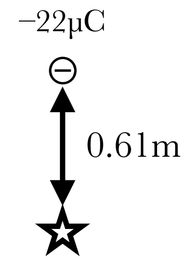
Physics 102 Homework #10

not to be turned in!

1. What is the electric field 0.61m below a -22μC negative charge? Give the magnitude **and direction**, please.



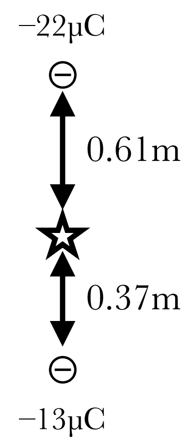
The electric field due to a point charge is $|\vec{E}| = k\frac{|q_s|}{r^2}$, so

$$E = (9 \times 10^9 \text{Nm}^2/\text{C}^2)\frac{22\mu\text{C}}{(0.61\text{m})^2} = 5.32 \times 10^5 \text{N/C or } \mathbf{532kN/C.}$$

Electric fields point towards the negative charge, or **upward**. Thus

$$\vec{E} = +532\text{kN/C} \uparrow .$$

2. Now suppose we add a -13μC charge 0.37m below the star. What is the electric field at the star now?



The electric field due to the second point charge is

$$E_2 = (9 \times 10^9 \text{Nm}^2/\text{C}^2)\frac{13\mu\text{C}}{(0.37\text{m})^2} = 8.55 \times 10^5 \text{N/C or } 855\text{kN/C}$$

towards the negative charge, which is downward. Thus

$$\vec{E}_2 = 855\text{kN/C} \downarrow .$$

The total electric field at the star is the sum of these two fields:

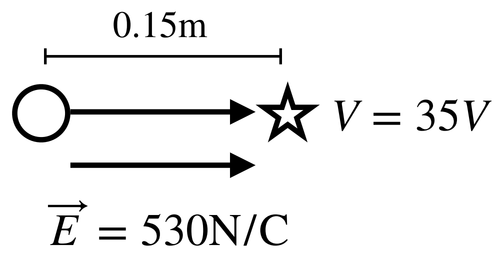
$$\vec{E} = \vec{E}_1 + \vec{E}_2 = 532\text{kN/C} \uparrow + 855\text{kN/C} \downarrow .$$

If we call downward the "positive direction", then

$$\vec{E} = \vec{E}_1 + \vec{E}_2 = (-532 + 855)\text{kN/C} = +323\text{kN/C} = \mathbf{323kN/C \downarrow.}$$

Some folks in the past used the Pythagorean Theorem, but you only use that if the vectors are perpendicular to each other (one horizontal, one vertical).

3. A star and a circle are 0.15m apart. The potential at the star is $V = 35$V. The electric field between the two shapes is 530N/C. What is the potential at the circle?



When the potential difference between two points a distance d apart is ΔV, the average electric field between them is $E_{avg} = \frac{\Delta V}{d}$. Thus $\Delta V = Ed$ = (530N/C)(0.15m)=80V. The electric field points "downhill", which means that the circle is 80V higher than the 35V star, or **115V.**

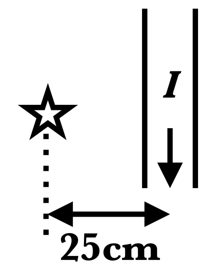
A lot of folks in the past got the ΔV correctly, but then did something sophisticated with V_f and V_i and got mixed up. The problem is that this equation $E = \Delta V/d$ doesn't really handle negative signs very well or directions very well. I really recommend doing it the way I did: the change is 80V, and the circle is uphill, so it must be 80V higher than 35V.
Another way would be to think of ΔV as $V_{\text{high}} - V_{\text{low}}$, where the electric field points from V_{high} to V_{low}. In this case, 35V must be V_{low}, so $80 = V_{\text{high}} - 35 \implies V_{\text{high}} = 115\text{V}$.

4. Referring to the same picture: if I place a +24μC charge in between the circle and the star, what is the force the charge feels due to the electric field? Include magnitude **and direction**, please.

