2019

(October)

PHYSICS

(Elective/Honours)

[PHY–01(T)]

(Mechanics, Optics, Acoustics)

Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer Question No. **1** which is compulsory and *any* **four** from the rest

1. *(a)* The gravitational potential at a point on the surface of a planet is $-1{\cdot}78\times10^{9}$ J/kg. The radius of the planet is $7{\cdot}13\times10^{7}$ m and $G = 6{\cdot}6\times10^{-11}$ SI units. Calculate the mean density of the planet assuming it to be a solid sphere. 4

(b) An incompressible fluid flows through a horizontal tube with non-uniform cross section. At a particular point, the flow velocity is 0·4 m/s and the pressure is 1245 N/m^2. Find the pressure at the point where the flow velocity is 0·55 m/s. 4

(c) An achromatic objective of focal length 0.25 m is made by combining two lenses in contact whose dispersive powers are in the ratio 2 : 3. Calculate the focal lengths of the two lenses. 4

(d) The intensity of sound increases to 10^3 times the initial value. Express the change in intensity in decibel. 3

2. (a) Obtain the radial and transverse components of velocity and acceleration of a particle moving in a plane. 2+3=5

(b) What are non-inertial frames of reference? Deduce the equation of motion showing the fictitious forces when motion of a particle is described in a rotating frame of reference. 1+6=7

(c) Show that a central force is conservative. 3

3. (a) Show that the motion of the centre of mass is same as that of a single particle of mass equal to the total mass of the system under the action of a force which is equal to the vector sum of all external forces acting on the system. 3

(b) Obtain the Lorentz transformation equations. 6

(c) Give the detailed explanations on *(i)* length contraction and *(ii)* time delation. 3+3=6

4. (a) State perpendicular axes theorem for a lamina and hence use the theorem to find moment of inertia of a circular disc about one of its diameter. 2+3=5

(b) What is modulus of rigidity of a substance? A cylinder of length l and radius a is clamped at one end and a torque is applied at the other end. Show that torsional rigidity τ of the cylinder is

$$\tau = \frac{\eta \pi a^4}{2l}$$

where η is the rigidity of modulus of the material of the cylinder. 1+4=5

(c) Derive Poiseuille's formula for flow of a liquid through a horizontal narrow tube. 5

5. (a) State Fermat's principle of extremum path. Using it, prove the laws of refraction when two media are seperated by a plane boundary. 1+5=6

(b) What are cardinal points? Draw a diagram illustrating the cardinal points of a coaxial lens system. 2+2=4

(c) Derive the lens maker's formula by matrix method. 5

* * *

6. (a) Describe the working and construction of oil immersion objective. 5

(b) Compute the conditions for maxima and minima in the interference of transmitted light in a thin wedge-shaped film. 6

(c) Name the types of fringes produced by Michelson interferometer. Explain how the difference in the wavelengths of two waves can be determined with a Michelson's interferometer. 1+3=4

7. (a) Give the theory of plane diffraction grating. 6

(b) What is elliptically polarized light? Describe a method to produce it. 1+4=5

(c) What are Fresnel half-period zones? Obtain the equation of the area of a zone. 4

8. (a) Derive the expression for velocity of sound in isotropic solid. 4

(b) What are the requirements of a good auditorium? 4

(c) Derive Sabine's formula for reverberation time. 7

★ ★ ★

2015

(October)

PHYSICS

(Elective/Honours)

FIRST PAPER

(Mechanics, Optics, Acoustics)

Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer Question No. **1** which is compulsory and *any* **four** from the rest

(Results of Question No. 1 should be in SI units)

1. *(a)* A solid sphere of radius 0·3 m is made of a material of density $\rho = 5000 \text{ kg/m}^3$. Find the moment of inertia about an axis through the centre of the sphere. 5

(b) A zone plate is designed to bring a parallel beam of light of wavelength 600 nm to the first focus at a distance of 2 m. Calculate the radius of the central element of the zone plate. 5

(c) An electron at rest has a mass of $9{\cdot}11\times10^{-31}$ kg. At what speed would the mass of the electron be doubled? 5

2. (a) A reference frame S' rotates with respect to an inertial frame S with a uniform angular velocity $\vec{\omega}$. If the position, velocity and acceleration of a particle in frame S' are represented by $\vec{r}$, $\vec{v}'$ and $\vec{a}'$ respectively, then show that the acceleration of the particle in frame S is given by

$$\vec{a} = \vec{a}' + 2\vec{\omega}\times\vec{v}' + \vec{\omega}\times(\vec{\omega}\times\vec{r})$$ 7

