Lecture 7 15.7-15.8, Review math. Field due to a long rod. iq05

1. Clicker **8-1** (Discussion related to **h3-11**): Effect on the measured field when the magnitude of the test charge is non-negligible.
2. Discussion on **h3-16**. (see p605, **E=0 and q=(Q/8)(L/r)^2**) Model estimate on the polarizability of a neutral atom: clicker **8-2**.
3. Charging and discharging.
   - Qualitative discussion on charging by induction.
   - Discharging: Spread the charges through the conducting medium.
4. Review Math (see class notes, **second bullet**): Trig functions, derivatives and an integral.
5. Field along x-axis (more generally along r-axis) due to a charged rod, **follow textbook**.

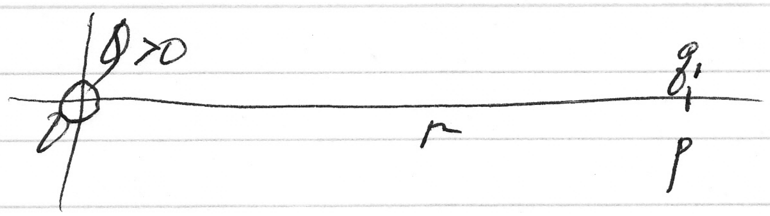
Class Announcements:

- **Clarification on iq-drops**:
  The 4-drops in our iq-grading system is <u>not</u> intended to be as an "entitlement", i.e to give student the "right" to miss four classes without legitimate excuses. During the semester each class is important. <u>I expect students to attend/participate every class, except for legitimate excuses</u>. Examples of legitimate excuses are: illness, a justified out of town trip, battery failure (hopefully the student will fix the problem right away, so that it will only cost one iq-credit). Absence due to religious holiday is another legitimate excuse. Use 1 of the four drops.

  Our 4-drops policy is the quick way (the e-way) to allow students to have up to 4 legitimate excuses without going into details to account for individual excuses. If any student who wants to ig05

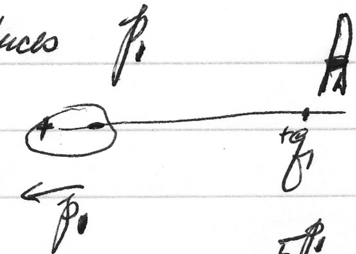
$$E = \lim_{q \to 0} \frac{F}{q}$$

What happens when q is finite. Look at 2 examples $q_2 > q_1 > 0$.



$$E_P^Q = \frac{kQ}{r^2} \qquad \rightarrow$$

Test charge q_1 at P. Induces p_1



$$E_A^{p_1} \quad \leftarrow$$

$$E_A = E_A^Q + E_A^{p_1}$$

$\rightarrow$ $\leftarrow$

$$E'_A = E_A^{+Q} + E_A^{p_2}$$

$\rightarrow$ $\leftarrow$

~~$q_2 > q_1$~~

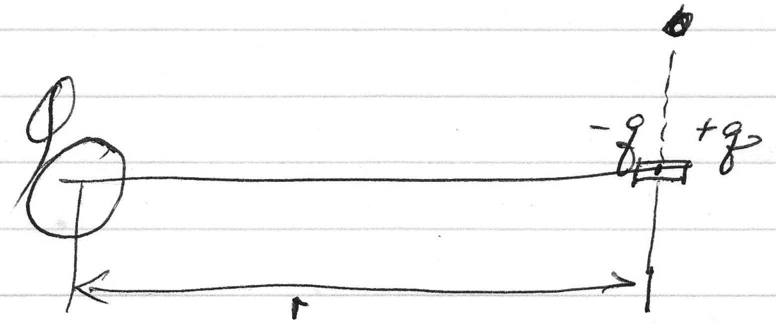
$q_1 < q_2$

$$E_A = E_A^Q + E_A^{p_1} \quad \leftarrow$$

$$E'_A = E_A^Q + E_A^{p_2} \quad \leftarrow$$

$\rightarrow$

HW 3-16



$$p = \alpha E$$

$$qL = \alpha \left(\frac{kQ}{r^2}\right)$$

Find q, α.

