1. A small block of mass m rests on the rough, sloping side of a triangular block of mass M which itself rests on a horizontal frictionless table as shown in Fig. 1. If the coefficient of static friction is μ, determine the minimum horizontal force F applied to M that will cause the small block m to start moving up the incline. (10%)

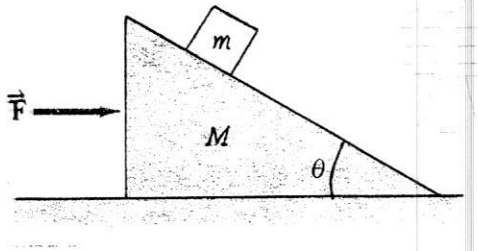


Fig. 1

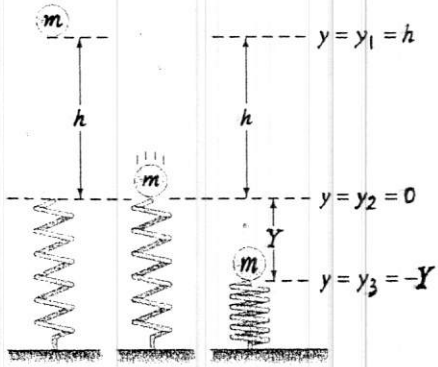


Fig. 2

2. A ball of mass m, starting from rest, falls a vertical distance h before striking a vertical coiled spring, which it compresses an amount Y, as shown in Fig. 2. Determine the spring stiffness constant of the spring. Assume the spring has negligible mass, and ignore air resistance. Measure all distances from the point where the ball first touches the uncompressed spring ($y = 0$ at this point). (10%)
3. The ballistic pendulum is a device used to measure the speed of a projectile, such as a bullet. The projectile, of mass m, is fired into a large block of mass M, which is suspended like a pendulum. As a result of the collision, shown in Fig. 3, the pendulum and projectile together swing up to a maximum height h. Determine the relationship between the initial horizontal speed of the projectile, v, and the maximum height h. (10%)

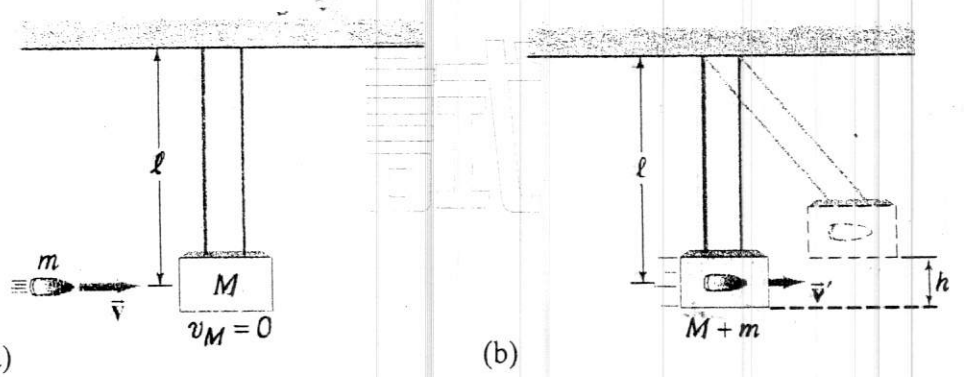


Fig. 3

4. The time-dependent position of a point object which moves counterclockwise along the circumference of a circle (radius R) in the xy plane with constant speed v is given by

$$\vec{r} = \hat{\imath}R\cos\omega t + \hat{\jmath}R\sin\omega t$$

where the constant $\omega = v/R$. Determine the (a) velocity $\vec{v}$ (3%), and (b) angular velocity $\vec{\omega}$ of this object (2%), and (c) show that these vectors obey the relation $\vec{v} = \vec{\omega}\times\vec{r}$. (5%)

5. There is a pendulum as shown in Fig. 5. The force of gravity acts at the center of gravity (CG) of the object located at a distance h from the pivot point O. (a) Find the torque on the physical pendulum calculated about point O. (2%) (b) If the moment of inertia of the object about the pivot point is I, please find the equation of SHM. (6%) (c) Please find the period T. (2%)