(b) What is conservative force? Give two examples of conservative force. Show that a central force is conservative. 1+1+3=5

(c) Deduce an expression for the gravitational field at a point on the outer surface of a shell of radius R. 3

3. (a) Define 'centre of mass' of a system. Show that when there is no external force acting on a body, the acceleration of the centre of mass is zero and its velocity is constant. 1+3=4

(b) In a one-dimensional elastic collision of two particles of equal mass, show that the particles simply interchange their velocities after collision. 3

(c) Describe the Michelson-Morley experiment and discuss its significance. 6+2=8

4. (a) State Hooke's law and deduce the relation between the elastic constants, Y, K, η of an isotropic solid (symbols have their usual meanings). 1+6=7

(b) Deduce the equation of continuity of flow of a non-viscous, incompressible fluid. 3

(c) Define 'capillarity' and 'surface tension'. When the size of a soap bubble is increased by blowing more air into it, the surface area increases. Does it mean that the average separation between the surface molecules is increased? Explain. 1+1+3=5

5. *(a)* What is Fermat's principle? Can the optical path length between two points ever be less than the geometrical path length between those points? 1+2=3

(b) What is chromatic aberration? Derive the condition of achromatism of a combination of two thin coaxial lenses, when they are *(i)* in contact and *(ii)* separated by a distance. 1+3+3=7

(c) With the help of a ray diagram, explain the working of a Ramsden eyepiece. Indicate, in a diagram, the position of the cardinal points in Ramsden's eyepiece. 1+3+1=5

6. *(a)* Why do we see colours when white light falls on a thin film of transparent medium? 2

(b) Differentiate between fringes of equal inclination and fringes of equal thickness. 3

(c) Give the theory of Newton's rings. How can the wavelength of monochromatic light be measured with the help of Newton's rings? 6+4=10

7. *(a)* What is zone plate? Write a formula for its focal length. Show that a zone plate has multiple foci. 1+1+3=5

(b) What is quarter-wave plate? Distinguish between a quarter-wave plate and a half-wave plate. Mention two applications of a quarter-wave plate. 1+2+2=5

(c) Explain Fresnel's theory of optical rotation of the plane of polarization. 5

8. *(a)* Distinguish between 'normal' and 'anomalous' dispersions. Give a simple theory of Rayleigh scattering. 2+3=5

(b) What are ultrasonic vibrations? Describe a simple method to generate ultrasonic waves. Mention three applications of ultrasonic waves. 1+3+3=7

(c) Define 'reverberation time' and 'absorption coefficient' in acoustics. 1½+1½=3

★★★

2016

(October)

PHYSICS

(Elective/Honours)

(Mechanics, Optics, Acoustics)

[Phy–01 (T)]

Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer Question No. **1** which is compulsory and *any* **four** from the rest

1. *(a)* Find the value of the deviation from vertical direction suffered by a body due to Coriolis force when it is dropped from a height of 200 m at *(i)* equator and *(ii)* latitude 45°N. 3+1=4

(b) The Young modulus of a material is $7\times10^{10}\ N/m^2$ and the rigidity modulus is $3\times10^{10}\ N/m^2$. Calculate the bulk modulus of the material. 4

(c) Two thin converging lenses of focal lengths 0·3 m and 0·4 m are placed coaxially 0·2 m apart. An object is placed at a distance of 0·5 m from the first lens. Calculate the focal length of the combination, the positions of the principal points and the image. 2+2+3=7

2. (a) Find the expressions for velocity and acceleration of a particle moving in a plane in polar coordinate system. 3+3=6

(b) What is central force? Write down three characteristics of central force motion. 1+3=4

(c) Calculate the gravitational potential and field at a point outside the thin spherical shell of mass M and radius R. 4+1=5

3. (a) Define elastic and inelastic collisions. During the direct impact two bodies stick together to form a single entity. Show that the collision is inelastic. 1+1+4=6

(b) State the postulates of special theory of relativity. 2

(c) What are the drawbacks of Galilean transformation equations? Derive Lorentz transformation equations. 2+5=7

4. (a) What is the physical significance of moment of inertia? 2

(b) State and prove parallel axes theorem of moment of inertia. 1+3=4

(c) Derive Poiseuille's equation. 6

(d) A soap bubble of surface tension 25×10^{-3} N/m is slowly enlarged from a radius of 0·03 m to a radius of 0·05 m. Calculate the work done in the process. 3

