PHY 114 A General Physics II
11 AM-12:15 PM TR Olin 101

Plan for Lecture 5:

1. More about electrostatic potentials
2. Review of Electrostatics (Chapters 23-25)
3. Advice about preparing/taking physics exams.

Announcements:

No.	Lecture Date	Topic	Text Sections	Problem Assignments	Assignment Due Date
1	01/19/2012	Coulomb's law	23.1-23.4	23.6,23.8a,23.13	01/24/2012
2	01/24/2012	Electric field	23.4-23.7	23.22,23.20,23.61a	01/26/2012
3	01/26/2012	Gauss's Law	24.1-24.3	24.22a,24.23,24.40	01/31/2012
4	01/31/2012	Electric potential	25.1-25.4	25.12,25.23,25.34,25.01	02/02/2012
5	02/02/2012	Electric potential	25.5-25.8	(Review for exam)	
	02/07/2012	Exam			

i-clicker question

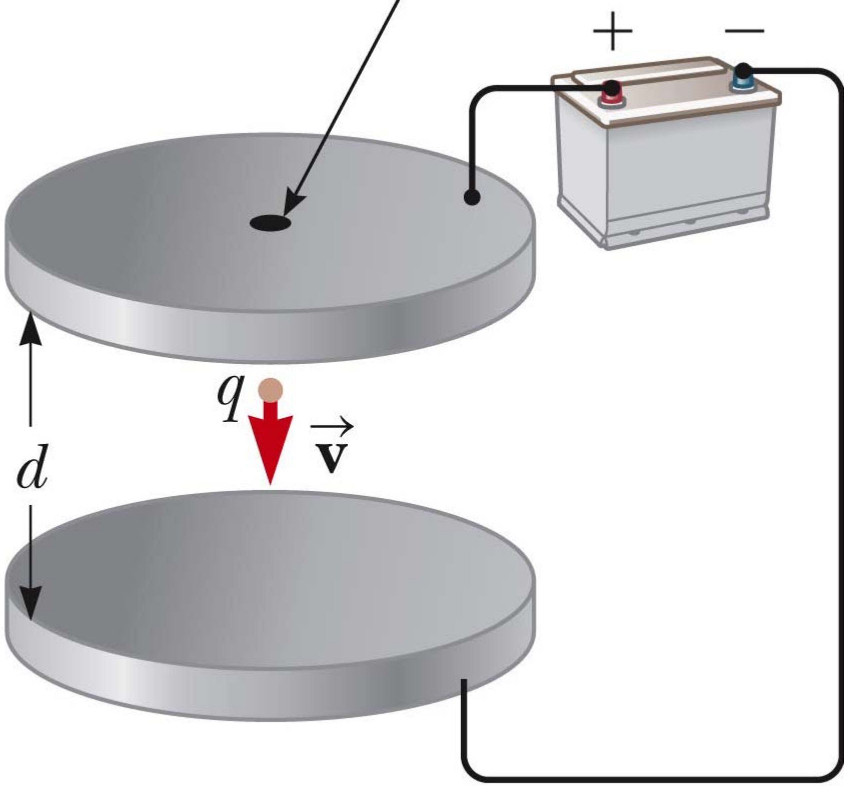
Would you attend a review session for next Tuesday's exam on:

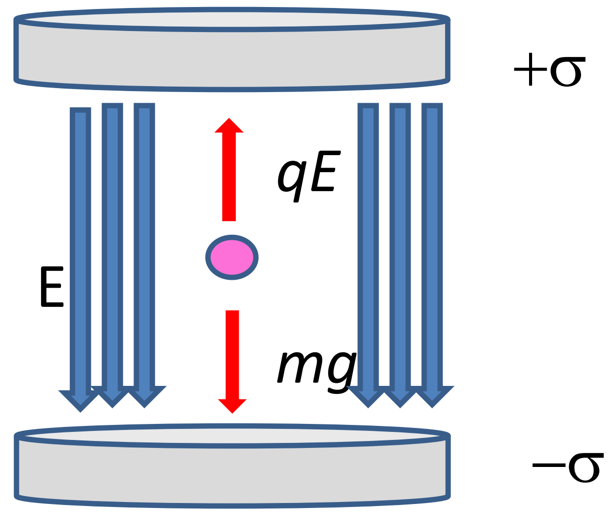
A. Sunday afternoon at 3 PM
B. Monday afternoon at 4 PM
C. Would like a review session at a different time.
D. Would not/could not attend a review session at any time.

More about electric potentials:
Electrical ground

➔The symbol ⏚ implies that the "grounded" object is supplied with any necessary charge to maintain voltage *V=0*.

