2017

PHYSICS

[Honours]

PAPER – II

Full Marks : 90

Time : 4 hours

The figures in the right hand margin indicate marks

Candidates are required to give their answers in their own words as far as practicable

Illustrate the answers wherever necessary

GROUP – A

Answer any **two** questions : 15 × 2

1. (*a*) What do you mean by Path integral of force ? Show that in a conservative force field sum of kinetic energy and potential energy of a particle at any point is constant. 1 + 3

(*b*) Define centre of mass. Show that the motion of centre of mass of a system is the same as if entire mass of the system is concentrated at that point. 1 + 2

(*c*) If the central force is inverse square attraction $\vec{F} = -\frac{k}{r^2}\hat{e}_r$ nature, then show that Laplace-Rung-Lenz vector $\vec{B} = \vec{P} \times \vec{L} - mk\hat{e}_r$ is constant of motion. 4

(*d*) Consider the motion of a rocket under an external force $\vec{F}$. Let at any instant t, the mass of the rocket be M and its velocity be $\vec{v}$ relative to a fixed co-ordinate system. Let the fuel be shot out with constant velocity $\vec{u}$ relative to the rocket in motion. Calculate $\vec{F}\,\Delta t$ and show that

$$M\frac{d\vec{v}}{dt} + \vec{u}\frac{dM}{dt} = \vec{F}$$

Find maximum burnt out velocity of the rocket in absence of external force. 4

2. (*a*) With necessary assumptions show that the number of molecules striking per unit area of a surface per unit time is $\frac{1}{4} n \bar{c}$, where n is the number density of molecules and $\bar{c}$ is the average velocity. 4

(*b*) Explain the temperature dependence of Maxwell's velocity distribution law graphically for one dimensional motion of gas particles. Define the expression of half width at half maximum of this distribution at certain temperature. 2 + 2

(*c*) State and prove Carnot's theorem regarding efficiency of heat engines. 1 + 4

(*d*) A reversible engine converts 1/6 th of the heat into work. If the temperature of the sink is reduced by 62 °C, its efficiency is doubled. Find the temperature of the source and sink. 2

3. (*a*) A point charge '*q*' is placed at a distance *f* from the centre of a grounded conducting sphere of radius *a* (*f* > *a*), Using the method of image find the density of induced surface charge (σ). Also find the ratio of $\frac{\sigma_{max}}{\sigma_{min}}$. 4 + 1

(*b*) Two similar point charges '*q*' are kept separated by a distance 2*d* in air. Now an insulated uncharged conducting sphere of radius '*a*' is placed midway between them. If *d* >> *a*, show that the introduction of the sphere reduces the force experienced by either point charge to $\left(1-\frac{24a^5}{d^5}\right)$ of its initial value. 3

(*c*) What do you mean by magnetic scalar potential? Find the expression for the magnetic scalar potential due to a circular current loop at an axial point. 1 + 2

(*d*) Using magnetic vector potential
$\vec{A} = e^{-x} \sin y \ \hat{i} + (1 + \cos y)\hat{j}$.
Calculate the current density $\vec{J}$. 2

(*e*) Draw (*B* - *H*) curves for soft iron and steel. 2

4. (*a*) Find the centre of mass of a uniform solid hemisphere of radius *R*. 3

(*b*) Two particles having masses m_1 and m_2 move so that their relative velocity is v and the velocity of their centre of mass is V_{cm}. If $M = m_1 + m_2$ is the total mass and $\mu = m_1 m_2/(m_1 + m_2)$ is the reduced mass of the system, prove that the kinetic energy is $1/2\ MV_{cm}^2 + 1/2\ \mu v^2$. 3

(*c*) Calculate the energy of a charged sphere of radius *R* in which the charge is uniformly distributed. 3

(*d*) Determine the magnetic vector-potential at a distance *r* from a very long thin straight wire carrying a current *I*. Hence find the corresponding magnetic field $\vec{B}$. 3 + 1

(*e*) What do you mean by free current and bound current in connection with magnetization of matter ? 2

GROUP – B

Answer any **five** questions : 8 × 5

5. (*a*) Show that if M be the mass of a sphere of radius R, the loss of gravitational potential energy in assembling the particles from a state of diffusion at an infinite distance is $\frac{3}{5}G\frac{M^2}{R}$, where G is the universal gravitation constant. What is its physical significance. 4 + 1

(*b*) What is a compound pendulum ? Find the condition of minimum time period of a compound pendulum. 1 + 2

6. (*a*) Show that the change of entropy is independent of path. Briefly explain why entropy increases in natural process. $1\frac{1}{2} + 1\frac{1}{2}$

(*b*) Two bodies of equal and constant thermal capacity C and at the absolute temperature T_1 and T_2 are allowed to attain the same temperature by placing those in direct thermal contact.—Prove it. 2 + 1

