moment of the charge distribution. 2

(b) Evaluate the fractional change in the number of He atoms in the velocity range 999·5 m/s to 1000·5 m/s, when a given mass of the gas is heated from 200 K to 1000 K at constant volume. (Given : $K = 1{\cdot}38 \times 10^{-23}$ SI units and mass of He atoms $= 6 \times 10^{-27}$ kg) 3

(c) A well-lagged wire of length L and cross-sectional area A has its ends maintained at temperatures T_1 and T_2. The thermal conductivity of the wire is given by $K = B + CT$, where T is the temperature, and B and C are constants. What is the rate of flow of heat along the wire? 3

(d) Two mutually perpendicular oscillations are represented by

$$x(t) = A_1 \sin \omega_1 t$$
$$y(t) = A_2 \sin(\omega_2 t + \phi)$$

If $\omega_2 = 2\omega_1$, sketch the Lissajous figure for the motion, when $\phi = -r$. 2

GROUP—A

(Heat)

2. (a) Find out the normalization constant in Maxwell's velocity distribution of ideal gas molecules. 3

(b) What is the energy distribution corresponding to Maxwell's velocity distribution? 3

(c) From this distribution, determine the root-mean-square speed of the gas molecules. 2

(d) Determine the number of molecules striking unit area of the gas container per unit time, keeping in mind that molecular collisions are possible. 4

3. (a) Discuss the limitations of Wien's law and Rayleigh-Jeans law in explaining black-body radiation spectral distribution. (Plot the black-body radiation distribution curves for three different temperatures.) 4

(b) Compare the heights of the peaks of experimental black-body radiation distribution curves at two different temperatures T_1 and T_2. 3

(c) Assuming the earth to be a spherical blackbody moving in a circular orbit of radius $1{\cdot}5 \times 10^8$ km and the sun as a sphere of radius 7×10^5 km radiating as a blackbody at a temperature of 6×10^3 K, find out the equilibrium temperature of the sun. Assume the radius of the earth is small compared to the radius of its orbit. 3

(d) Show that Newton's law of cooling follows as a corollary from Stefan-Boltzmann law. 2

4. *(a)* Show that a perfectly rigid body has got three degrees of freedom. 2

(b) Derive the relation $\eta = \frac{1}{4} mn \lambda \bar{C}$, where η is the coefficient of viscosity of a gas, m is mass of a gas molecule, n is molecular density, λ mean free path of gas molecules and $\bar{C}$, the mean molecular speed. 5

(c) Estimate the number of molecules and the number of moles per unit volume of air at atmospheric pressure and 0 °C. 2

(d) Discuss the physical origin of the parameters a and b occurring in the van der Waals' equation of state of a real gas. 3

GROUP—B

(Sound)

5. *(a)* Consider a simple harmonic oscillator that is subjected to a damping force and an external force given by $F(t) = F_0 \cos \omega t$, where $\omega \neq \omega_0$, ω_0 being the natural frequency of the oscillator. Find the steady-state solution of the differential equation, and hence find an expression for amplitude and phase angle. 2+4

(b) Distinguish between amplitude resonance and velocity resonance. 3

(c) Show that the group velocity v_g of a wave group in a dispersive medium with refractive index n is given by

$$v_g = \frac{u}{n + \omega \frac{dn}{d\omega}}$$

where u is the phase velocity and ω, the angular frequency of the wave. 3

6. *(a)* Consider the wave equation

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 y}{\partial t^2}$$

Show that $y(t) = f_1(x - vt) + f_2(x + vt)$ is a general solution of the wave equation. 4

(b) Prove that the velocity of soundwaves in a solid bar is given by $\sqrt{Y/\rho}$, where Y is the Young's modulus and ρ is the density of the material of the bar, mentioning clearly the assumptions made in the derivation. 6

(c) State Young-Helmholtz law of a vibrating string. 2

GROUP—C

(Electricity—I)

7. *(a)* Show that there should be no electric field inside a conductor. Hence, show that any excess charge given to a conductor, resides only on its surface. 2+2

(b) The distance between the plates of a parallel-plate air capacitor is d. A dielectric slab of thickness x is introduced in the air gap. Show that the capacitance of the capacitor will be doubled if the dielectric constant of the slab is given by $K = \frac{2x}{2x-d}$. 4

