RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. FIRST SEMESTER EXAMINATION, MARCH 2022

FIRST YEAR [BATCH 2021-24]

Date : 10/03/2022 **PHYSICS (HONOURS)**

Time : 11 am – 1 pm **Paper : II [CC 2]** Full Marks : 50

Answer **any five** questions of the following: [5×10]

1. a) What is Galilean transformation?

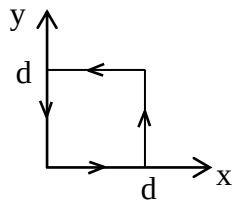
   b) Two astronauts, initially at rest in free space $(g = 0)$, pull on either end of a rope. Astronaut 'A' is stronger than astronaut 'B'. The maximum force which 'A' can pull is larger than maximum force which 'B' can pull. Find their motion if each pull on the rope as hard as he can.

   c) A 45^o wedge is pushed along a table with constant acceleration A. A block of mass *m* slides without friction on the wedge. Find its acceleration. [2+5+3]

2. a) Find the equation of motion of a rocket under gravitational field.

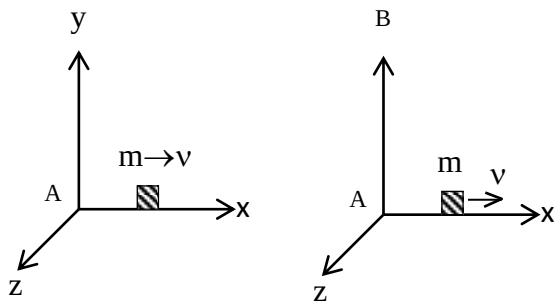
   b) A proton makes a head-on collision with an unknown particle at rest. The proton rebounds straight back with $\frac{4}{9}$ of its initial kinetic energy. Find the ratio of the mass of the unknown particle to the mass of the proton assuming the collision is elastic. [6+4]

3. a) How much work is done around the path that is shown by the force $\vec{F} = A\left(y^2\hat{i} + 2x^2\hat{j}\right)$ where A is a constant and *x* and *y* are in meters?



   b) What is the advantages of centre of mass frame over laboratory frame?

   c) Find the angular momentum for the following two conditions.

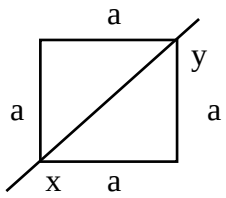


   i) about Point A

   ii) about point B. [4+2+(2+2)]

4. a) Prove the perpendicular and parallel axis theorem of moment of inertia.

   b) What will be the moment of inertial of the plate about axis x-y of mass m.



   c) A disk of mass M and radius b is pulled with constant force F by a thin tape wound around its circumference. The disk slides on ice without friction. Find its acceleration. [(2+2)+4+2]

5. a) If stresses in three mutually perpendicular directions in an isotropic body be 2×10^8, $4 \times 10^8$and 3×10^8 dynes cm^{-2}. What will be the volume strain? [Given: $Y = 20 \times 10^{11}$ dynes cm^{-2} and $\sigma = 0.3$]

   b) Show that, for the same cross-sectional areas, the beam of square cross-section is stiffer than one of circular cross-section of the same length and material. Show also that for a given load, the depression in the two cases are in the ratio $3:\pi$.

   c) The velocity components in a steady flow are given by

   $v_x = x^2 + z^2$, $v_y = y^2 + z^2$, $v_z = -2z(x + y)$.

   Show that the equation of continuity is satisfied.

   d) Three capillaries of lengths $8L$, $0.2L$ and $2L$ and radii r, $0.2r$ and $0.5r$ respectively are connected in series. If the total pressure across the system in an experiment is p, calculate the pressure across the shortest (middle) capillary. [3+2+2+3]

6. a) A particle of mass m moves in a force field defined by $\vec{F} = -\frac{K}{r^3}\hat{r}$. If it starts on the positive x-axis at a distance a away from the origin and moves with speed v_0 in the direction making an angle α with the positive x-axis.

   i) Prove that the differential equation for the radial position r of the particle at any time t is

$$\frac{d^2r}{dt^2} = -\frac{K - ma^2v_0^2 sin^2\alpha}{mr^3}$$

   ii) Show that the differential equation for the orbit is given in terms of $u = \frac{1}{r}$ by $\frac{d^2u}{d\theta^2} + (1 + \gamma)u = 0$, where $\gamma = \frac{K}{ma^2v_0^2 sin^2\alpha}$.

   iii) Solve the differential equation and interpret physically. [2+2+2]

   b) A satellite is moving in a circular orbit of radius R about Earth. By what fraction must its velocity v be increased for the satellite to be in an elliptical orbit with $r_{min} = R$ and $r_{max} = 2R$? [4]

7. a) A planet have a spherical core (density ρ and radius R_1) and a thick cloud of dust (density σ and radius R_2). What is the force on a particle of mass m placed within the dust cloud.

   b) A projectile located at colatitude λ is fired with velocity v_0 in the southward direction at an angle α with the horizontal.

   i) Prove that after time t the projectile is deflected toward the East of the original vertical plane of the motion by the amount

$$\frac{1}{3}\omega g t^3 \sin\lambda - \omega v_0 t^2 \cos(\alpha - \lambda).$$

   ii) What is the total deflection when it returns to the horizontal compare to its path when we neglected the axial rotation of the Earth? [2+(5+3)]

8. a) A particle is moving with simple harmonic motion along a straight line. Its velocity, when passing through the points 3 cm and 4 cm from the centre of its path is 16 cm/s and 12 cm/s respectively. Find the amplitude and period of the motion.

   b) The natural frequency of a mass vibrating on a spring is 20 Hz, while its frequency with damping is 16 Hz. Find the log decrement.

   c) An undamped driven harmonic oscillator satisfies the equation of motion $m\frac{d^2x}{dt^2} + \omega_0^2 x = F(t)$. The driving force $F(t) = F_0 \sin\omega t$ is switched on at $t = 0$.

   i) Find $x(t)$ for $t > 0$ for the initial conditions $x = 0$ and $v = 0$ at $t = 0$.

   ii) Find $x(t)$ for $\omega = \omega_0$ by taking the limit $\omega \to \omega_0$ in your result for part (i). [4+2+(3+1)]

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