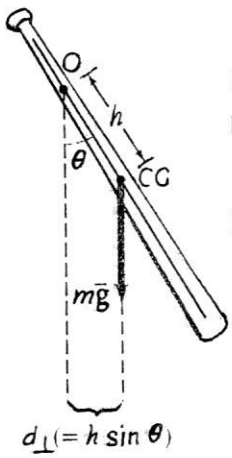


Fig. 5

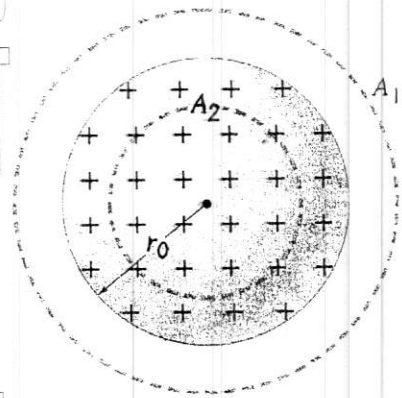


Fig. 6

6. An electric charge Q is distributed uniformly throughout a non-conducting sphere of radius r_0, as shown in Fig. 6. Determine the electric field (a) outside the sphere ($r > r_0$) (5%), and (b) inside the sphere ($r < r_0$) (5%).
7. A thin flat disk, of radius R_0, has a uniformly distributed charge Q, as shown in Fig. 7. (a) Determine the potential at a point P on the axis of the disk, a distance x from its center. (6%) (b) Determine the electric field at point P. (4%)

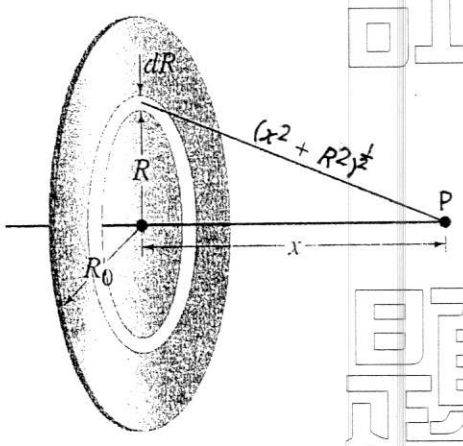
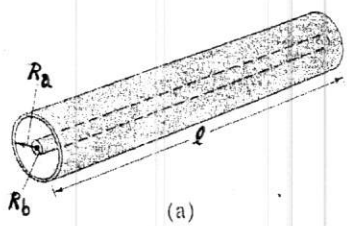
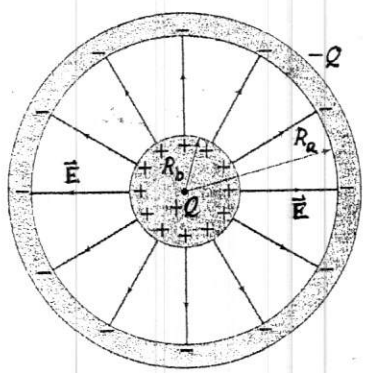


Fig. 7



(a)



(b)

Fig. 8

8. A cylindrical capacitor consists of a cylinder (or wire) of radius R_b surrounded by a coaxial cylindrical shell of inner radius R_a, as shown in Fig. 8. Both cylinders have length l which we assume is much greater than the separation of the cylinders, so we can neglect end effects. The capacitor is charged (by connecting it to a battery) so that one cylinder has a charge $+Q$ (say, the inner one) and the other one a charge $-Q$. (a) Find the electric field (3%) and (b) the electric potential difference between the two shells. (4%) (c) Determine the capacitance of the two shells. (3%)
9. A long straight cylindrical wire conductor of radius R carries a current I of uniform current density in the conductor, as shown in Fig. 9. Determine the magnetic field due to this current at (a) points outside the conductor ($r > R$) (5%), and (b) points inside the conductor ($r < R$). (5%) Assume that r, the radial distance from the axis, is much less than the length of the wire.

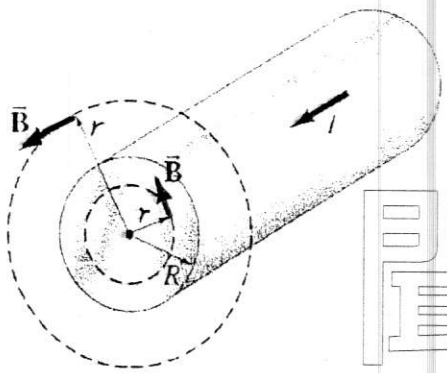


Fig. 9

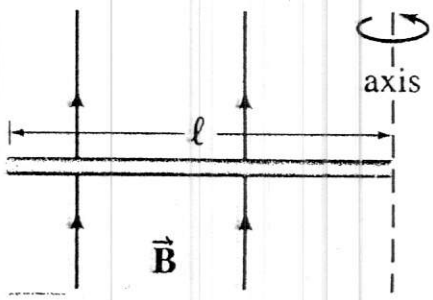


Fig. 10

10. A thin metal rod of length ℓ rotates with angular velocity ω about an axis through one end (Fig. 10). The rotation axis is perpendicular to the rod and is parallel to a uniform magnetic field $\vec{B}$. Determine the emf developed between the ends of the rod. (10%)