(c) Prove that the field inside a spherical cavity in an isotropic dielectric is given by $E_{in} = E + \frac{P}{3\varepsilon_0}$, where the symbols have their usual meanings. 4

8. *(a)* Consider a closed region in space. Show that Laplace's equation has a unique solution in the region if potential is specified at all points on the boundary of the region. 4

(*Continued*)

(b) Consider a grounded conducting plane of infinite extent. A point charge $(+q)$ is placed at a distance d above the plane. Using the method of images, find the potential at any point in the region above the plane. Also find the total charge induced on the plane. 3+3

(c) Find out whether the field $\vec{E} = k(xy\,\hat{i} + 2yz\,\hat{j} + 3xz\,\hat{k})$ is a possible electrostatic field. 2

9. *(a)* Calculate the electric field in free space due to a dipole. Determine the potential energy and torque on a dipole in a uniform electric field. Find also the interaction energy when one dipole interacts with another dipole. 3+2+3

(b) Find an expression for current flowing through the galvanometer in an unbalanced Wheatstone bridge. 4

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B II (Three Year H)
Under 1+1+1 System

2014

PHYSICS (Honours)

FOURTH PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **one** from each Group.

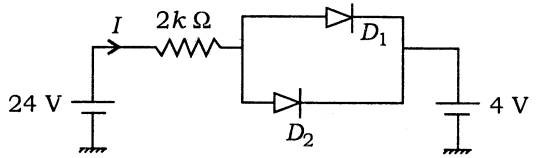
1. *(a)* A parallel incident beam falls on a solid glass sphere at normal incidence. Locate the image in terms of the index of refraction n and sphere radius r. 2

(b) How will you test the flatness of a surface by interference? 2

(c) How do the ray fringes produced by Michelson's interferometer differ with that produced by Newton's rings? 2

(d) At a given temperature, prove that an intrinsic semiconductor has a minimum conductivity σ_m is given by $\sigma_m = 2en_i (\mu_n \mu_p)^{1/2}$, where the symbols have their usual meaning. 2

(e) Determine the current I in the circuit shown below. Assume diodes to be of S_i and forward resistance of diodes to be zero : 2



GROUP—A

(Geometrical Optics)

2. (a) Explain the term aplanatic foci of a reflecting or a refracting surface. Discuss how the principle of aplanatic foci is used in the construction of high power microscope objective. 1+3

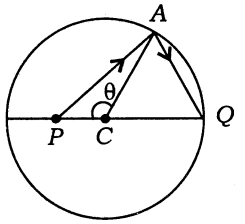
(b) Define cardinal points of a thick lens. 3

(c) Two convex lenses of focal lengths 10 cm and 20 cm are placed 5 cm apart in air. Find the cardinal points of the system. 3

(d) Why is Ramsden eyepiece called a positive eyepiece and Huygens eyepiece a negative eyepiece? 2

3. (a) What do you mean by optical and geometrical path lengths between two points? 2

(b) P is a point source at a distance $0 \cdot 6\, r$ from the centre C of a spherical reflecting surface of radius r shown in the figure below. From the Fermat's principle, show that if a ray PA is reflected to Q, the angle θ is given by $\cos^2(\theta/2) = 2/3$: 4



(c) What do you mean by a telescopic system? Show that for a telescopic system, the lateral magnification is reciprocal of angular magnification. 1+5

GROUP—B

(Physical Optics—I)

4. (a) What is plane diffraction grating? Obtain an expression for the intensity of a beam diffracted from such a grating when monochromatic light is incident normally upon it. 1+5

(b) What are Fresnel's half-period zones? Discuss the Fresnel's diffraction at a small opaque disc illuminated by monochromatic light. 1+3

(c) What would happen on grating spectra if the distance between the rulings is made very large or very low compared to the wavelength of light? 2

5. (a) Give Stokes' treatment to explain the change of phase of light wave reflecting from a denser medium. 2

(b) What do you mean by anti-reflection coating? What should be the thickness of a non-reflecting layer to be deposited on glass surface corresponding to wavelength 6000 Å? Refractive index of the layer is 1·35. 1+2

(c) What are Newton's rings? Derive the relation for the diameter of the bright rings in case of reflected light. Hence obtain the relation between the fringe width and diameter of the rings. How do the rings differ when observed with transmitted light? 1+3+2+1

6. (a) Show that in two dimensions, the shape of the fringes in Young's experiment is hyperbolic. Why are these fringes called non-localized? 4+1

(b) Suppose that in a microscope the space between the object and objective is filled with an oil of refractive index n. Show that the limit of resolution in this case is

$$\frac{\lambda}{2n}\sin\theta$$ 3

(c) The refractive index of a prism depends upon the wavelength according to Cauchy's formula

$$n(\lambda) = A + \frac{B}{\lambda^2}$$

where A and B are constants.

