

Recitation

5

More E-Fields



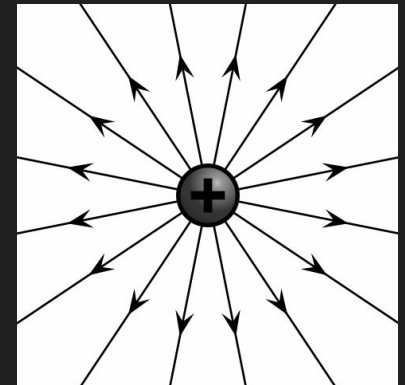
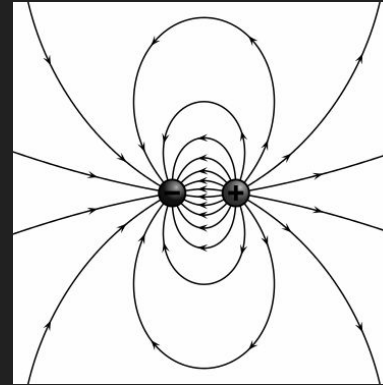
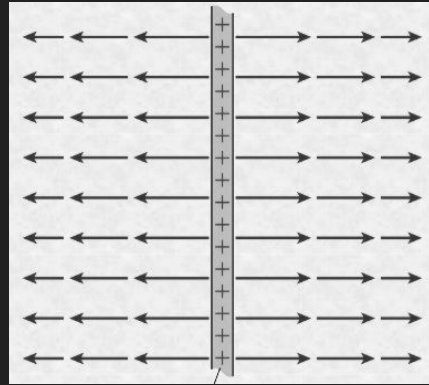
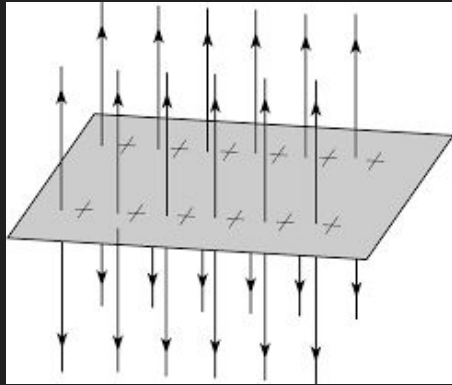
Review: What You've Done

Force Between Two Charges

- Calculate it with Coulomb's Law: $F = \frac{k|q_1||q_2|}{|\Delta\vec{r}_{12}|^2}$
- Calculate it with Electric Field: $F = \vec{E}(\vec{r})q$
- Between two charges: $F = \frac{kq_1}{|\Delta\vec{r}_{12}|^2}q_2\hat{r}$

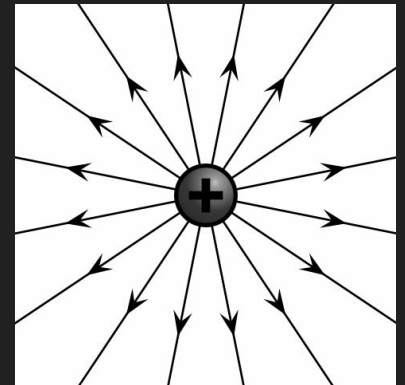
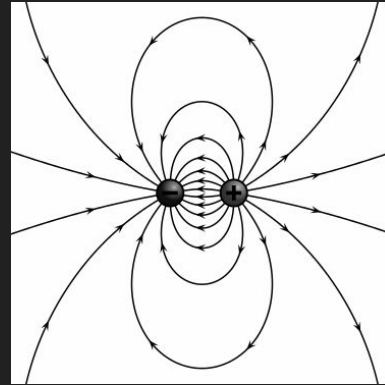
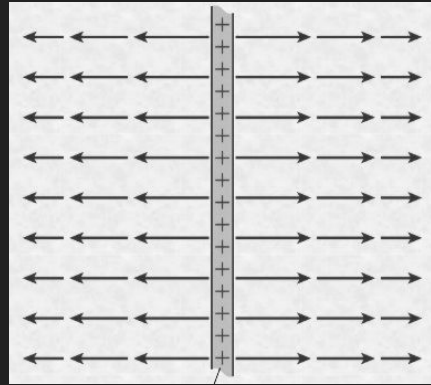
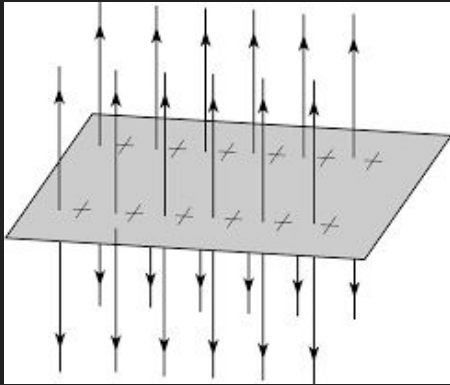
Electric Fields for Charge Distributions