Millikan oil drop experiment



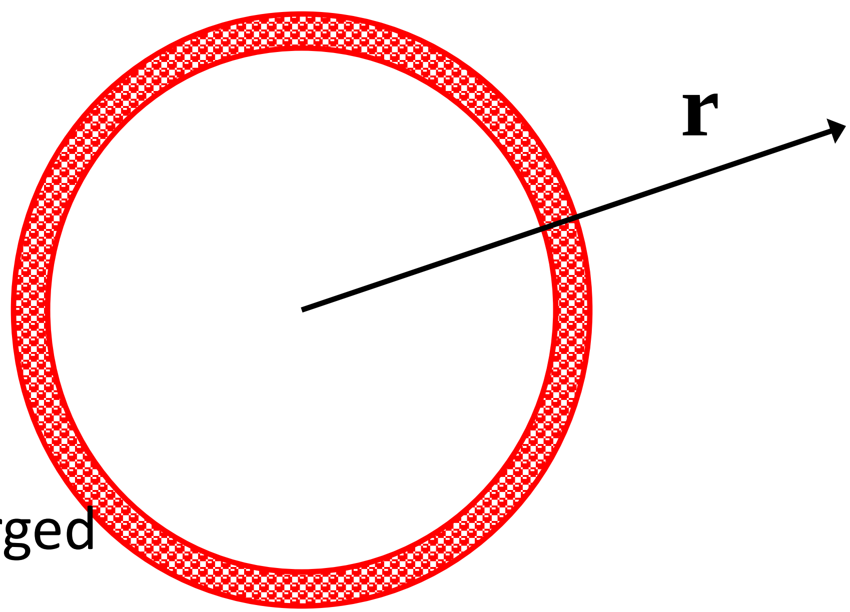


$$\text{Equilibrium condition: } qE = mg$$

If E and m are known, q is measured by the experiment.

It is reasonable to assume that $q = -Ne$.

Van de Graaff generator



$$\mathbf{E} = \frac{k_e Q \hat{\mathbf{r}}}{r^2}$$

$$V = \frac{k_e Q}{r}$$

Uniformly charged spherical shell

Strong fields can break chemical bonds as does lightning.

Electrostatic potential due to continuous charge distributions

- Can determine potential from electric field according to

$$V = -\int_{\mathbf{r}_{ref}}^{\mathbf{r}} \mathbf{E} \cdot d\mathbf{s}$$

- Can perform integral over charge distribution directly

$$\mathbf{E}(\mathbf{r}) = k_e \sum_i \frac{q_i}{|\mathbf{r} - \mathbf{r}_i|^3}(\mathbf{r} - \mathbf{r}_i) = k_e \int \frac{dq(\mathrm{r}')}{|\mathbf{r} - \mathbf{r}'|^3}(\mathbf{r} - \mathbf{r}')$$

$$V(\mathbf{r}) = k_e \sum_i \frac{q_i}{|\mathbf{r} - \mathbf{r}_i|} = k_e \int \frac{dq(\mathrm{r}')}{|\mathbf{r} - \mathbf{r}'|}$$

Example – consider a long thin uniformly charged rod:

