

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/m³.
- 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 ($L = 1\text{mH}$) 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 $1\mu\text{m}$ are used to determine the wavelength of a monochromatic beam of light. If the intensity is maximum at $\theta = 0^\circ$ 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 $5\mu\text{F}$ capacitor, 4) a parallel combination of a $2\mu\text{F}$ and a $3\mu\text{F}$ 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.