(i) Find how resolving power of prism varies with wavelength.

(ii) A prism spectrometer uses a prism of base 5 cm and is of material having

$$\frac{dn}{d\lambda} = 200$$

in the range $\lambda = 500$ Å. Calculate the smallest difference of wavelength in the range resolvable by spectrometer. 2+2

7. (a) Describe the principle of operation of Michelson stellar interferometer. How can it be used to measure the angular diameter of a star? 3+3

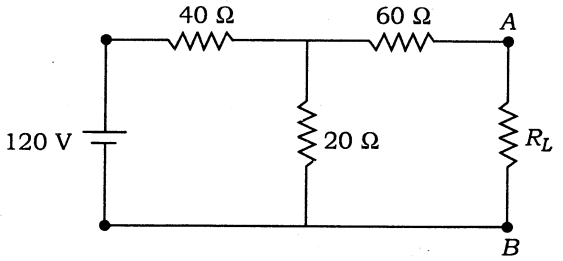
(b) A Michelson interferometer is set for the white light straight fringes. When a mica sheet of thickness 0·005 cm is put in front of the fixed mirror, then in order to bring back the coloured fringes to their original position, the movable mirror is moved by 0·0025 cm. Calculate the refractive index of mica. 2

(c) Explain with necessary theory how one can determine the refractive index of a liquid by means of Newton's rings. 4

GROUP—C

(Electronics—I)

8. (a) State and explain Thevenin's theorem and hence calculate the value of load resistance R_L to which maximum power may be transferred for the circuit shown below : 3+2



(b) Explain briefly how Zener diode maintains constant voltage across a load. 2

(Continued)

(c) A T-network uses three resistances 1·2 Ω, 2 Ω and 3 Ω. Find the corresponding resistances in an equivalent π-network. 2

(d) Explain with necessary circuit diagram, how a diode can be used as a clamper. 3

9. (a) Draw the *I-V* characteristics of SCR and explain it. 2

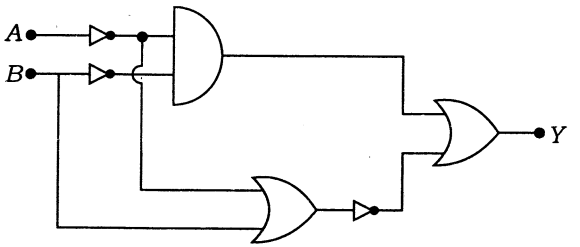
(b) Draw the small-signal low-frequency hybrid parameter equivalent circuit of a CE amplifier and derive the expression for current gain and voltage gain. 1+2+2

(c) Smplify the expression

$$ABC + \bar{A}BC + A\bar{B}C + \bar{A}\bar{B}C + \bar{A}\bar{B}\bar{C}$$

and also construct a circuit to implement above Boolean relation using minimum number of logic gates. 3

(d) Find the output logic expression from the given logic gates and then form a truth table : 2



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B II (Three Year H)
Under 1+1+1 System

2014

PHYSICS (Honours)

FIFTH PAPER

(Revised New Syllabus)

Time : 4 hours *Full Marks* : 70

The figures in the margin indicate full marks.

Answer Question No. **1** and **five** from the rest, taking at least **two** from each Group.