(*c*) What would be the loss of available energy ? Show that it is T_0 times the increase in entropy. Briefly explain about the Gibb's paradox. 2

7. (*a*) A beam of particles is passed through a low pressure gas. The mean freepath of particles in the gas is 5×10^{-4} m. Find the traditional attenuation in the intensity of the beam in traversing a thickness of 10^{-2} mm of the gas sample. 2

(*b*) An ideal gas expands adiabatically in such a way that its volume is doubled. How many times will be number of collisions per second of the molecules decrease ? 4

(*c*) Obtain the expression for energy distribution law using Maxwell's speed distribution law. 2

8. (*a*) Show how the Clausious theorem leads to the concept of entropy as state function. What is unit of entropy ? 3 + 1

(*b*) A Carnot cycle operates on heat engine between two bodies of equal and same specific heat C until temperatures are equal. If the initial temperature of the two bodies were $4T$ and T respectively, show that the final temperature is $2T$ and work done by the engine is CT. 2 + 2

9. (*a*) Define Polarisation vector $\vec{P}$ for dielectric substance. Show that electric field produce by polarised dielectric can be given by the contribution form a bound surface charge density $\sigma_b = \vec{P} \cdot \hat{n}$ and volume charge density $\rho_b = -\vec{\nabla} \cdot \vec{P}$ where $\hat{n}$ is unit vector normal to the surface. 1 + 4

(*b*) Starting from Coulomb Law, prove that $\vec{\nabla} \times \vec{E} = 0$. Explain it's physical significance. 2 + 1

10. (*a*) Deduce that the Joule-Thomson co-efficient μ is given by

$$\mu = \left(\frac{\partial T}{\partial P}\right)_H = \frac{1}{C_p}\left[T\left(\frac{\partial V}{\partial T}\right)_p - V\right]$$

Hence find the inversion temperature for van-der-Waal's gas. 3 + 3

(*b*) Write down the difference between adiabatic expansion and Joule-Thomson expansion. 2

11. (*a*) What is a central force ? Prove that for a particle moving under a central force

(*i*) angular momentum about the centre of force is a constant of motion.

(*ii*) the motion of the particle is always confined to a plane.

(*iii*) the areal velocity of the line joining the center of force and the particle is a constant of motion. 1 + 3

(*b*) Prove that the speed v of a particle moving in an elliptic path in a force field $F(r) = -\frac{k}{r^2}$ is given by

$v^2 = \frac{k}{m}\left(\frac{2}{r} - \frac{1}{a}\right)$, where a is semi-major axis. Hence deduce the value of escape velocity. 3 + 1

12. (*a*) Derive an expression for the moment of inertia of a rigid body about an axis having direction co-sines l, m, n. What is meant by ellipsoid of inertia at a point ? 3 + 1

(*b*) (*i*) What are the principal axes and principal moment of inertia at a point.

(*ii*) Find the moment of inertia of a thin uniform rod about an axis making an angle θ with the rod passing through centre of mass. 2 + 2

GROUP – C

Answer any **five** questions : 4×5

13. A force is defined as $\vec{F} = \frac{-\hat{i}x + \hat{j}y}{(x^2 + y^2)}$. Evaluate $\int \vec{F} \cdot d\vec{r}$ along the paths designated by the coordinate position : (*i*) (–1, 0) to (0, 1) and (*ii*) (0, 1) to (1, 0). What is the nature of this force ? $1\frac{1}{2} + 1\frac{1}{2} + 1$

14. Derive the expression for deflection of a freely falling body from a height h at latitude λ due to Coriolis acceleration. 4

15. (*a*) Apply first law of thermodynamics to define enthalpy of a system.

(*b*) Find the expression of heat absorbed in an isochronic process for an ideal gas system. $2 + 2$

16. State and explain the boundary conditions of B and H. Compare the conditions with those obtained in electrostatics. Here, the terms are of usual meaning. 4

17. Show that

$$C_p - C_v = T\left(\frac{\partial P}{\partial T}\right)_v \left(\frac{\partial V}{\partial T}\right)_p$$

Hence for a Van-der-Waal's gas show that

$$C_p - C_v = R\left(1 + \frac{2a}{RTV}\right).$$ 2 + 2

18. Apply Laplace's equation to obtain the capacitance of a cylindrical capacitor. 4

19. (*a*) Define the term emissive and absorptive power of a blackbody.

(*b*) State and prove Kirchhof's law. 1 + 3

20. A uniform spherical shell of radius *a*, carrying uniform charge density σ is set to spinning with angular velocity *w* about diameter (X axis). Find the magnetic field at the centre of the shell and also equivalent magnetic dipole moment. 4
