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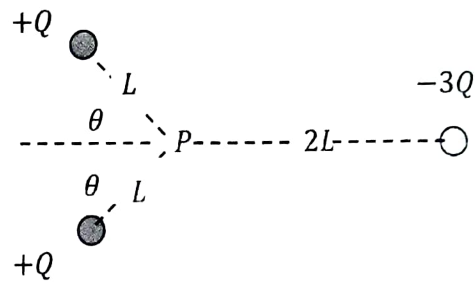
After this activity you should know: • *Be able to recognize when to use electric fields and when to use electric potential.*

1. Three charges are arranged as shown.



a. The magnitude of the electric field at point P due to one of the $+Q$ charges is E_o. What is the magnitude of the net electric field at P? Write answer in terms of E_o and/or θ only.

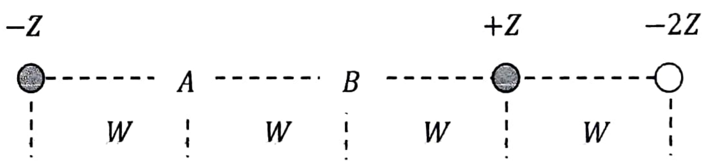
$$2E_o\cos(\theta) + \frac{3}{4}E_o$$

$$= \frac{11}{4}E_o$$

b. The electric potential at point P due to one of the $+Q$ charges is V_o. What is the net voltage at point P? Take $V = 0$ at infinity. Write answer in terms of V_o and/or θ only.

$$2V_o - \frac{3}{2}V_o = \frac{1}{2}V_o$$

2. Three charges are on a line as shown. An electron (charge $-e$, mass m) is released from rest at point A. We want to determine how fast the electron is moving at point B.



a. A common mistake is to calculate the electric force on the electron at point A and then use Newton's 2nd law and constant acceleration kinematics to find the speed of the electron at point B. Why won't this work?

The acceleration isn't constant

b. Use conservation of energy to determine the speed of the electron a point B.

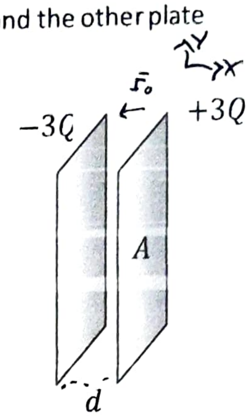
$$KE_f = -q\Delta V$$

$$= q\left(\cancel{\frac{-kZ}{2w}} + \cancel{\frac{kZ}{w}} - \cancel{\frac{kZ}{w}} + \cancel{\frac{kZ}{w}} - \cancel{\frac{kZ}{2w}} + \frac{2}{3}\frac{kZ}{w}\right)$$

$$\frac{1}{2}mv_f^2 = -(-e)\cdot\frac{2}{3}\frac{kZ}{w}$$

$$\boxed{v_f = \sqrt{\frac{4kZe}{3wm}}}$$

3. One way to generate a uniform electric field is to use a parallel plate capacitor. The two plates of the capacitor each have an area A and are separated by a small distance d. The plate on the left has charge $-3Q$ and the other plate has a charge $+3Q$.



   a. What is the magnitude and direction of the electric field in the gap between the plates?

~~Left~~ $-x$

$$\frac{\cancel{2}\eta}{\cancel{2}\epsilon_0} = \frac{\cancel{2}}{\cancel{2}\epsilon_0}\cdot\frac{3Q}{A}$$

   b. Which plate is at a higher voltage?

$+3Q$

   c. What is the voltage across the plates? ("Voltage across" means the absolute value of the voltage difference.)

$$|\Delta V| = -Ed = \left|-\frac{3Q}{A\epsilon_0}\cdot d\right| = \frac{3Qd}{A\epsilon_0}$$

   d. A positive ion (charge $+2e$, mass m) is traveling at speed v_o at the positive plate toward the negative plate. What is the ion's kinetic energy just before it hits the negative plate?

