University of Jaffna, Sri Lanka
General Degree Examination in Science – Level 1G -2006
End of Course Examination

PHYSICS

PHY102GC3 : Mechanics, Relativity & Structure of Matter

By selecting at least *one* question from each section answer any *five* Questions.

Time: *Three* hours.

SECTION - A

Acceleration due to gravity at the earth's surface (g) $= 10.0\ m\ s^{-2}$

Avogadro's Number (N_A) $= 6.03\times 10^{23} mol^{-1}$

1. State the Newton's second law of motion.
Write down an expression for the centripetal acceleration of a particle moving in a circle of radius r with uniform angular speed ω.
   (a) The bob of a conical pendulum is whirled around in a horizontal circle at a constant speed so that the cord makes an angle of 30^0 with the vertical. If the mass of the bob is 500g and the length of the cord is 1.5m estimate the following:
      (i) The centripetal force acting on the bob.
      (ii) The period of the conical pendulum.

   You may neglect the dimensions of the bob.

   (b) In a space laboratory, two astronauts are seated in cages mounted at opposite ends of a 20m arm and the system is rotated at uniform angular speed in a vertical circle about the mid point of the arm. Estimate the following:
      (i) The angular speed of rotation required to produce weightless state to the astronauts when at the top of the circle.
      (ii) The acceleration experienced by the astronaut at the bottom of the circle when the arm rotates at the angular speed which gives weightless state to the astronaut at the top of the circle.

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2. What is meant by the centre of mass of a system of particles?

(a) Consider a system of N particles each subjected to an external force and show that the centre of mass of this system of particles moves as if the total mass of the particles is concentrated at that point and all external forces are applied to it.

(b) A particle of mass M is scattered elastically by a target particle of mass m ($<M$) initially at rest. Show that the angle of scattering in the laboratory frame is always less than a certain value and obtain an expression for this maximum value.

(c) In a nuclear physics experiment, a deuteron moving with velocity v is scattered elastically by a proton at rest. Estimate the following:

(i) The velocity of the deuteron in the centre of mass frame.

(ii) The maximum angle through which the deuteron would be scattered in the laboratory frame.

(iii) The recoil angle of the proton in the laboratory frame when the scattering angle is maximum.

You may assume that the mass of a deuteron is twice that of a proton.

3. What do you understand by potential, kinetic and mechanical energies of an object?

(a) Consider a particle of mass m moving along the x-axis under the action of a net force acting along the x-axis and show that the change in kinetic energy of the particle is equal to the work done by the net force.

(b) Give two examples of conservative forces. Prove the law of conservation of mechanical energy of a particle moving under the action of conservative forces.

(c) A ball bearing of mass 5g is fired vertically down word from a height of 20 m above the earth's surface with an initial speed of $15ms^{-1}$. It gets buried in the earth to a depth of 25cm. What is the average upward resistive force exerted by the earth on the ball to make it comes to rest?

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4. Obtain an expression for the moment of inertia of a solid uniform sphere of mass M and radius R about any of its diameter. You may assume that the moment of inertia of a uniform circular disc of mass m and radius r about an axis passing through its centre and perpendicular to its plane is $\frac{mr^2}{2}$.

A solid uniform sphere of mass 8.0 kg and radius 10 cm starts rolling down an inclined surface from its top. Estimate the velocity of the sphere when it reaches the bottom of the inclined surface if its slope is 15^0 and the length is 3.0 m.

SECTION - B

5. Write down the Lorentz transformation equation of the spatial and time coordinates of an event described in two inertial frames Σ and Σ', the later moving with velocity v relative to the former along the common x-axis.

The velocity components of a particle measured by the observers in Σ and Σ' respectively are (u_x, u_y, u_z) and (u'_x, u'_y, u'_z). Obtain the Lorentz velocity transformation equations.

A particle moves in the xy- plane of the Σ frame in a direction 60^0 to the x-axis with a velocity of 0.8c. Determine its direction and velocity in the Σ' frame which is moving with a velocity of 0.4c relative to the Σ frame along the common x-axis.

6. (a) Write down the expressions for the relativistic mass m, momentum p, energy E and kinetic energy T of a particle of rest mass m_0 moving with a velocity v.

Hence obtain the following relationships for a relativistic particle.

(i) $E^2 = p^2c^2 + m_0^2c^4$.

(ii) $T = E\{1-(1-\frac{v^2}{c^2})^{1/2}\}$.

(b) In a laboratory experiment, a proton of rest mass 940 MeV/c^2 moving with a velocity 0.8c collides with another stationary proton. Estimate the following:

(i) The momentum of the colliding proton.
(ii) The kinetic energy of the colliding proton.
(iii) The total energy of the system in the laboratory frame.
(iv) The total energy of the system in the centre of mass frame.

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PART – C

7. (a) Giving suitable examples in each case, explain what you understand by isotopes and isobars.

(b) (i) Draw a clear sketch of the Thomson's apparatus and explain how it was used for measuring the $\frac{q}{m}$ ratio of electrons.

(ii) Indicate clearly the directions of the electric and magnetic fields in your diagram, and explain the reasons for choosing those directions.

(c) Assuming that the electrons undergo small deflections, show that

(i) the deflection due to electric field $Y_E = \frac{qEL}{mv_x^2}(\frac{L}{2} + D)$ and

(ii) the deflection due to magnetic field $Y_B = -\frac{qBL}{mv_x}(\frac{L}{2} + D)$,

where v_x is the velocity of the electrons while entering the parallel plates, L is the length of the plates, D is the distance of the screen from the edge of the plate that is close to the screen and the other symbols have their usual meaning.

(d) In such an experiment, the electrons beam went undeflected when the potential difference between the plates and the magnetic field are 2.8 kV and 8.0×10^{-4} T respectively. Assuming the separation between the plates is 2.5 cm; determine the velocity of the electrons while entering the plates.

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8. (a) Define the term "packing fraction" for a crystal structure.

(b) (i) Assuming that the atoms are rigid spheres and that any two nearest neighbour atoms are always in a state touching each other, find the radius of the atoms that crystallise in a body centred cubic structure, in terms of the lattice constant of that structure.

(ii) Estimate the packing fraction of the above structure.

(c) Sodium crystallises in a body centred cubic structure. Its density and atomic mass are $970 kgm^{-3}$ and 23g respectively. Calculate the following for sodium:

(i) The nearest neighbour distance between the atoms.

(ii) The packing fraction of the structure.

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