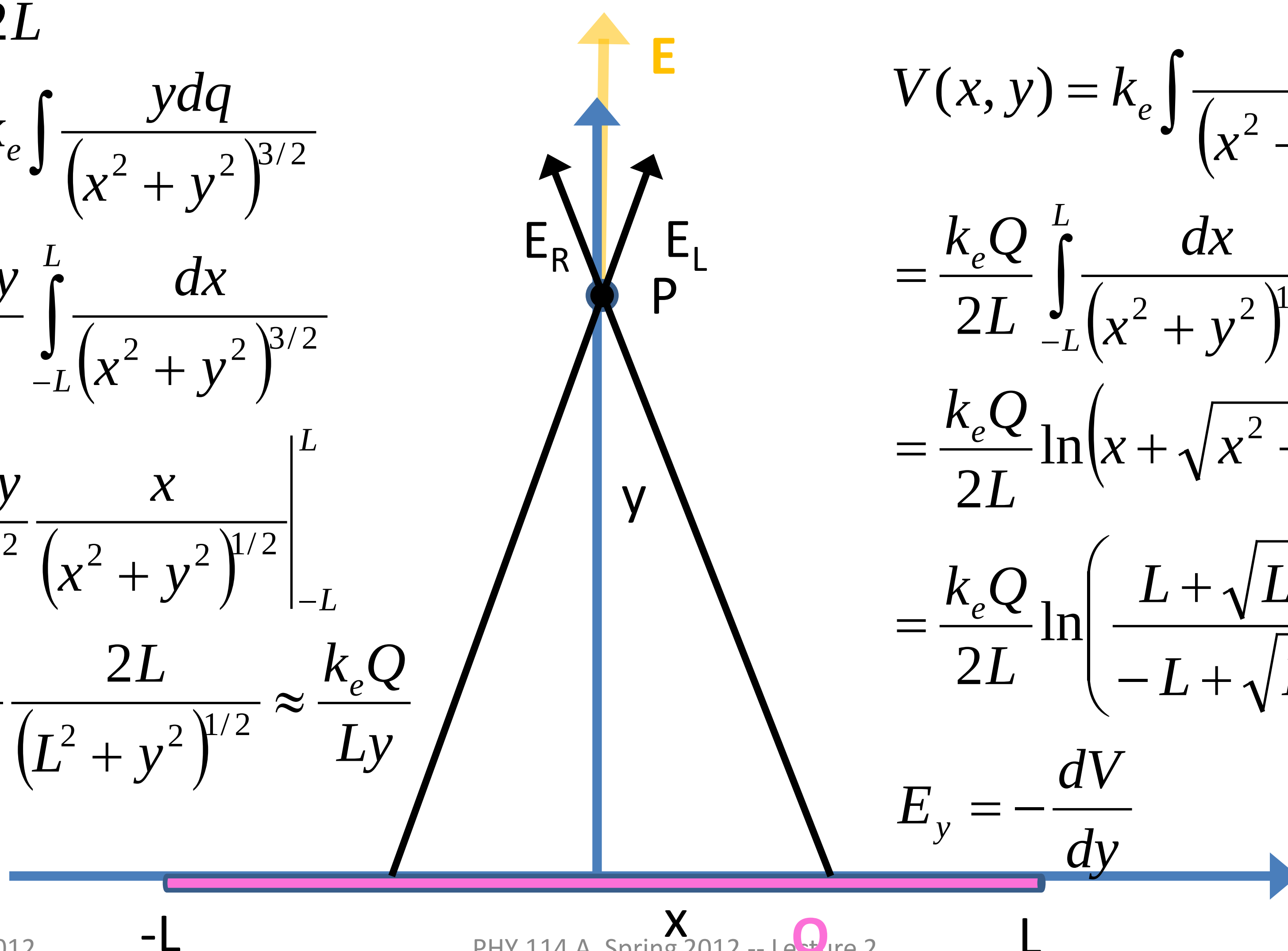
$$dq = \frac{Q}{2L}dx$$

$$E_y = k_e \int \frac{y\,dq}{\left(x^2+y^2\right)^{3/2}}$$

$$= \frac{k_e Q y}{2L}\int_{-L}^{L}\frac{dx}{\left(x^2+y^2\right)^{3/2}}$$

$$= \frac{k_e Q y}{2Ly^2}\left.\frac{x}{\left(x^2+y^2\right)^{1/2}}\right|_{-L}^{L}$$

$$= \frac{k_e Q}{2Ly}\frac{2L}{\left(L^2+y^2\right)^{1/2}} \approx \frac{k_e Q}{Ly}$$



$$dq = \frac{Q}{2L}dx$$

$$V(x,y) = k_e \int \frac{dq}{\left(x^2+y^2\right)^{1/2}}$$

$$= \frac{k_e Q}{2L}\int_{-L}^{L}\frac{dx}{\left(x^2+y^2\right)^{1/2}}$$

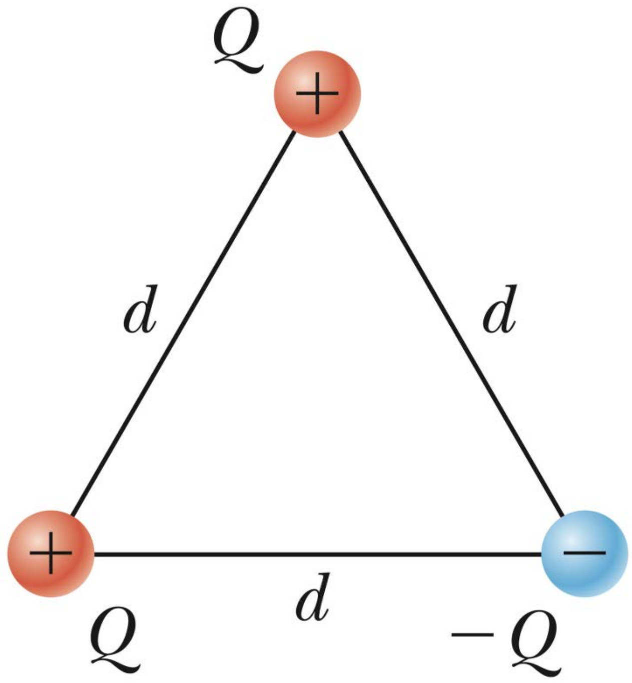
$$= \frac{k_e Q}{2L}\ln\left(x+\sqrt{x^2+y^2}\right)\Big|_{-L}^{L}$$

$$= \frac{k_e Q}{2L}\ln\left(\frac{L+\sqrt{L^2+y^2}}{-L+\sqrt{L^2+y^2}}\right)$$

$$E_y = -\frac{dV}{dy}$$

i-clicker question:

Consider the distribution of charges shown below.
Which of the following statements is *most* accurate.