$$\Delta V = \frac{\Delta U}{q} = -\Delta KE$$

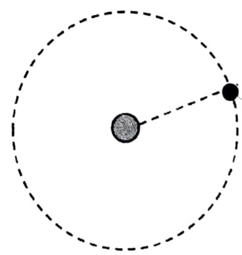
$$= \frac{1}{2}m(v_0^2 - v_f^2)$$

$$-\left(\frac{3Qd}{A\epsilon_0}\cdot 2e + \frac{1}{2}mv_0^2\right) = \boxed{\frac{1}{2}mv_0^2 - \frac{\cancel{3}6Qde}{A\epsilon_0}} = KE_f$$

4. The Bohr model (Neils Bohr, 1913) treats the hydrogen atom as a minature solar system. Although the model is incorrect it provided early insight into the quantum mechanics of atoms. Assume the electron (mass m, charge $-e$) is in a circular orbit of radius r around the proton (charge $+e$, mass M). $M \gg m$ so the proton is stationary.

   a. From Physics 211, an object moving in a circle at constant speed will experience a centripetal acceleration v^2/r directed toward the center of the circle. Use circular motion dynamics to determine the speed of the electron in orbit. Answer in terms of r, e, m and/or M. Gravitational forces are negligible at the atomic level.

$$m\frac{v^2}{r} = qE = -\frac{Ke^2}{\cancel{r}}\cdot\frac{r}{m} \qquad \boxed{|v| = \sqrt{\frac{Ke^2}{m}}}$$



   b. What is the kinetic energy of the electron in orbit? Answer in terms of e, r and/or m.

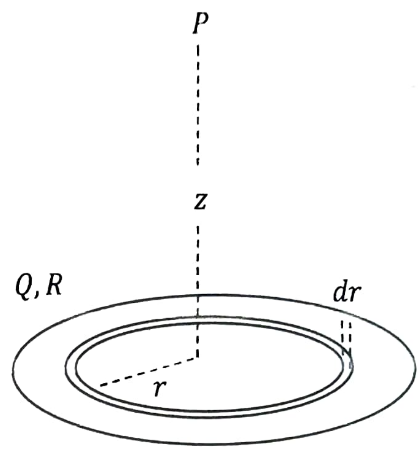
$$KE = \frac{1}{2}mv^2 = \frac{1}{2}\cancel{m}\left(\frac{Ke^2}{\cancel{m}}\right)$$

$$\boxed{= \frac{1}{2}Ke^2}$$

c. What is the total energy ($KE + U$) of the electron in orbit? Answer in terms of e, r and/or m.

$$U = \frac{Kqq}{r} = \cancel{Kq^2} \quad \boxed{\frac{Ke^2}{r} + \frac{1}{2}Ke^2}$$

5. **Bonus (4 – you must finish rest of worksheet to receive credit for bonus):** The diagram shows a thin circular disk of radius R with charge Q distributed uniformly over the surface. We want to find the electric potential a distance z above the center of the disk along its axis.



On the previous activity, we showed that the electric potential for a thin ring of radius r is

$$V = \frac{KQ}{\sqrt{R^2 + z^2}}$$

We can use this to find the electric potential of the disk by breaking up the disk into thin rings of radius r and very small thickness dr.

a. What is the charge dq in the thin ring of radius r and thickness dr? Answer in terms of Q, R, r and dr. Make sure your answer for dq has dimensions of charge.

Comment: Since the charge Q is spread uniformly over the area of the disk you will need to find the charge per area and then multiply by the area of the thin ring ($dA = 2\pi r\ dr$).

$$\frac{Q}{\cancel{2\pi} R^2} \cdot \cancel{2}\pi dr$$

$$\frac{Q}{\cancel{\pi} R^2} \cdot \cancel{\pi}(dr^2) = Q \cdot \frac{dr^2}{R^2}$$

b. What is the electric potential dV due to the thin ring of radius r and thickness dr at the point shown. Answer in terms of Q, R, z, r and dr. *Hint: you know the electric potential of a thin ring.*

$$dV = \frac{K\,dq}{r} = \frac{KQ\,dr^2}{R^2\sqrt{r^2 + z^2}}$$

c. Summing dV from the entire disk will give the total electric potential. Write down corresponding integral with limits. Do the integration. It should be a simple u-sub. Show work.

$$V = \frac{KQ}{R^2}\int_0^R \frac{dr^2}{\sqrt{r^2 + z^2}} = \frac{KQ}{R}\Big($$