Part A : Brief Questions (40%)

1. A person stands at one end of a canoe that is stationary relative to the shoe. He then walks to the opposite end of the canoe, away from the shore. ***How*** does the canoe move? (5%)

2. There are two oscillating systems: a simple pendulum and a block hanging from a vertical spring. You carefully adjust the length of the pendulum so that both oscillations have the same period. Now, these two oscillators are taken to the Moon. ***How*** do their periods change? (5%)

3. Two firefighters must apply a total force of 600N to steady a hose that is discharging water at a rate of 3600 liter/min. ***Estimate*** the speed of the water as it exits the nozzle. (5%)

4. A secret agent is trapped in a building on the top of an elevator car at a lower floor. He attempts to signal a fellow agent on the roof by tapping a message in Morse code on the elevator cable so that transverse pulses move upward on the cable. (a) As the pulses move up the cable toward the accomplice, does the speed with which they move say ***the same***, ***increase***, **or** ***decrease***? (2%) (b) If the pulses are sent 1s apart, do they receive ***more than***, ***less than***, **or** ***exactly*** 1s apart by the agent on the roof? (3%)

5. An infinitely slab of charge of thickness $2t$ lies in the xy-plane between $z = -t$ and $z = +t$. The volume charge density ρ (C/m^3) is a constant. (a) ***Find*** (3%) and (b) ***draw*** (2%) the electric field from $z = 0$ to $z = +3t$.

6. A capacitor is made of two parallel plates with air between them. A student is attempting to determine the work lost or gained when the two plates are moved apart. The plates, each of area A, are connected to a battery of potential difference V. The student sets the initial separation of the plates to d_1, and they are to be moved further apart to a separation d_2. ***What*** is the work done in changing the separation from d_1 to d_2? (5%)

7. A person looking into an empty container is able to see the far edge of the container's bottom as shown in Figure 1(a). The height of the container is h, and its width is d. When the container is completely filled with a fluid of index of refraction n and viewed from the same angle, the person can see the center of a coin at the middle of the container's bottom as shown in Figure 1(b). ***Find*** the ratio h/d in terms of n. (5%)

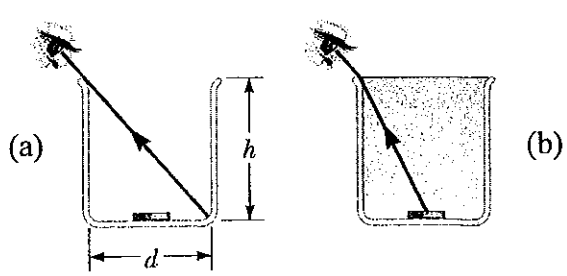

Figure 1

8. A plane electromagnetic wave varies sinusoidally at 90.0 MHz as it travels through vacuum along the positive x direction. The peak value of the electric field is 2.00 mV/m, and it is directed along the positive y direction. (a) ***Write down*** expressions for the space and time variations of the electric field and of the magnetic field. Include both numerical values and unit vectors to indicate directions. (3%) (b) ***Find*** the intensity this wave carries through space. (2%)

Part B : Problems (60%)

9. Two blocks are connected by a light string that passes over a frictionless pulley, as shown in figure 2. The block of mass m lies on a frictionless incline of angle θ relative to horizontal and is connected to a spring of spring constant k. The block of mass M is hanged vertically. The system is released from rest when the spring is unstretched.
   (a) ***Calculate*** the maximum extension of the spring. (5%)
   (b) ***What*** is the speed of M when the spring extends half of its maximum extension? (10%)

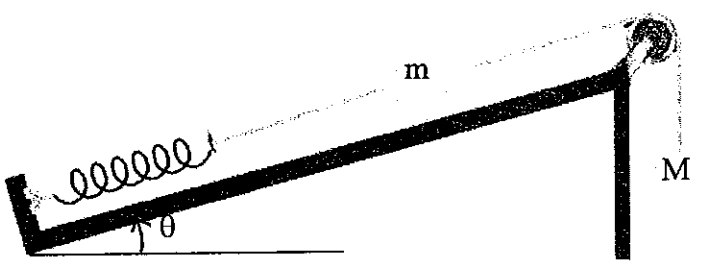

Figure 2

10. A uniform bar of mass m lies symmetrically across two rapid rotating fixed rollers A (counterclockwise) and B (clockwise) with distance L between each roller and center of mass of the system, as shown in figure 3. The rollers slip against the bar with coefficient of kinetic friction μ_k. Let the bar is displaced horizontally <u>left</u> by a distance x and then released. Neglect the friction between the floor and rollers.
    (a) ***What*** are the normal forces of both rollers exerted on the bar in terms of distance x? (8%)
    (b) ***Find*** the equation of motion for x. (5%)
    (c) ***What*** is the period T of the resulting horizontal simple harmonic motion of the bar? (2%)

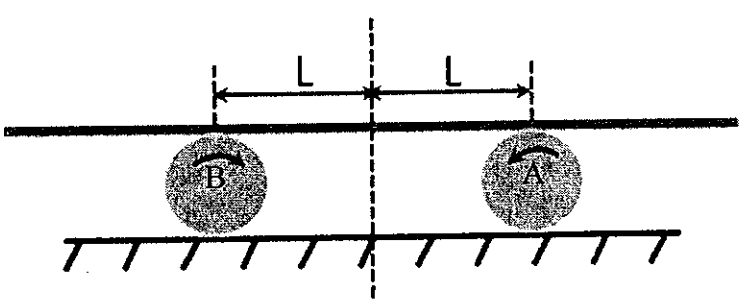

Figure 3

11. A long rectangular conducting loop, of length L, resistance R and mass m, is hung vertically in a horizontal, uniform magnetic field B, as shown in figure 4. The magnetic field exists only above line PQ.
    (a) When this loop is dropped, it initially accelerates, then reaches a constant velocity, and finally falls freely under the influence of gravity. ***Explain.*** (3%)
    (b) ***Find*** the constant velocity reached by the loop. (4%)
    (c) When the loop is falling at constant velocity, ***calculate*** the power expended by the force due to gravity and the rate of electrical heat generation in the loop. (6%) ***What*** is your conclusion from the calculated result? (2%)

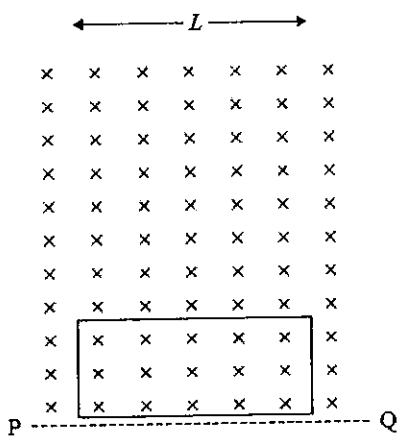

Figure 4

12. (a) ***Find*** the total electric potential energy of a conducting solid sphere of radius R that carrier a total charge Q distributed uniformly on its surface. (4%)
    (b) ***Find*** the total electric potential energy of a nonconducting solid sphere of radius R that carrier a total charge Q distributed uniformly throughout its volume. (6%)
    (c) Four identical particles, each having charge q and mass m, are released from rest at the vertices of a square of side L. ***How fast*** is each particle moving when their distance from the center of the square doubles? (5%)