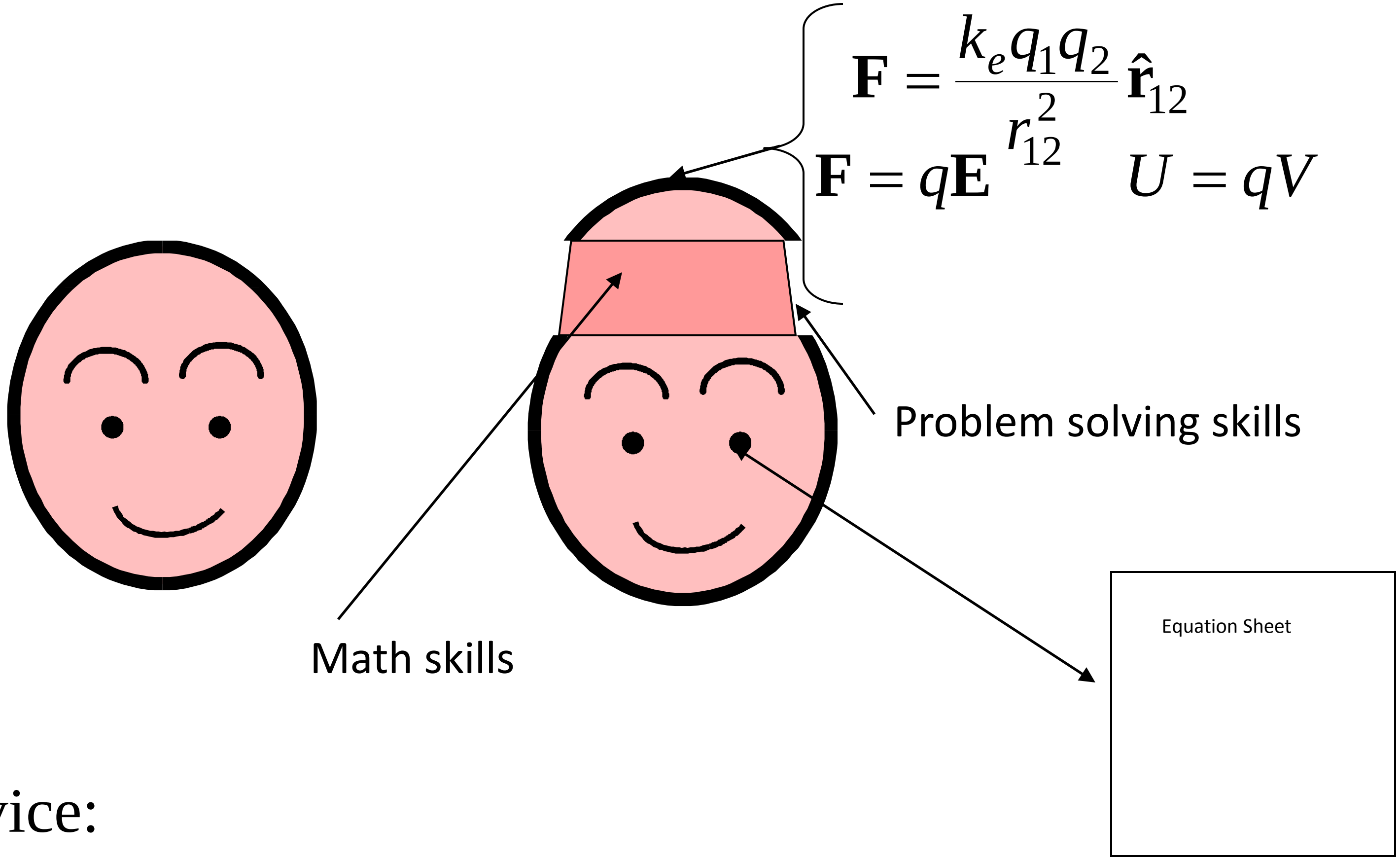


A. This charge distribution was introduced by evil physics professor to torture their students.
B. This charge distribution is stable with no additional forces.
C. The charge distribution can be stable only with additional forces.

Reminder:

1. **First exam – Tuesday, February 6, 2012**
   – covering Chapters 23-25.

   - ~5 problems – show your work and reasoning for possible partial credit.
   - Should bring 1 8½" x 11" sheet of paper to the exam (to be turned in with your exam papers).
   - Should bring calculator for numerical work. Must not use cell phones or computers during the exam.