5. (a) Define cardinal points of a system of coaxial lenses. Name the different cardinal points and represent them in a ray diagram. 1+3=4

(b) What is monochromatic aberration? Name the different kinds of monochromatic aberration and define them. 1+2½+5=8½

(c) Which of the two eyepieces, Ramsden or Huygens, one should prefer for observing biological specimens? Explain. 2½

6. (a) Describe the construction and working principle of Michelson interferometer. What are the conditions to observe circular and straight fringes? 2+4+2=8

(b) In Newton's rings experiment, if the diameters of the 3rd and 23rd rings are $1{\cdot}81\times10^{-3}$ m and $5{\cdot}1\times10^{-3}$ m respectively and the radius of curvature of the curved surface of the lens is 1 m, calculate the wavelength of the light used. 4

(c) Define normal and anomalous dispersion. 3

7. (a) Define resolving power of an optical instrument. Obtain an expression for the resolving power of a plane diffraction grating. 1+4=5

(b) What is double refraction? How is this phenomenon used to produce plane polarized light? 2+3=5

(c) What is grating element? Discuss how you can use a plane diffraction grating to determine the wavelength of an unknown monochromatic light. 1+4=5

8. (a) What are reverberation and reverberation time? Derive Sabine's formula for reverberation time. 2+6=8

(b) Find an expression for the velocity of sound in a thin long rod. 4

(c) Explain the terms 'intensity' and 'loudness'. What are their units (SI system)? 2+1=3

★★★

2017

(October)

PHYSICS

(Elective/Honours)

(Mechanics, Optics, Acoustics)

[Phy–01 (T)]

Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer Question No. **1** which is compulsory and *any* **four** from the rest

1. *(a)* Calculate the radius of gyration of a thin rod of mass 1 kg and length 1 m about an axis passing through its centre of gravity and perpendicular to its length. 3

(b) A small hollow sphere which has a small hole in it, is immersed in water to a depth of 0·4 m before any water penetrates into it. If the surface tension of water is 0·073 newton/metre, find the radius of the hole. 3

(c) How fast would a rocket have to go relative to an observer for its length to be contracted to 99% of its length at rest? 3

(d) Two thin converging lenses of 0·2 m and 0·3 m focal lengths are placed coaxially 0·1 m apart in air. An object is located 0·6 m in front of the lens of smaller focal length. Find the position of the two principal planes and that of the final image from the second lens. Also find the size of the image. 1½+1½+2½+½=6

2. (a) Show that the total linear momentum in the centre of mass system is zero. 4

(b) In a uniformly rotating frames of reference, obtain the acceleration of a particle in inertial frame. 5

(c) Show that central force is conservative. Also show that angular momentum is conserved under central force. 3+3=6

3. (a) Show that if (x_1, y_1, z_1, t_1) and (x_2, y_2, z_2, t_2) are the coordinates of one event in S_1 and the corresponding event in S_2 respectively, then the expression $dS_1^2 = dx_1^2 + dy_1^2 + dz_1^2 - C^2 dt_1^2$ is invariant under a Lorentz transformation of coordinates. 3

(b) Briefly describe Michelson-Morley experiment with neat diagram. 2+4=6

(c) Derive Einstein's mass-energy relation. 4

(d) At what speed is a particle moving, if the mass is equal to three times its rest mass? 2

4. (a) Explain the term 'surface tension' and give its unit and dimensions. Describe one laboratory method of determining the surface tension of a liquid giving necessary theory. 2+3=5

(b) Explain why a liquid is either raised or depressed in a capillary tube. Find an expression for the magnitude of this effect. 5

(c) Calculate the moment of inertia of a thin spherical shell about a diameter. 5

5. (a) Describe with a relevant theory, how a cantilever may be used to determine Young's modulus of the material of the bar. 6

(b) Show that axial chromatic error for parallel rays is equal to ωf, where the symbols have their usual meaning. 4

(c) Describe the construction and working of Ramsden or Huygens' eyepiece. 2+3=5

6. (a) Describe the construction, working principle and application of Fabry-Perot interferometer. 3+2+2=7

(b) Describe how you would use Newton's rings to measure the wavelength of light. Give an outline of the necessary theory along with its diagram. 4+3+1=8

7. (a) What is a zone plate? Derive an expression for its focal length and compare it with that of a converging lens. 1+4+1=6

