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5 SEM TDC DSE PHY (CBCS) 1 (H)

2023

(November)

PHYSICS

(Discipline Specific Elective)

(For Honours)

Paper : DSE–1

(Classical Dynamics)

Full Marks : 80
Pass Marks : 32

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct answer : 1×8=8

(a) The ratio between the electric field and the magnetic field is

(i) $\mu_0\varepsilon_0$

(ii) $\dfrac{1}{\mu_0\varepsilon_0}$

(iii) $\dfrac{1}{\sqrt{\mu_0\varepsilon_0}}$

(iv) $\sqrt{\mu_0\varepsilon_0}$

(b) A cylinder constrained to move on a plane such that its axis of symmetry is always parallel to the plane, then the degrees of freedom are

(i) 2

(ii) 4

(iii) 5

(iv) 6

(c) In variational principle, the line integral of some functions between two end points is

(i) zero

(ii) infinite

(iii) extremum

(iv) one

(d) For a particle moving under the action of conservative force, the Lagrangian of the system

(i) is independent of position

(ii) increases in the direction of conservative force

(iii) decreases in the direction of conservative force

(iv) More information needed

(e) A stick of one metre in length is moving away from an observer at a speed of 0·80c. The observer will see the length of the stick as

(i) 0·6 m

(ii) 1·255 cm

(iii) 1 m

(iv) 1·66 m

(f) A square is travelling with the velocity of light in its diagonal direction. The observer in the rest observes it as

(i) square

(ii) rectangle

(iii) parallelogram

(iv) rhombus

(g) In a nuclear plant, 10^{17} joule energy is available from mass conservation. How much mass was lost?

(i) 0·1 kg

(ii) 1 kg

(iii) 10 kg

(iv) 100 kg

(h) A fluid is called turbulent when

(i) the viscosity of fluid is high

(ii) Reynolds' number is greater than 2000

(iii) Reynolds' number is less than 2000

(iv) the density of fluid is low

2. *(a)* If a charged particle is moving through a transverse uniform electric field, show that the path of the particle will be parabola inside this field. 2

(b) State and prove Hamilton's principle. 3

Or

A particle of mass m falls a given distance z_0 in time $t_0 = \left(\frac{2z_0}{g}\right)^{1/2}$ and the distance travelled in time t is given by $z = at + bt^2$, where constants a and b are such that the time t_0 is always the same. Show that the integral $\int_0^{t_0} L\,dt$ is extremum for real values of the coefficients only when $a = 0$ and $b = \frac{g}{2}$.

(c) A particle of mass m is projected with initial velocity u at an angle α with the horizontal. Use Lagrange's equations to describe the motion of the projectile. The resistance of the air may be neglected. 3

3. *(a)* Establish the Euler-Lagrange equations of motion by differential method. 5

(b) Using Hamilton's equation of motion, deduce the equations of motion of a compound pendulum. 3

Or

Derive the Hamiltonian for a charged particle in electromagnetic field.

(c) Define generalized momentum. Establish the principle of conservation of angular momentum using generalized notations. 1+4=5

Or

An inverted pendulum consists of a particle of mass m supported by a rigid massless rod of length l. The pivot O has a vertical motion given by $z = A\sin\omega t$. Obtain the Lagrangian and differential equation of the motion. 5

4. *(a)* If a particle is slightly displaced from the point of equilibrium executing small oscillations, then calculate the potential energy about a point of stable equilibrium. 3

(b) Three rigid spheres are connected by light flexible rods with relative masses $m_1 : m_2 : m_3 = 1:2:1$. Describe all the normal modes of the system and the normal frequencies. 6

Or

Show that the total energy of a coupled system with three degrees of freedom is equal to the sum of energies of its principal mode of oscillation.

5. *(a)* State the postulates of special theory of relativity. 2

(b) Write short notes on any *two* of the following : 3×2=6

(i) Length contraction

(ii) Twin paradox

(iii) Momentum 4-vector

Or

An astronaut wishes to determine his velocity of approach as he nears the moon. He sends a radio signal of frequency 5×10^9 Hz and compares this frequency with its echo, observing a difference of 86 kHz. What is the velocity of space vehicle relative to the moon? (Use the terms of first-order v/c) 6

(c) Discuss space like, time like and light like intervals. 3

6. *(a)* Derive the expression of relativistic total energy. 4

(b) Explain the concept of simultaneity in the context of special relativity. 4

Or

A muon is travelling with speed $v = 0\cdot99c$ (c stands for velocity of light) vertically down through the atmosphere. Its half-life in its own rest frame is 1·5 microsecond. What is its half-life as measured by an observer on the earth?

(Continued)

(c) Show that $E^2 - p^2c^2$ is invariant under Lorentz transformation. 4

7. *(a)* Define relativistic Doppler effect. Discuss the salient features of relativistic Doppler effect. 2+3=5

Or

Excited Fe^{57} nuclei sometimes decay to produce γ-ray photon of frequency $3\cdot46\times10^{18}$ Hz. Find the frequency of the photon emitted at an angle of 60° in the laboratory frame relative to the direction of the Fe^{57} nucleus, when it is moving with a velocity 6×10^7 ms^{-1}. 5

(b) Explain the concept of four-force and discuss the conservation of four-momentum. 2+3=5

Or

A beam of $10^4\pi^+$ mesons moves in a circular path of radius 20 metre at a speed 0·99c. The proper mean life of the π^+ meson is $2\cdot5\times10^{-8}$ sec.

(i) How many mesons survive when the beam returns to the point of origin?

(ii) How many mesons would left in a beam that had remained at rest at the origin for the same period of time? 2+3=5

(Turn Over)

8. *(a)* Write the equation of continuity of flow of liquid and prove it. 2

(b) Write down Poiseuille's equation for liquid flowing through a capillary tube. From this equation, show that if two capillaries of radii r_1 and r_2 having lengths l_1 and l_2 respectively are set in series, the rate of flow V is given by

$$V = \frac{\pi P}{8\eta}\left(\frac{l_1}{r_1^4} + \frac{l_2}{r_2^4}\right)^{-1}$$

where P is pressure difference across the arrangement and η is the coefficient of viscosity. 1+3=4

Or

Three capillaries of lengths $8L$, $0 \cdot 2L$ and $2L$, with radii r, $0 \cdot 2r$ and $0 \cdot 5r$ respectively are connected in series. If the total pressure across the system in an experiment is P, then calculate the pressure across the shortest capillary. 4

(c) Write the qualitative description of turbulence of a liquid. What is Reynolds' number? 1+2=3

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