1. *(a)* Efficiency of a Carnot engine does not depend upon the properties of the working substance. Why? 2

(b) Explain why negative temperature on absolute scale of temperature is not possible. 2

(c) In an underdamped series *L-C-R* circuit, the time required for amplitude to fall 5% of its original value is 6 sec. Calculate the time required for the total energy to fall 50%. 3

(d) Show that $\vec{\nabla}\times\vec{E} = -\frac{\partial \vec{B}}{\partial t}$ and explain the significance of the relation. 3

GROUP—A

(Thermodynamics)

2. *(a)* What is the concept of internal energy? On what state, variable does it depend for a perfect gas? 2+1

(b) Prove that the slope at adiabatic curve through a point in a *P-V* graph is $\gamma = (C_P / C_V)$ times the slope of the isothermal curve through the same point. 3

(c) Show that for an adiabatic change in a perfect gas, PV^{γ} = constant, where γ is the ratio of specific heats at constant pressure and constant volume respectively. 4

(d) Explain why the specific heat of a gas at constant pressure is greater than that at constant volume. 2

3. *(a)* State zeroth law in thermodynamics and discuss its theoretical importance. 2

(b) Show that for an isentropic transformation

$$\left(\frac{\partial V}{\partial T}\right)_S = -\frac{C_V}{C_P - C_V}\left(\frac{\partial V}{\partial T}\right)_P$$ 3

(c) Two gases of amounts m_1 and m_2 moles of partial pressures P_1 and P_2 and constant volume specific heats C_1 and C_2 are mixed at temperature T. Find out the entropy of the mixture. State briefly the physical significance of entropy. 3+1

(d) A Carnot engine whose low temperature reservoir is at 7 °C has an efficiency of 40%. It is desired to increase the efficiency to 50%. By how many degrees should the temperature of the source be increased? 3

4. (a) What is a tripple point? Discuss the tripple point in thermodynamics. 4

(b) Show that the enthalpy

$$H = \left[\frac{\partial(G/T)}{\partial(I/T)}\right]_V$$

where G is the Gibbs energy. 4

(c) Establish the Clapeyron equation for a system which can have a first-order phase transition. 4

5. (a) State and explain Nernst heat theorem. Hence show that at the neighbourhood of absolute zero, the pressure coefficient and volume coefficient of a substance are zero. 2+3

(b) Show that in Joule-Thomson expansion, no temperature change occurs if

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

Hence, calculate the ratio of inversion temperature to critical temperature for a van der Waals' gas. 2½+2½

(c) Define Helmholtz free energy. Why is it called free energy? 1+1

GROUP—B

(Electricity—II)

6. (a) Starting from Biot-Savart law, show that $\vec{\nabla}\cdot\vec{B} = 0$. What is the physical significance of the equation $\vec{\nabla}\cdot\vec{B} = 0$? 3+2

(b) Starting from Biot-Savart law, establish Ampere's circuital law. 3

(c) Find out the magnetic field due to a long straight current-carrying conductor using Ampere's circuital law. 4

7. (a) What is magnetic vector potential? Find the magnetic vector potential at a distance r from an infinite straight wire carrying current I. Hence calculate the magnetic field. 1+3+1

(b) (i) The magnetic field is given as $\vec{B} = BK$. Find its corresponding magnetic vector potential. 1

(ii) What is the dimension of magnetic induction $\vec{B}$? 1

(c) Two solenoids, each of radius 2 cm and length 4 cm, are placed coaxially with a gap of 1 cm between them. Determine the magnetic field at the centre of the gap if a current of 2 amp flows through the two solenoids in series. Assume that each solenoid contains 40 turns per cm. 5

8. (a) A d.c. source of voltage V is suddenly applied to a circuit consisting of a resistor R and a capacitor C in series. Write down the instantaneous e.m.f. equation and hence find how the charge on the capacitor grows with time. How does the charging current vary with time? 4+1

(b) What are Peltier and Thomson co-efficients? Applying thermodynamics to a thermocouple, establish the following relation

$$\sigma_a - \sigma_b = -T\frac{d^2E}{dT^2}$$

where the symbols have their usual significances. 2+2

(c) What do you mean by thermoelectric power? 1

(d) Calculate the r.m.s. value of e.m.f. given by $E = 8\sin\omega t + 6\sin 2\omega t$ volt. 2

9. (a) Establish Faraday's law of electro-magnetic induction when a conducting loop moves with a velocity $\vec{v}$ in a non-uniform magnetic field. 4

(b) Show that the charge sensitivity of a moving-coil instrument is $\frac{T}{2\pi}$ times the current sensitivity, where T is the period of free oscillations of the coil. 2

(c) Show that the energy stored in an inductor is $\frac{1}{2}LI^2$, where I is the current through it. 2

(d) Obtain an expression for reflected impedance from the secondary of an alternating voltage transformer. 4

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