(b) Develop the theory of dispersion of light. 5

(c) What do you understand by a quarter-wave plate and a half-wave plate? Calculate the thickness of a quarter-wave plate for light of wavelength 6000 Å. The refractive index for the ordinary ray is 1·544 and for extra-ordinary ray is 1·553. 2+2=4

(*Continued*)

8. (a) Describe briefly one method of producing ultrasonic waves. What are its uses? 4+1=5

(b) What are live and dead room? Define reverberation time and hence obtain an expression for it. 1+1+2+6=10

★★★

2018

(October)

PHYSICS

(Elective/Honours)

(Mechanics, Optics, Acoustics)

[Phy–01 (T)]

Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer Question No. **1** which is compulsory and *any* **four** from the rest

1. *(a)* Calculate the rest mass energy of an electron in MeV. Given mass of electron, $m_e = 9 \cdot 1 \times 10^{-31}$ kg. 4

(b) In a certain experiment to determine the coefficient of viscosity of a liquid the following data was obtained :

Volume of the liquid collected per minute = 7·08 cc

Pressure difference at the two ends of the capillary is equal to 34·1 cm of water column

Length of the capillary tube = 56·45 cm
Radius of the tube = 0·0514 cm
Calculate the coefficient of viscosity of the liquid. 4

(c) Two thin lenses are placed 4 cm apart to form an achromatic combination. Find the focal length of each lens, if the combination reduces the spherical aberration to the minimum level. 4

(d) Refractive index of glass is 1·5. Find the angle of polarization and corresponding angle of refraction. 3

2. (a) Write the expression for total force experienced by an object in a uniformly rotating frame and identify the different terms. Also find an expression for the centrifugal acceleration at a place on earth surface. What will be its value at a place on 60° N latitude? 1+2+3+1=7

(b) Prove that the gravitational force is a conservative force. 3

(c) Calculate the gravitational potential and field at a point inside a solid sphere of mass M and radius R. From the result, make an inference on the value of g at the centre of earth. 4+1=5

3. (a) Two particles stick together after collision. Prove that the collision is inelastic. Also calculate the loss in kinetic energy. [Consider one particle is at rest before collision] 3+1=4

(b) State the basic postulates of special theory of relativity. 2

(c) Write Lorentz transformation equations. Use Lorentz transformation equations to show that length is not an absolute quantity. 2+3=5

(d) Establish Einstein velocity addition theorem. 4

4. (a) State and prove parallel axes theorem of moment of inertia. 1+3=4

(b) Calculate the moment of inertia of a disc about an axis passing through its centre and perpendicular to its plane. Also find its moment of inertia about diameter. 3+1=4

(c) A system of particles is rotating about a fixed axis. Write the expression for total angular momentum of the system. Prove that if the total torque acting on the system is zero, total angular momentum of the system remains constant. 1+3=4

(d) Prove that the value of Poisson's ratio lies between -1 and $\frac{1}{2}$. 3

5. (a) State and prove Bernoulli's theorem. 1+4=5

(b) Find the expression for excess pressure within a spherical soap bubble. Calculate the excess pressure inside a soap bubble of radius 3 cm if the surface tension of the soap solution is 45 dynes/cm. 3+2=5

(c) Define principal point and nodal point of a lens system. Show that the distance between the principal points and the nodal points are equal. 2+1+2=5

6. (a) Discuss the working principle of an oil immersion objective. 4

(b) Describe in brief how Michelson interferometer is used to determine the wavelength of monochromatic light. 4

(c) In a Newton's ring experiment, the diameters of 3rd and 23rd dark fringes are 0·2 cm and 0·6 cm respectively. If the radius of curvature of the plano-convex lens is 92 cm, find the wavelength of light. 3

(d) What are the fringes of equal thickness and equal inclination? Give one example of each. 3+1=4

(Continued)

7. (a) Explain the difference between Fraunhofer diffraction and Fresnel diffraction. 4

(b) Explain in brief how a plane transmission grating can be used to find the wavelength of a monochromatic light. 3

(c) What are circularly and elliptically polarized light? Describe one method each to produce circularly and elliptically polarized light. 2+3+3=8

8. (a) What are ultrasonic waves? Describe one method used to detect it. Mention two of its uses. 1+3+1=5

(b) Derive the expressions for growth and decay of sound intensity in an auditorium. Also represent this variation graphically. 6+1=7

(c) The amplitude of a sound wave is doubled; by how many decibels will the loudness increase? 3

★★★