Advice:

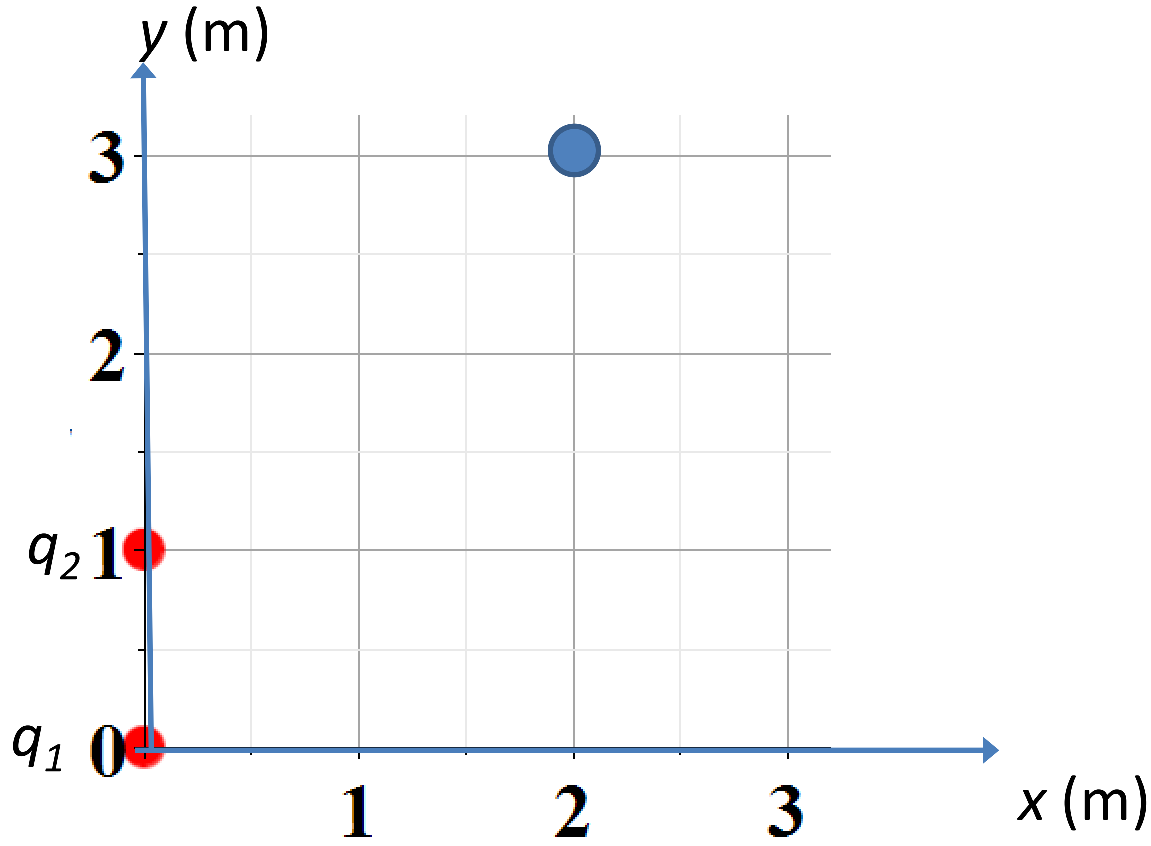
1. Keep basic concepts and equations at the top of your head.
2. Practice problem solving and math skills
3. Develop an equation sheet that you can consult.

Problem solving steps

1. Visualize problem – labeling variables
2. Determine which basic physical principle(s) apply
3. Write down the appropriate equations using the variables defined in step 1.
4. Check whether you have the correct amount of information to solve the problem (same number of knowns and unknowns).
5. Solve the equations.
6. Check whether your answer makes sense (units, order of magnitude, etc.).

Example problem:

Consider the following configuration of point charges q_1=2μC and q_2=4μC as shown. Determine the electric field **E** at the position (in meters) $\mathbf{r} = 2\hat{\mathbf{i}} + 3\hat{\mathbf{j}}$