Match the image of the electric field lines and the type of charge distribution



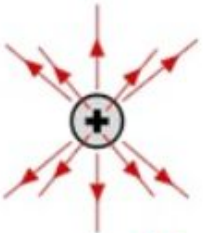
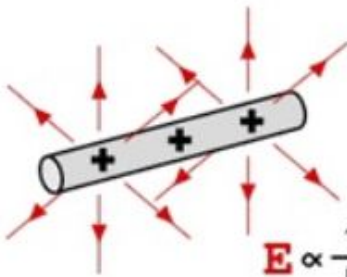
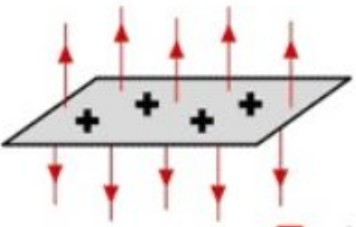
Point Charge, Sheet Charge, Dipole, Line Charge

What are the characteristics of each?



Think about symmetries, how the lines diverge, where the field lines point, how the fields decay, etc.

Symmetries

	point charge	infinite line of charge	infinite plane of charge
electric field \vec{E} units: N/C	 <p>$E \propto \frac{1}{r^2}$</p>	 <p>$E \propto \frac{1}{r}$</p>	 <p>$E \propto 1$</p>

Why it's cool

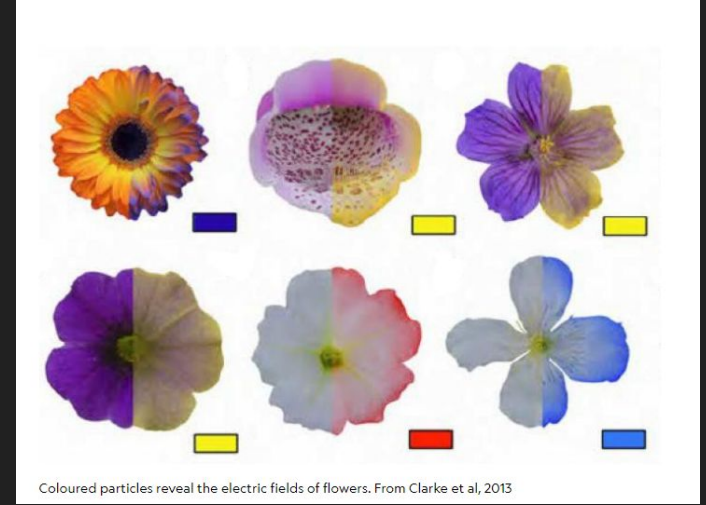
Bumble Bees feel electric fields!

- Bumble bees have a positive charge from flying through the air. Collisions with dust and other molecules strip some electrons off of the bees
- Flower petals have an overall negative charge
- Tests were done to see if bees sense this electric field



Bumble Bees feel electric fields!

- Two groups: Sugary water with electric field, bitter water without electric field
- Bees learned to visit the charged flowers with 81% accuracy
- When the field was taken away, bees couldn't tell which had the sugary water
- Bees can tell the difference between the fields created by different charge distributions with 70% accuracy