The force on a target charge in an electric field is $\vec{F} = q_t\vec{E}$, and so the force on the 24μC charge is

$$\vec{F} = (24\mu\text{C})(530\text{N/C} \rightarrow) = \textbf{0.0127N to the right.}$$

5. What is the magnitude of the magnetic field at the star, if the current in this long, straight wire is I=0.37A?

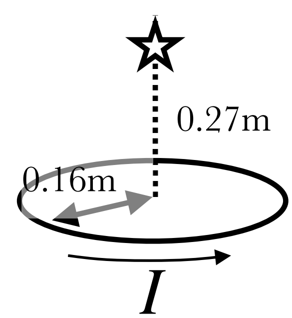


The field a distance r from a wire is given by

$$\vec{B} = \frac{\mu_0 I}{2\pi r} = \frac{(1.26\,\mu\text{T}\cdot\text{m/A})(0.37\text{A})}{2\pi(0.25\text{m})} = 0.3\mu\text{T} = 3.0 \times 10^{-7}\text{T}.$$

Though it's more precise to write $\mu_0 = 4\pi \times 10^{-7}\text{Tm/A}$, on a calculator it is more convenient to use $\mu_0 = 1.26 \times 10^{-6}\text{Tm/A}$ or $\mu_0 = 1.26\,\mu\text{T}\cdot\text{m/A}$.

6. This circular loop of wire has a radius of 0.16m, and carries a current of 0.45A counter-clockwise (as seen from above). What is the magnetic field (**magnitude and direction**) at the star, a distance of 0.27m above the center of the circle?



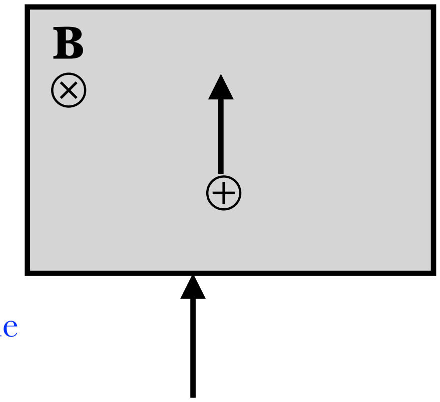
The field a distance z above the center of a loop of wire with radius R is

$$\vec{B} = \frac{\mu_0 I R^2}{2(z^2+R^2)^{3/2}} = \frac{(1.26\,\mu\text{T}\cdot\text{m/A})(0.45\text{A})(0.16\text{m})^2}{2[(0.27\text{m})^2+(0.16\text{m})^2]^{3/2}} = 0.23\mu\text{T}$$ **upward.**

A lot of people missed the instruction to include the *direction* of the field. Use a circle-line RHR to find it.

If you used $\frac{\mu_0 I R^2}{2z^3}$, you were assuming that z is much larger than R, and you got the answer 0.37μT. This isn't particularly close, so apparently that assumption is false.

7. The grey area contains a magnetic field of 3.9×10^{-2}T which points into the page. A +47μC charge with a mass of 2.5×10^{-9}kg is moving at 350m/s upward. What is the force (*magnitude and direction)* on the charge due to the magnetic field?



The force on a charge in a magnetic field is equal to $F = qvB$ if the charge is moving perpendicular to the field. Thus
$F = (47\mu C)(350 m/s)(3.9 \times 10^{-2} T) =$ **6.4×10^{-4} N**
To find the direction we use the "qvB right-hand rule": fingers point to the right, palm points into the page, thumb points up. Thus the force points **leftward** (perpendicular to both field and motion).

8. In the picture above, the charge will start spinning in a circle. What will be the radius of the circle? And will the charge spin clockwise ↻ or counterclockwise ↺?

The force will cause the charge to turn to the left, and it will keep turning to the left, taking a **counterclockwise** path. The radius of the circle is given by

$$r = \frac{mv}{qB} = \frac{(2.5 \times 10^{-9} kg)(350 m/s)}{(47\mu C)(3.9 \times 10^{-2} T)} = \mathbf{0.48m} \text{ or } 48cm.$$