Power Education: Electromagnetism Review Problems

December 5, 2002

Note: These are not yet complete nor comprehensive. Refer to in-class notes, and old tests to get a more complete review!! It's unlikely I'll finish them before the exam (though possible)

1 Electric Fields

1. Find the tension in the 150 m, non-conducting cable connecting two 5 meter radius spheres, one carrying a uniform surface charge of 3 millicoulombs and the other carrying a uniform surface charge of 5 millicoulombs.

2. Find the electric field at (-2,3) due to a charge of 5 nanocoulombs at (0,1), a charge of -3 nanocoulombs at (0,4), and a final charge of 2 nanocoulombs at the origin.

3. Find the electric field at the point (0,1) due to a uniform line of charge going from (0,-4) to (0,-1).

4. Two balls of mass 50 grams each are carrying equal charges. If they are attached to strings 0.5 meters long and, due to repulsion, have an angle of 30 degrees between them, find the charges.

5. Find the electric field on the y-axis due to a circle of uniform charge, 2 $microcoulombs/m^2$, with radius 0.5 m, centered on the origin in the x-z plane.

2 Electric Flux and Gauss's Law

6. Find the flux through a circle of radius 2 meters in the y-z plane, if the electric field is given by $\vec{E} = (2, 3, 4)$

7. Use Gauss's law to find the electric field everywhere in the figure.

8. Use Gauss's law to find the electric field inside and outside the sphere with

charge density $\rho = \alpha r^2$.

9. Use Gauss's law to find the electric field in all regions due to a wire carrying charge 3 coulombs/meter surrounded by a cylinder of radius 0.5 meters carrying charge -2 coulombs/meter.

10. Use Gauss's law to find the electric field of a plate of uniform charge.

11. Find the electric field is a potential function is given by $V = -xy + 3y^2 + 2z^3 - 5$.

Solution: Take the gradient.

$$\vec{E} = -\nabla V = -\left(-y, -x + 6y, 6z^2\right)$$

3 Electric Potential Energy and Electric Potential

12. A proton starting at rest is accelerated through a potential difference of 30 volts. Find the kinetic energy and the momentum. Suppose an electron at rest goes through a voltage difference of similar magnitude, find its energy and momentum, and compare to the proton.

4 Capacitors

13. Two 3-Farad capacitors are in series with each other and with two 2-Farad Capacitors in parallel. If a voltage of 10 V. is applied across the circuit, find the charges and voltage drops for each of the capacitors.

5 Resistors and Direct Current Circuits

14. Find the currents in all branches of the following diagram.

15. Suppose the resistivity of a material is $5 \times 10^{-6}\ \Omega - meter$. Using a volume of 0.2 m^3, create a wire with current density 5 $coulomb/m^2$

6 Magnetic Forces

16. A proton enters a cyclotron with magnetic field 4 T, going perpendicular to the field. If the proton is going 50,000 m/s per second, what is the frequency of

its gyration?

Solution:

$$-\frac{mv^2}{r} = -qvB$$

$$v = \frac{2\pi r}{T}$$

Combine and solve for T, flip to get f.

17. Velocity selector problem. Particles travelling in the positive y-direction enters a velocity selector with $\vec{E} = 5000\hat{z}$ and $B = 0.2\hat{x}$. (A) What velocity particle makes it through? (B) If it makes a semicircle with radius 5 mm, what's the charge to mass ratio?

18. Calculate the net force of a long straight wire carrying current 10 amps on a rectangle, to the right of the wire and carrying current two amps in the clockwise direction. Assume the parallel sides are 2 meters long and the perpendicular sides are 1 meter long, and that the nearest side is 1 meter away.

7 Magnetic Fields

19. Use Ampere's law to compute the magnetic field of a cable with inner radius a and outer radius b, carrying constant current density, J_0.

Solution: Outside the cable it's just like a long straight wire, while inside the inner radius cable the field is zero. Within $a < r < b$, however, ignoring difference in permeability, the field is

$$B \cdot 2\pi r = \mu_0 I_{inside} = \mu_0 J_0 \left(\pi r^2 - \pi a^2\right)$$

Divide and you're done.

8 Magnetic Induction

20. Find the self-inductance of a toroidal solenoid.

Solution The toroidal solenoid magnetic field can be found from Gauss's law:

$$B(2\pi R) = \mu_0 NI \Rightarrow B = \frac{\mu_0 NI}{2\pi R}$$

The self-inductance is given by

$$L = \frac{N\phi_B}{I} = \frac{NBA}{I}$$

The area is the cross section area of the tube. Dump in B and you're there, note that I cancels.

21. Two three Henry inductors, each in series with a 4 ohm resistor, are put in parallel, these put in series with a 7 ohm resistor. If ten volts is put across this configuration, find the current after the current achieves steady state.

9 Electromagnetic Waves

22. If the electric field of an electromagnetic wave is 3 V/m, what is the magnetic field at that point?

23. Find the Poynting vector, if the electric field is such and such and the magnetic field is such and such at a given time.

24. If the magnetic field is given as

$$\vec{B} = 2 \times 10^{-7} \cos(kx - \omega t)\hat{z}$$

, and the wave has wavelength 0.2 meters, find the electric field, if the wave is propagating in the positive y-direction.

10 Diffraction

25. A soap bubble reflects light, enhancing wavelengths of 400 nm. Find the minimum thickness of the bubble.

26. In a Young's experiment the first maximum is 0.2 cm up from the central maximum, when the screen is 2.5 meters away from the slits. Determine the slit separation approximately, assuming small angles, and exactly, if the light used is 500 nm.

27. A diffraction grating has 2000 lines per centimeter. If 400 nm light is shown on it, the first maximum is 0.3 cm above the central maximum, while if 600 nm light is shown, the first maximum is 0.5 meters up from the central maximum. Find the slit separation.

28. Wedge problem.

29. Suppose coherent light is split by a mirror and recombined, and the path length difference results in total destructive interference. If this path difference is 0.00025 meters, what is the maximum wavelength?

11 Quantum Theory

30. Find the wavelength of maximum intensity in the Sun, which is very nearly a perfect black body.

31. Find the de Broglie wavelength of an alpha particle (helium nucleus) with kinetic energy of 2000 eV.

Solution:

$$\lambda = \frac{h}{p}$$

$$E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$

Find the momentum and plug in.

32. Find an approximate momentum of a neutron in a deuteron, using the uncertainty principle.

Solution: Use the fact that

$$\Delta p = \sqrt{< p^2 > - < p >^2} = \sqrt{< p^2 >}$$

and that the deuteron is about one femtometer in size. Dump into Heisenberg's uncertainty principle for a gross estimate of p.

33. Find the wavelength of a photon with energy 2 MeV.

34. In a photoelectric experiment, voltage must be increased to 2 volts to stop the current. What must the voltage be adjusted to in order to stop the current when the light intensity is tripled? (A) 6 V. (B) 12 V (C) 4 V (D) no change (E) none of these

The answer is none of these, since intensity doesn't affect the maximum kinetic energy, only the frequency.