Assume center of the pipe : $E = E_0^Q + E_0^{dipole}$

$$\frac{kQ}{r^2} \qquad \frac{2kq}{\left(\frac{L}{2}\right)^2}$$

$$qL = \alpha \frac{2kq}{\left(\frac{L}{2}\right)^2}$$

$$\alpha = \left(\frac{L}{2}\right)^2 \frac{L}{2k} = \frac{\left(\frac{L}{2}\right)^3}{k}$$

Lec 7-3

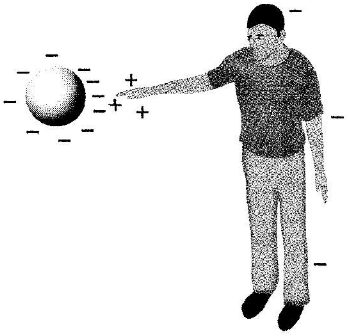


Figure 15.43 The metal is charged, and the person is uncharged but slightly polarized.

} "Neutralize" metal ball

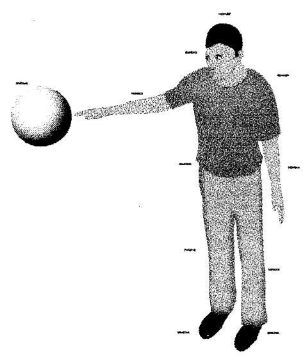


Figure 15.44 The net negative charge is distributed over a much larger area, nearly neutralizing the metal.

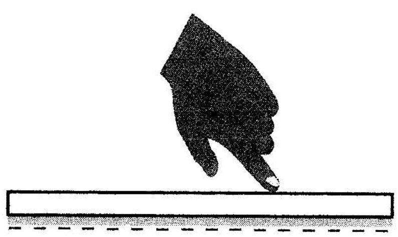


Figure 15.45 You run your finger along the slick side of the tape, and the tape seems to become neutralized.

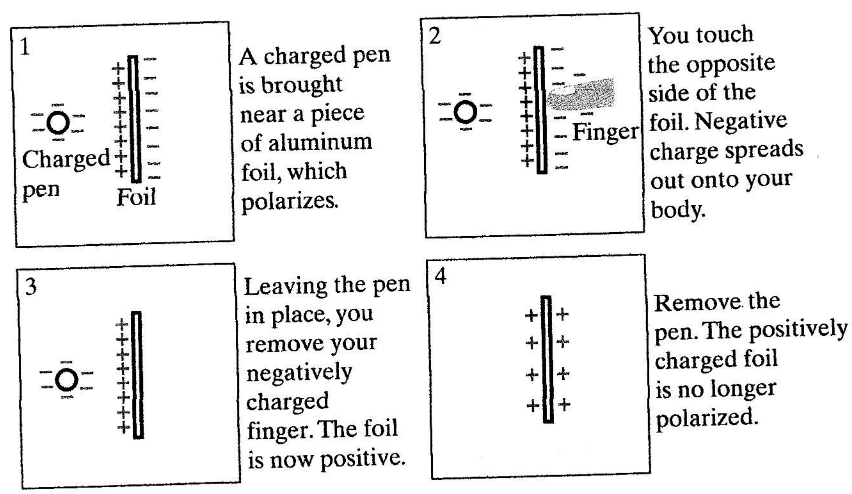


Figure 15.47

Charging by induction

■ Related experiment: 15.EXP.24

} "Neutralize the tape"

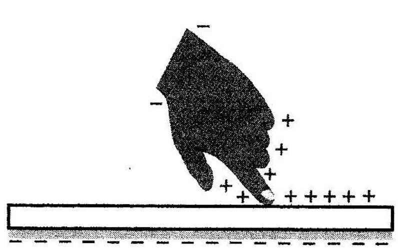
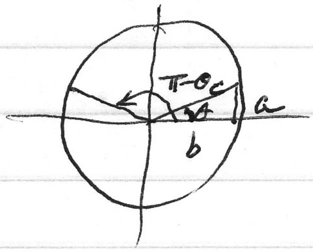


Figure 15.46 Positive ions from the salt solution on your skin are attracted to the negatively charged tape.