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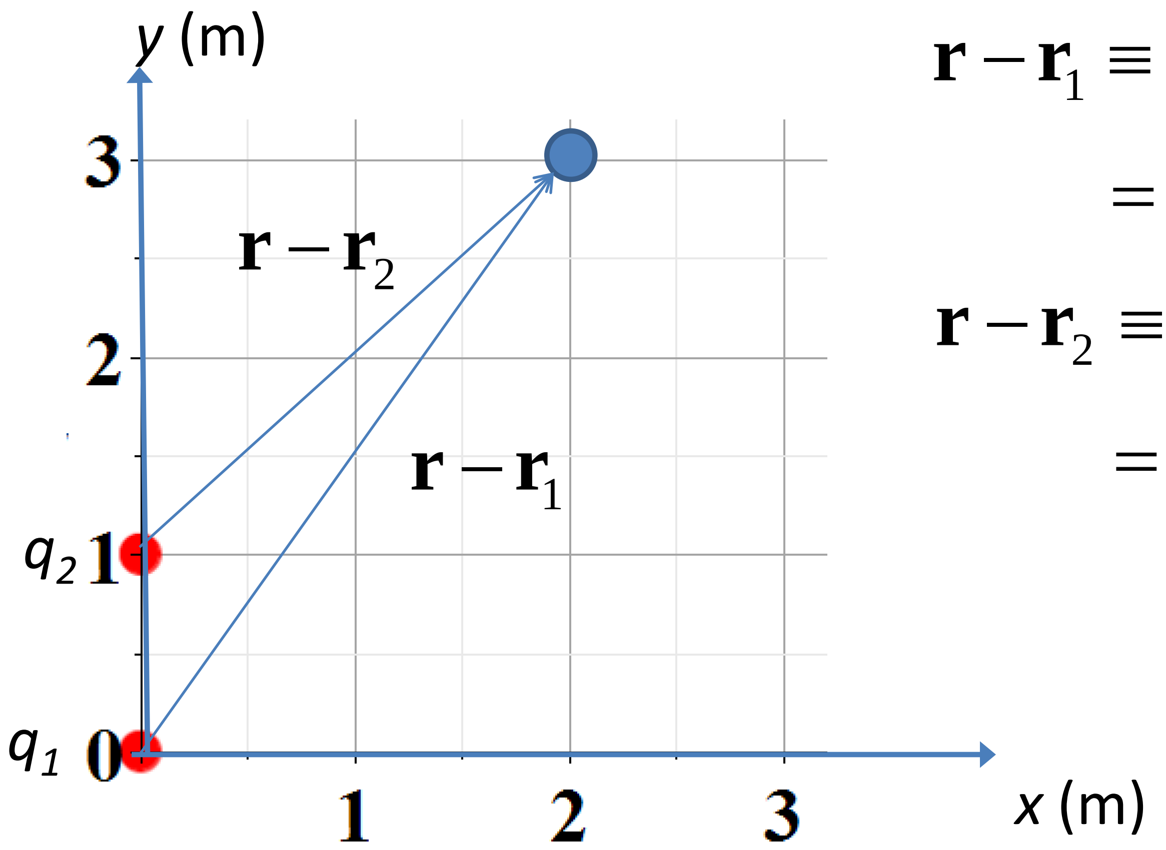
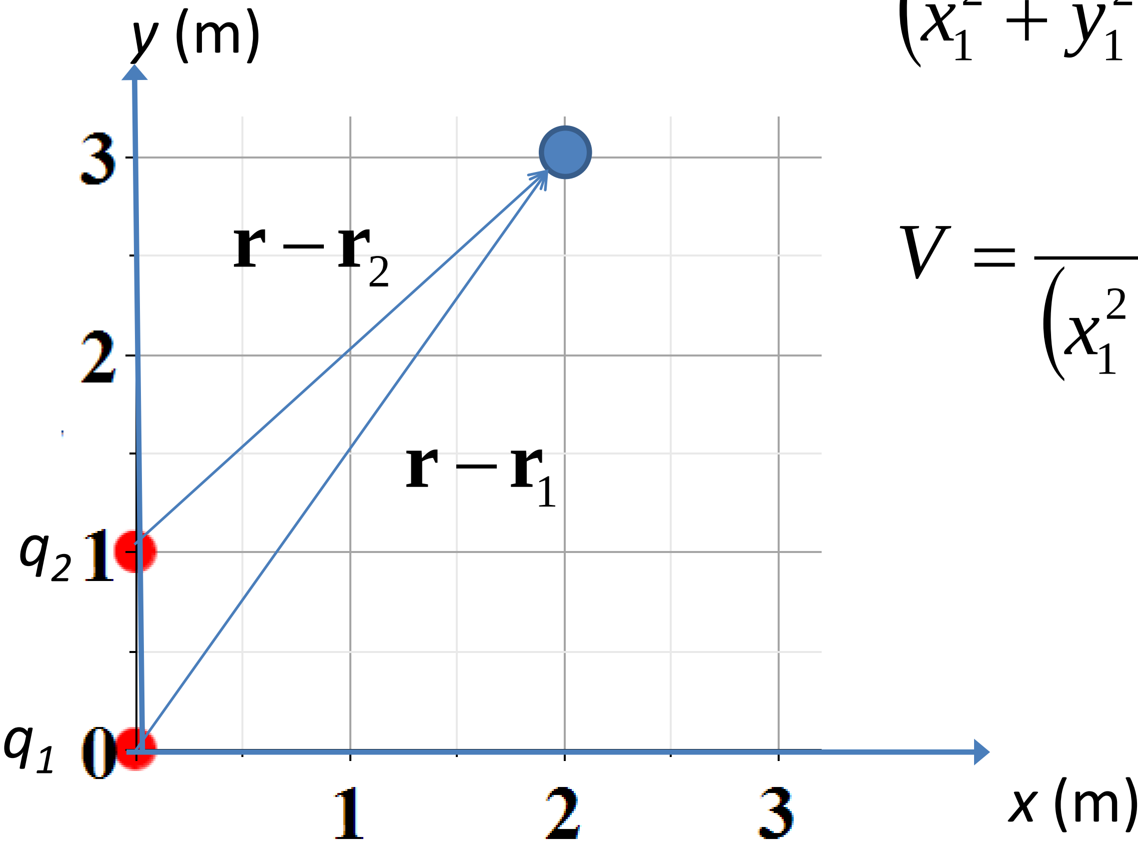


