Physics 1B: Review for Final Exam

Problem Worksheet

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In this worksheet we review material from the following chapters of Young and Freedman (plus some additional concepts):

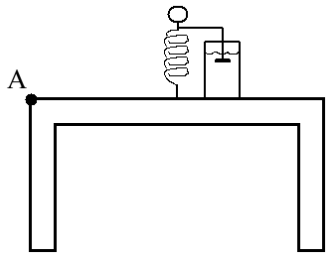
- Chapter 13: Periodic Motion
- Chapter 15: Mechanical Waves
- Chapter 16: Sound and Hearing
- Chapter 25: Current, Resistance, and Electromotive Force
- Chapter 26: Direct-Current Circuits

1. *Damped harmonic oscillation of a charged bob.* A spring of relaxed-length L and spring constant k is attached to the center of a tabletop of width W. An arm of negligible weight is attached to the spring with one end immersed in a viscous fluid that provides a damping constant b for oscillation of the spring. A small bob of mass m with charge q (insulated so the charge does not escape) is attached to the spring and held (by you) so that there is no force between the bob and the spring. You let go of the bob at time $t = 0$.

   (a) What is the height y of the bob above the tabletop as a function of time?

   (b) Using what you know about electric fields, what is the magnitude of the electric field at the edge of the tabletop (point A in the 2D drawing) as a function of time?

   (c) What is the magnitude of the electric field at the edge of the tabletop after a very long time?

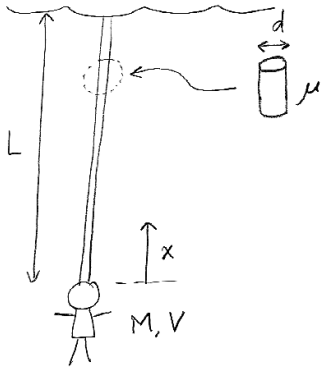


2. *Mechanical wave of variable speed.* (Y&F 15.82) A deep-sea diver is suspended beneath the surface of Loch Ness by a cable of length L that is attached to a boat on the surface. The diver and his suit have a total mass M and a volume V. The cable has a diameter d and a linear mass density μ. The diver thinks he sees something moving in the murky depths and jerks the end of the cable back and forth to send tansverse waves up the cable as a signal to his companions in the boat.

   (a) What is the tension in the cable at its lower end, where it is attached to the diver? Do not forget to include the buoyant force that the water (density ρ_{w}) exerts on him.

   (b) What is the tension in the cable a distance x abover the diver. The buoyant force on the cable must be included in your analysis.

   (c) The speed of transverse waves on the cable is given by $v = \sqrt{F/\mu}$. The speed therefore varies along the cable, since the tension is not constant. (This expression neglects the damping force that the water exerts on the moving cable.) Integrate to find the time required for the first signal to reach the surface.

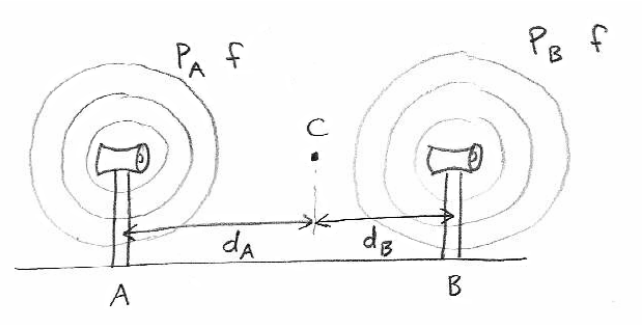


3. *Sound wave interference.* (∼Y&F 16.84) Two loudspeakers, A and B, radiate sound uniformly in all directions in air at 20 °C. The acoustic power output from A is 8.00×10^{-4} W, and from B it is 6.00×10^{-5} W. Both loudspeakers are vibrating in phase at a frequency of 172 Hz.

   (a) Determine the difference in phase of the two signals at a point C along the line joining A and B, 3.00 m from B and 4.00 m from A.

   (b) Determine the intensity at point C from speaker A if speaker B is turned off and the intensity at point C from speaker B if speaker A is turned off.

   (c) With both speakers on, what is the intensity at C?



4. *Current and resistance between concentric spheres.* (Y&F 25.64) The region between two concentric conducting spheres with radii a and b is filled with a conducting material with resistivity ρ.

   (a) Show that the resistance between the spheres is given by $R = (\rho/4\pi)(1/a - 1/b)$.

   (b) Derive an expression for the current density as a function of radius, in terms of the potential difference V_{ab} between the spheres.

   (c) Show that the result in part (a) reduces to $R = \rho L/A$ when the separation $L = b - a$ between the spheres is small.

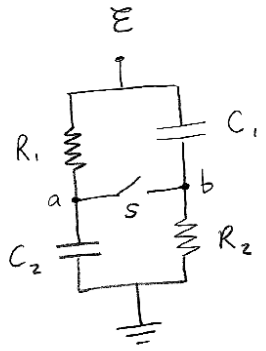
5. *Voltages in an RC circuit with a switch.* (Y&F 26.74)

   (a) What is the potential of point a with respect to point b in the figure below when switch S is open?

   (b) Which point, a or b is at higher potential?

   (c) What is the final potential of point b with respect to ground when switch S is closed?

   (d) How much does the charge on each capacitor change when S is closed?



6. *Equivalent resistance of a cube frame of resistors.* (Y&F 26.92) Suppose a resistor R lies along each edge of a cube (12 resistors in all) with connections at the corners. Find the equivalent resistance between two diagonally opposite corners of the cube (points a and b in the figure).