1. [20 %]

In Figure 1, the uniform solid cylinder, mass 5 kg and radius 10 cm, is supported on a frictionless horizontal axis. The blocks, masses 2 kg and 4 kg, are released from rest. There is no slipping between the rope and the cylinder. Find (a) the tensions T_1 and T_2 in the rope while the blocks are accelerating and (b) the speed of the 4-kg block after it descends 4 m from rest.

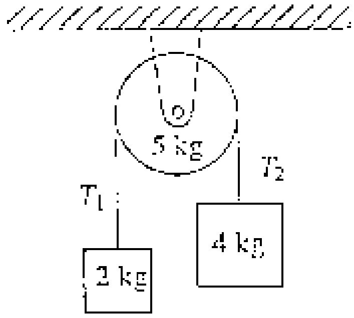


Figure 1

2. [10 %]

As shown in Figure 2, in one type of mass spectrometer charged particles (mass m and charge q) are accelerated from rest by a potential difference V. They then enter a region of uniform magnetic field B perpendicular to the plane of diagram. Starting with Newton's second law, derive an expression for the radius R of the particles' path in the field in terms of m, q, V, and B.

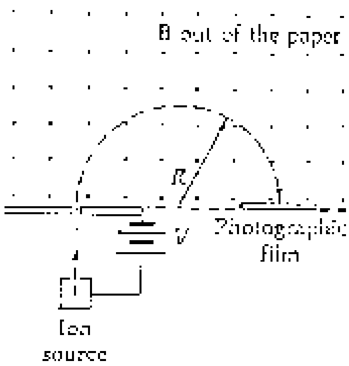


Figure 2

3. [10 %]

A mass m on the end of a spring of force constant k stretches the spring to a length l when at rest. The mass is now set into motion so it executes up-and-down vibrations while swinging back and forth as a pendulum. The mass moves in a figure-eight pattern in a vertical plane, as shown in Figure 3b. Express the force constant k in terms of m, l, and g.

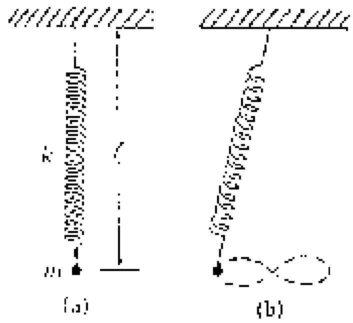
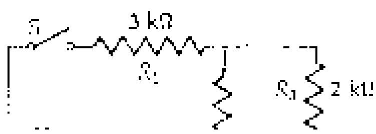


Figure 3

4. [10 %]

Consider the circuit in Figure 4. Find the steady-state currents in R_1, R_2, and R_3.



5. [10 %]

A rectangular wire loop of mass m, total resistance R, and dimensions as shown in Figure 5 is falling freely under gravity as it emerges from a region of uniform, horizontal magnetic field B. The plane of the loop is perpendicular to B. (a) Is the induced current in the loop clockwise or counterclockwise? (b) At a certain speed v, the loop falls without acceleration while emerging from the field. Show that this speed is $v = mgR/B^2a^2$.

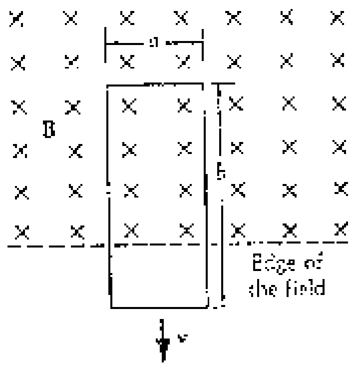


Figure 5

6. [20 %]

Phase velocity of a wave is given by $v_\phi = \omega / k$, where ω and k are the frequency and wave number respectively. For electromagnetic waves, the refractive index "n" is defined to be $n = c / v_\phi$. An EM wave propagates from region I into region II as illustrated in Figure 6. Show that the path of this EM wave is given by Snell's law,

$n_1 \sin\theta_1 = n_2 \sin\theta_2$.

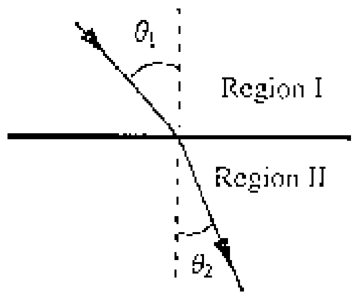


Figure 6

7. [20 %]

A spaceship travels at speed of 0.8 c, where c is the speed of light. This spaceship is coming back to the Earth. The ground station on the Earth finds this spaceship on radar screen and figures out that it takes 20 hours for this ship to land on the Earth. If you are the commander of the ship, what would you expect to see on your control panel for the following data

(a) distance to the earth?

(b) time before landing?

(c) According to your operation handbook, the frequency of ground station's radar is set at 50 GHz. What frequency shall you choose in order to communicate with people in the ground Station?