Sample Final Exam Questions

Physics 102
May 2003

These questions have appeared on previous final exams in Physics 102 at William & Mary.

- 1. A water bed has dimensions 2m x 1.5m x 0.3m and is filled with water at a temperature of 10°C. It is too cold for comfortable sleep and you must raise the temperature to 22°C.
  (a) How much energy is required to do this?
  (b) How long will it take for a 500 watt heater to do the job?
  (c) The heater plugs into the 110 volt (rms) wall socket. What is the resistance of the heater?
  (d) Virginia Power rates are 10 cents/kW hr. What did it cost to heat the water?
  Data: The specific heat of water is 4.18 kJ/kg and the density of water is 1000 kg/m^3.

- 2. An inexperienced spear fisherman aims his spear along the line of sight to a fish. His line of sight makes an angle of 30° with the surface of the water. The fish is 1 meter below the surface of the water. What is the distance D by which the spear misses the fish ($n_{\text{water}} = 1.33$).

- 3. A circular coil is located in a magnetic field. The coil has 5 turns, a total resistance of 10Ω, and a radius of 1 cm. The magnetic field is time-dependent, and is given by $\mathbf{B}(t) = 10\mathbf{i} + 5t\mathbf{j} + (8 + 4t + 2t^2)\mathbf{k}$ in units of Tesla.
  (a) Assume the plane of the coil is perpendicular to the x-axis. Find $\Phi_B(t)$ and the current in the coil, $I(t)$.
  (b) Repeat, this time assuming the plane of the coil is perpendicular to the z-axis.

- 4. A long wire of circular cross section and radius R carries a total current I_1 along the x-axis, which is distributed uniformly through the wire.
  (a) Find the magnetic field due to this current for the regions $0 \leq r \leq R$ and $r > R$. (r is the radial distance from the center of the wire.)
  (b) Plot $B(r)$ vs. r for $0 < r < 3R$.
  (c) An electron is moving with speed v parallel to and directly above the wire at a distance $r = 2R$. What is the magnitude and direction of the force on the electron?

- 5. A metallic spherical shell of outer radius R_1 has a total positive charge Q distributed uniformly on its surface.
  (a) Find the electric field for $0 < r < R_1$ and $r > R_1$. Plot $E(r)$ vs. r for $0 < r < 2R_1$.
  (b) How much work is required to bring a proton, of charge q_p, that was

at rest and located at a distance of $4R_1$ in to a distance of $2R_1$ from the center of the metallic sphere?

- 6. A storm cloud with a flat bottom of area 10 square kilometer is 0.5 km above the surface of the earth. The cloud carries positive charge distributed uniformly over this surface. A corresponding negative charge is induced to the surface of the earth.
  (a) Suppose the electric field between the cloud and the earth is 10^5 volts/m. What is the total charge on the cloud?
  (b) What is the capacitance of the storm cloud-earth system?
  (c) What is the voltage difference between cloud and earth?
  (d) How much energy is stored in the cloud-earth system?

- 7. A 1Ω light bulb, capacitor (C), and inductor ($L = 1$mH) are connected in series with an AC voltage supply $V(t) = 110\sqrt{2}\cos(2\pi \cdot 60t)$. What value of C makes the bulb burn the brightest? The light bulb glows white. The resulting electromagnetic waves that your eye can detect are characterized by ... (Write an intelligent and correct ending; include something quantitative).

- 8. A soap bubble ($n = 1.3$) appears dark (*i.e.* no light is reflected) when light of 700 nm wavelength is incident normal to its surface. What possible thicknesses could the film have?

- 9. A pair of narrow slits separated by 1μm are used to determine the wavelength of a monochromatic beam of light. If the intensity is maximum at $\theta = 0°$ and next at $30°$, what is the mystery wavelength?

- 10. What is the permittivity ϵ of quartz ($n = 1.544$)?

- 11. A person 1.7 m tall stands 8 m from a circular mirror with focal length 2 m. Draw the ray diagram and determine the distance of the image from the mirror. What is the magnification?

- 12. A magnifying glass with focal length 5 cm is held 2 cm away from a page of writing. How much is the writing magnified?

- 13. A glass prism with the profile of an equilateral triangle sits with one face on a horizontal table top. A red laser shines horizontally onto the prism. Calculate the angle with respect to the horizontal of the light that emerges from the prism if $n_{\text{red}} = 1.50$ for the glass.

- 14. In some hands-on science museums, you may find the trick of a levitating coin. Suppose we begin with a concave mirror at the bottom of a box, such that its center of curvature is even with the top of the box. The focal length is 2 cm.
  (a) Where inside the box should we fix a real penny such that the image of that penny is above the top of the box and is twice the size of a real penny?

(b) How far is the image from the mirror?
(c) Is the image real or virtual?

- 15. An infinitely long non-conducting cylinder of radius a has a surface charge density σ. The cylinder rotates with angular velocity ω. What are the electric and magnetic fields (magnitude and direction) at all points in space?

- 16. A 10 volt battery is connected in series with 1) a 10Ω resistor, 2) a parallel combination of a 4Ω and a 6Ω resistor, 3) a 5μF capacitor, 4) a parallel combination of a 2μF and a 3μF capacitor, and 5) a switch.
(a) Calculate the charge on each capacitor at a long time after the switch is closed.
(b) What is the RC time constant for charging up this circuit?
(c) Determine the current $I(t)$ and graph this as a function of time.