Physics - I
Department of Physics
Indian Institute of Technology Guwahati

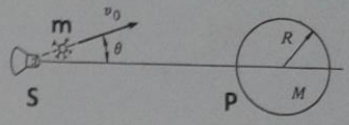
Course: PH 101
Date: 25/11/2011

# End-Semester Examination

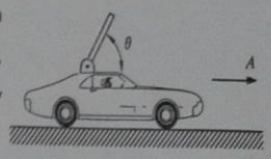
Total Marks: 50
Time: 1-4.00 pm

## Classical Mechanics

1. (a) A spaceship S fires a packet of mass $m$ at a speed $v_0$ to reach a planet P. At what angle $\theta$ (see figure) should the packet be fired such that it just grazes the surface of the planet. The planet has a radius $R$ and mass $M$. The mass of the packet is much smaller than that of the spaceship or the planet so that the spaceship and the planet are at rest throughout. The distance of the spaceship from the center of the planet is $5R$. [4]

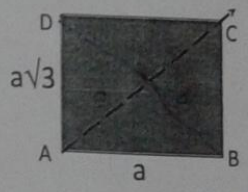



(b) A uniform thin rod of length $L$ and mass $M$ is pivoted to the top of a car by one end as shown in the figure. If the car has an acceleration $A$, find the equilibrium angle $\theta$ the rod makes with the horizontal. Gravity acts vertically down. [2]

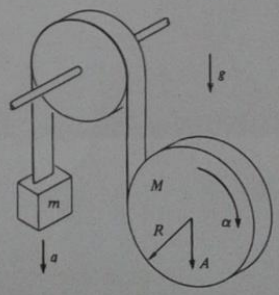



2. (a) A bowling ball (assume that it is a solid sphere) is thrown down a horizontal alley with speed $v_0$. Initially it slides, but due to friction it begins to roll without sliding. Find the speed of the center of mass of the ball when it starts rolling without sliding. [4]
Note that initially the velocity of the ball is purely translational, that is, $\omega(0) = 0$. The initial velocity, $v(0) = v_0$, should be assumed parallel to the surface.

(b) A thin rectangular lamina of sides $a$ and $\sqrt{3}\,a$, and mass $M$ is rotated about a diagonal AC (see figure) with an angular velocity $\omega$. Find the angle between the angular momentum $\vec{L}$ about its center of mass and $\vec{\omega}$. [4]




3. A disk of mass $M$ and radius $R$ unwinds from a light tape wrapped around it (see figure). The tape passes over a massless-frictionless pulley, and a block of mass $m$ is suspended from the other end. Assume that the disk moves vertically. Find the linear acceleration $A$ of the disk, the angular acceleration $\alpha$ of the disk about its center, and the acceleration $a$ of the block. [6]




Useful data: $h = 6.626 \times 10^{-34}\ J.s$ | $c = 3 \times 10^{8}\ m/s$ | $m_e = 9.11 \times 10^{-31}\ kg$
$m_p = 1.672 \times 10^{-27}\ kg$ | $e^- = -1.602 \times 10^{-19}\ C$

Please Turn Over...

## Relativity & Quantum Mechanics

4. Give **only the final** answers to **this question**. All your answers should appear in a single page, and in the same order. You may do the calculations in the rough sheet.

   (a) A solid cube has a density $\rho_0$ in its rest frame. What is its density as measured by an observer moving parallel to one of its sides with a velocity $v = \frac{\sqrt{3}}{2}c$. [1½]

   (b) Two simultaneous events take place at $L$ separation in a train moving at $c/2$ speed. What is the time interval between the events for an observer on the platform. [1½]

   (c) What is the speed of an electron whose kinetic energy equals its rest mass energy? [1]

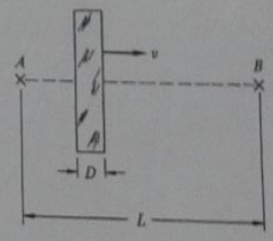
   (d) What is the energy in $eV$ of a photon of wavelength 7000 Å. [1]

   (e) A particle is in its ground state of a 1-dimensional box with energy $\epsilon_0$. What energy should it be supplied that it goes to the second excited state. [1]

5. (a) Two rockets, A and B, leave their space station along perpendicular paths. Rocket A move along the Y-axis at a speed of $0.8c$ and B along the X-axis at a speed of $0.6c$, as measured by an observer in the space station. Find the **speed** of A measured by an observer in B. [3]

   (b) A particle of rest mass $m_0$ move along the x-axis at a speed $v$. This particle collides with a particle of rest mass $m_0/2$ coming in the opposite direction at the same speed $v$ and coalesce (stick together). Find the rest mass of the resulting particle. [4]

6. A glass slab of thickness $D$ and refractive index, $n = 3/2$ (both measured in its rest frame) moves to the right with a speed $v = 0.5c$ (see figure). An observer standing at A see a flash of light emitted from A passes through the glass slab and reach B, at distance $L$ from A. Find the following **as measured by an observer at** A: **(i)** the time spent by light in the glass slab, **(ii)** the distance travelled by light in the glass slab and **(iii)** the total time taken by light to travel from A to B. [6]




7. (a) Assume that the wave function of a certain particle in three different regions of space is given by,

   $\psi(x) = Ae^{kx}$ for $-\infty \le x \le 0$

   $\psi(x) = Bx^2 + Cx + D$ for $0 \le x \le L$

   $\psi(x) = 0$ for $x \ge L$,

   where $k > 0$. Find $B$, $C$ and $D$ in terms of $A$, $L$ and $k$. [3]

   (b) Find the De-Broglie wavelength of a proton moving with a speed $v = 0.86c$? [2]

8. The wave function of a particle in some potential is given by $\psi(x) = A\,x\,e^{-kx}$, for $0 \le x \le \infty$, where $k > 0$ and $\psi(x) = 0$ elsewhere. Find $A$, and the probability of finding the particle between 0 and $1/k$. [6]