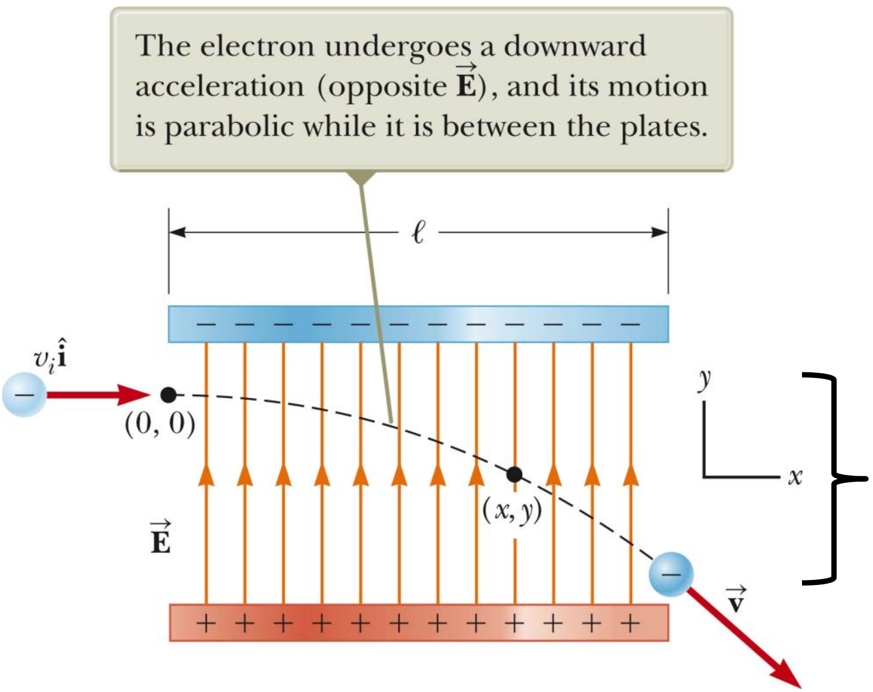
$$\mathbf{r}-\mathbf{r}_1 \equiv x_1\hat{\mathbf{i}} + y_1\hat{\mathbf{j}}$$
$$= 2\hat{\mathbf{i}} + 3\hat{\mathbf{j}}$$
$$\mathbf{r}-\mathbf{r}_2 \equiv x_2\hat{\mathbf{i}} + y_2\hat{\mathbf{j}}$$
$$= 2\hat{\mathbf{i}} + 2\hat{\mathbf{j}}$$

$$\mathbf{E} = \frac{k_e q_1 \left(x_1 \hat{\mathbf{i}} + y_1 \hat{\mathbf{j}}\right)}{\left(x_1^2 + y_1^2\right)^{3/2}} + \frac{k_e q_2 \left(x_2 \hat{\mathbf{i}} + y_2 \hat{\mathbf{j}}\right)}{\left(x_2^2 + y_2^2\right)^{3/2}}$$



$$V = \frac{k_e q_1}{\left(x_1^2 + y_1^2\right)^{1/2}} + \frac{k_e q_2}{\left(x_2^2 + y_2^2\right)^{1/2}}$$

Example: An electron enters the region of a uniform electric field E=200 N/C as shown with $v_i=3\text{x}10^6$ m/s . The horizontal length of the plates is l=0.1m. Find the vertical displacement y of the electron as it leaves the plates. (Ignor any field fringing effects.)



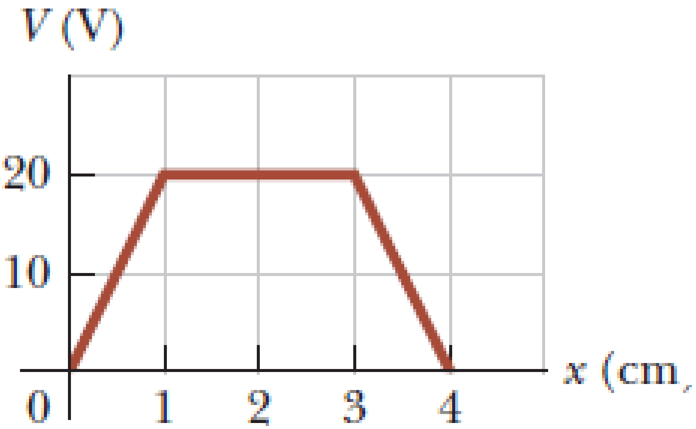
$$y=\frac{1}{2}\frac{eE}{m}\left(\frac{\ell}{v_i}\right)^2$$