Review math:

1. Trig function –



$$\sin\theta = \frac{a}{c}, \quad \cos\theta = \frac{b}{c}$$

$$\sin(\pi-\theta) = \sin\theta, \quad \cos(\pi-\theta) = -\cos\theta$$

$$\tan\theta = \frac{a}{b} = \frac{\sin\theta}{\cos\theta}$$

2. Derivatives:

$$\frac{d\sin\theta}{d\theta} = \cos\theta, \quad \frac{d\cos\theta}{d\theta} = -\sin\theta$$

$$\frac{d\tan\theta}{d\theta} = \frac{d\,\frac{\sin\theta}{\cos\theta}}{d\theta} = \frac{\cos\theta\,\frac{d\sin\theta}{d\theta} - \sin\theta\,\frac{d\cos\theta}{d\theta}}{\cos^2\theta}$$

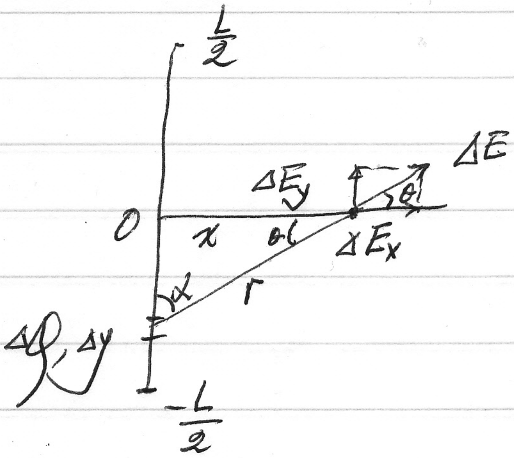
$$= \frac{\cos^2\theta + \sin^2\theta}{\cos^2\theta} = \frac{1}{\cos^2\theta} = \frac{c^2}{b^2}$$

3. Integration –

$$d\cos\theta = -\sin\theta\, d\theta$$

$$\int_{\theta_1}^{\theta_2} \sin\theta\, d\theta = \int_{\theta_1}^{\theta_2} d(-\cos\theta) = -(\cos\theta_2 - \cos\theta_1) = \cos\theta_1 - \cos\theta_2$$

$$\int_{x_1}^{x_2} \frac{1}{x^2}\, dx = -\frac{1}{x}\Bigg|_{x_1}^{x_2} = \frac{1}{x_1} - \frac{1}{x_2}.$$



$E_x = \sum \Delta E_x$

$E_y = \sum \Delta E_y = 0$. by symmetry

$\Delta E_x = \frac{k \Delta q}{r^2} \cdot \cos\theta$

$\cos\theta = \frac{x}{r}$

Put together: $\Delta E_x = \frac{k \Delta q \, x}{r^3}$

Uniform charge —

$\frac{\Delta q}{\Delta y} = \frac{Q}{L}$, $\Delta q = \frac{Q}{L} \Delta y$ or $\Delta E_x = \left(\frac{kQ}{L} x\right) \frac{\Delta y}{r^3}$.

$\therefore E_x = \frac{kQx}{L} \sum \frac{\Delta y}{r^3}$

$E_x = \frac{kQ}{L} x \int_{-\frac{L}{2}}^{\frac{L}{2}} \frac{dy}{r^3}$.

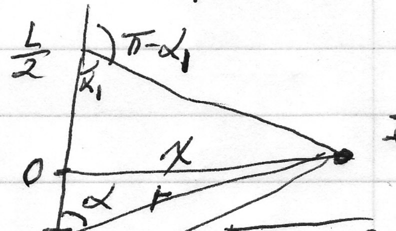
Previous Analytic Result

Change variable of integration

$E_x = \frac{kQ}{L} \int \frac{dy}{r^2} \sin\alpha$.

Math ID: $\frac{dy}{r^2} = \frac{d\alpha}{x}$

$E_x = \frac{kQ}{L} \int \frac{d\alpha \sin\alpha}{x}$



$E_x = \frac{kQ}{L} \cdot \frac{1}{x} \left(-\cos\alpha\right)\Big|_{\alpha_1}^{\pi-\alpha_1}$

$2\cos\alpha_1 = \frac{2\frac{L}{2}}{r_1} = \frac{L}{r_1}$

$= \frac{kQ}{Lx} 2\cos\alpha_1 = \frac{kQ}{Lx}\frac{L}{r_1} = \frac{kQ}{x r_1}$ (p633)