

State Any Assumptions You Need To Make – Show All Work – Circle Any Final Answers
Use Your Time Wisely – Work on What You Can – Be Sure to Write Down Equations
Feel Free to Ask Any Questions ☆1c ☆2c ☆4a ☆4b

The Phantom Menace (50,000 points)

1.) Consider the two protons in the nucleus of helium. At a distance of 1.00×10^{-15} m, we found in class that the force between the protons amounted to about 231. N. (a) Write down the equation for the Coulomb repulsive force between two protons *but do not solve*.

(b) Find the Coulomb repulsive force between the two protons when they are at opposite ends of the universe. Assume that there is nothing else in the universe.

☆(c) The work to move the protons apart will be $\int_a^\infty \vec{F}_E \cdot d\vec{r}$, where $a = 1.00 \times 10^{-15}$ m. Do the integration and find the work.

(d) We found in class that the initial acceleration of the two protons was quite high. Since any $1/r^2$ force such as gravity or electric is a conservative force, the work comes from the change in the potential energy, and goes into the change in the kinetic energy. Assuming the proton begins from rest, use the classical K.E. to find the final speed of the proton – assuming nothing else in the universe. *If you did not get an answer to (c), use 1.00×10^{10} J.*

(e) Repeat step (d), except this time use the relativistic K.E. formula. Which is required for the speeding proton – classical or relativistic?

An Electrifying Discussion (50,000 points)

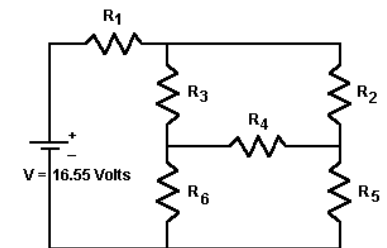
2.) An electric field is given by the equation $\vec{E} = axyz \hat{k}$, where $a = 1.00 \text{ N/C}\cdot\text{m}^3$. (a) Evaluate $\vec{E} \cdot \hat{i}$, $\vec{E} \cdot \hat{j}$ and $\vec{E} \cdot \hat{k}$.

(b) Find the value of E for $z = 0$.

☆(c) A cube of side $d = 1.00$ m is placed with one corner at the origin and the diagonal corner at $x = y = z = +d$. Calculate the total flux coming out of the cube, $\Phi_E = \oint \vec{E} \cdot d\vec{A}$.

(d) Use Gauss' Law to determine how much charge is inside the cube.

(e) Technically, this circuit cannot be solved using network reduction, but requires Kirchhoff's Laws. However, if I told you that all the resistors were 111Ω and that because of symmetry *one* of the resistors was actually quite useless (*i.e.* no current flows through it and you could remove it or shoot it with a .45 pistol and not change the circuit at all), then find the equivalent resistance of this circuit by network reduction.



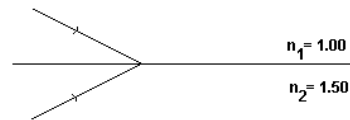
“Lights, Cameras, Action!” (50,000 points)

3.) (a) Suppose it takes a force of 10,000. N to blow apart the insulation along a 30.0 meter extension cord. Wires carrying opposing currents experience a repulsive force. If a D.C. current of I is sent down one wire and then returned to generate a force of 10,000 N – what is the value of the current, I ? The two wires are 5.00 mm (0.00500 m) apart.

(b) At the wall socket, a voltmeter tells you that there is a potential difference of 120. V. At the end of the extension cord, the same voltmeter tells you that there is a potential difference of 98.0 V. What is the resistance, R , of the extension cord?

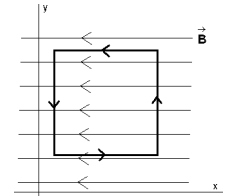
(c) How much energy per second is being dissipated in this extension cord?

Two light rays hit an air-glass boundary at $\theta = 60^\circ$. Make your calculations and show on the diagram what happens to the refracted and reflected rays of (d) the light ray coming from the air and (e) the light ray coming from the glass.

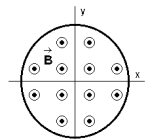


Dr. Phil’s Magnetic Personality (50,000 points)

4.) ☆(a) A uniform \vec{B} -field in the $-x$ direction passes through a region of space. Use Ampère’s Law to find the current, I , enclosed in the Ampèrian Loop in the xy plane, as shown.

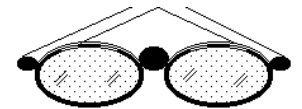


☆(b) Find the magnetic flux, $\Phi_B = \int \vec{B} \cdot d\vec{A}$, in a circular area of radius a in the xy plane, centered on the origin, for a magnetic field $\vec{B} = br\hat{k}$, where b is an arbitrary constant.



You’re standing in the middle of a giant solenoid electromagnetic that at 4.00 meters in diameter is roughly twice as tall as you are, and is 15.0 meters long with 125,000 windings. As you look down the length of the coil ($+x$ -axis), a current, $I = 155$ A, goes above your head from left to right (and around to under your feet from right to left). (c) From your vantage point, does the B-field come toward you or go away from you?

You are holding a 1/100th scale model of the solenoid in hand, lined up with its bigger cousin. Its cross-sectional area is 1/10,000th (0.0000100) that of the big solenoid. (d) What is the magnitude of the B -field from the big coil that is passing through the smaller coil?



Dennis Rodman, the strange visitor from another planet who once played for the Chicago Bulls basketball team, decides to get out his college physics textbook and design a pair of really cool shades. He wants a maximum reflection coating ($n = 1.36$) on his glasses ($n=1.60$) so that they will brightly reflect 555 nm yellow light... to match his hair *du jour*. (e) What is the minimum thickness, d , for Dennis’ maximum reflection coating?