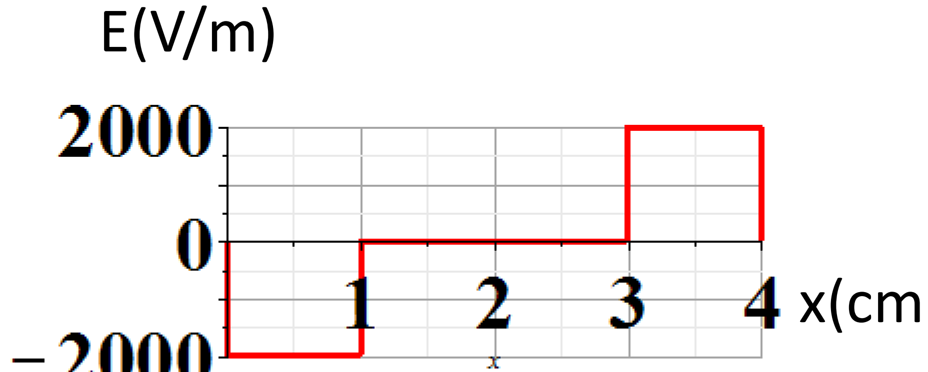
$$=\frac{1}{2}\frac{1.6\times10^{-19}\cdot200}{9.1\times10^{-31}}\left(\frac{.1}{3\times10^6}\right)^2$$

$$=0.0195 \quad \text{m}$$

y

Integral-differential relationship between **E** and V in one dimension.





$$E_x(x) = -\frac{dV(x)}{dx} \qquad V(x) = -\int_{x_{ref}}^{x} E(x')dx'$$

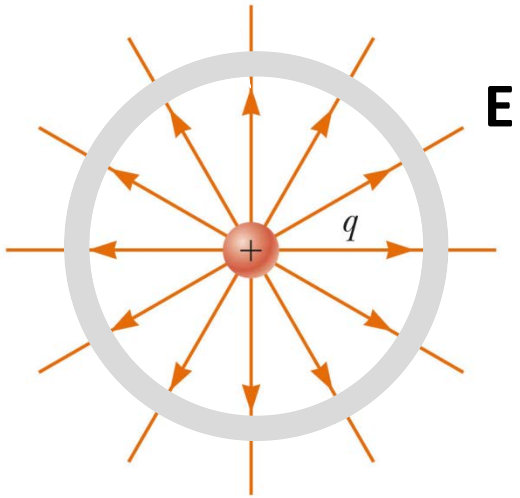
$$\text{For} \quad 0 \le x \le 1\,\text{cm} \quad \frac{dV(x)}{dx} = \frac{20}{0.01} \ \text{V/m} = 2000 \ \text{V/m}$$

$$\text{For} \quad 1 \le x \le 3\,\text{cm} \quad \frac{dV(x)}{dx} = 0 \ \text{V/m}$$

$$\text{For} \quad 3 \le x \le 4\,\text{cm} \quad \frac{dV(x)}{dx} = \frac{-20}{0.01} \ \text{V/m} = -2000 \ \text{V/m}$$

Review question

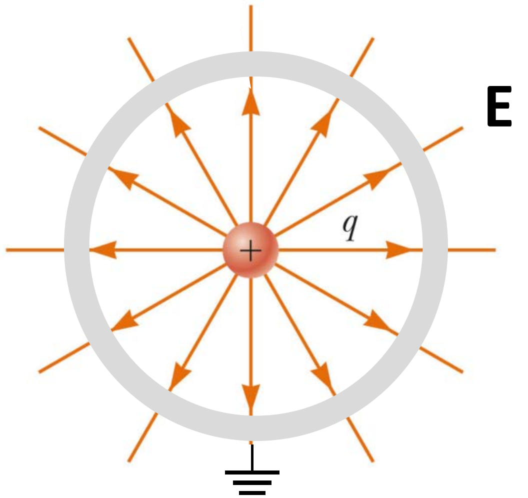
The diagram below shows a point positive charge q placed at the center of an electrically *isolated* conducting shell. What is the magnitude of the field **E** measured at a radius r outside the shell?



A. E=0
B. $E=k_e\, q/r^2$
C. Not enough information to solve this problem

Review question

The diagram below shows a point positive charge q placed at the center of an electrically *grounded* conducting shell. What is the magnitude of the field **E** measured at a radius r outside the shell?



A. E=0
B. $E=k_e\, q/r^2$
C. Not enough information to solve this problem

Summary of electric fields and potentials for special charge distributions:

Point charge q at the origin: $\mathbf{E}(\mathbf{r}) = \dfrac{k_e q \mathbf{r}}{r^3}$

Charge q uniformly distributed on long wire $L >> r$:

$r \equiv$ perpendicular distance from center of wire: $\mathbf{E}(\mathbf{r}) = \dfrac{k_e (q/L) \mathbf{r}}{r^2}$

Charge q uniformly distributed on flat plate $A >> z$:

$z \equiv$ perpendicular distance from center of plate: $\mathbf{E}(z) = 2\pi k_e (q/A)\hat{\mathbf{z}}$