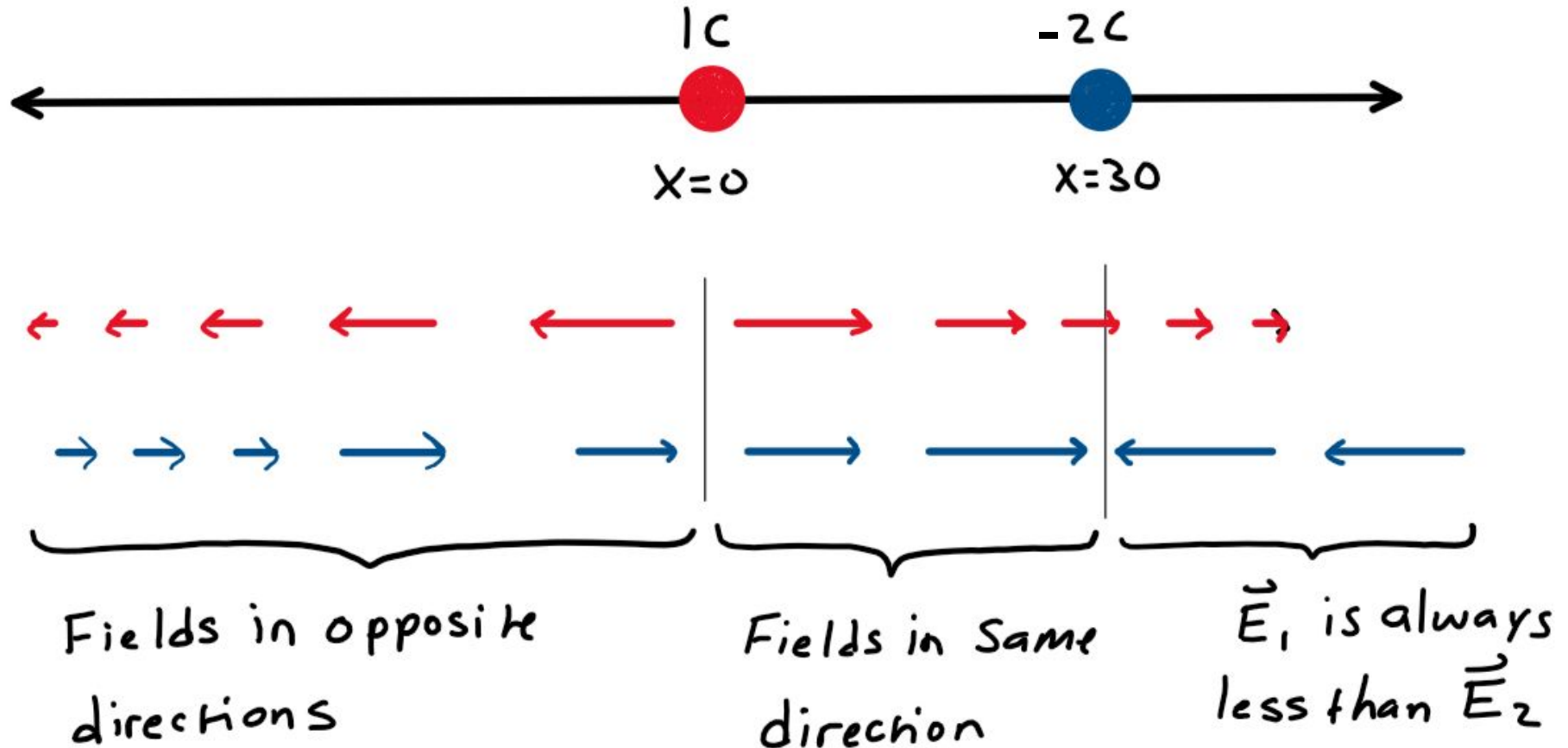
Putting It to Practice

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3. A +1 C charge is placed at the origin. A -2 C charge is placed on the x-axis, 30 cm to the right of the origin. Which of the following statements are true?

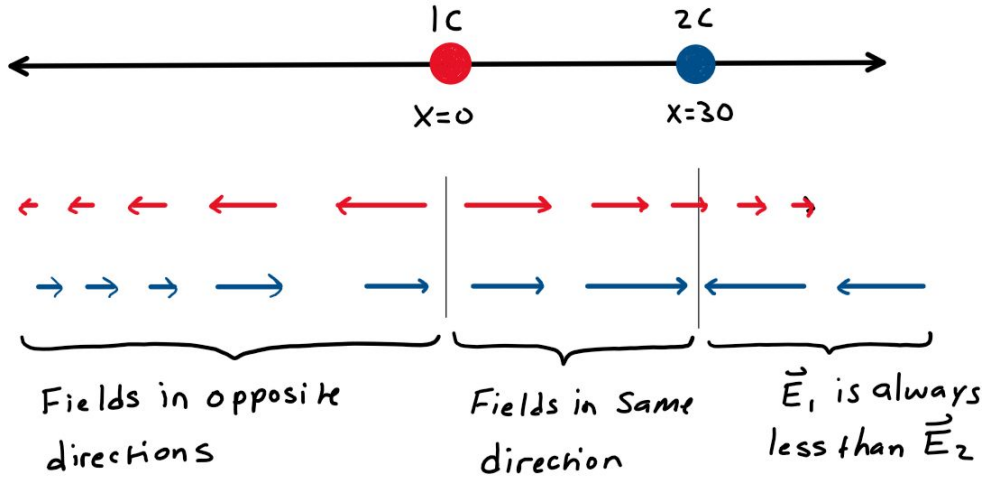
- a) Other than $x = \pm\infty$, there are no locations on the x axis where the electric field magnitude is zero.
- b) Other than $x = \pm\infty$, there is only one location on the x axis where the electric field magnitude is zero.
- c) In addition to $x = \pm\infty$, there is more than one location on the x axis where the electric field magnitude is zero.
- d) The electric field is zero at a point between the two charges.
- e) Other than $x = -\infty$, the electric field is zero at one point to the left of both charges.
- f) Other than $x = \infty$, the electric field is zero at one point to the right of both charges.
- g) The electric potential energy of the -2 C charge is greater than the electric potential energy of the +1 C charge.

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Write down an expression for the fields to the left of the origin



On the left of the origin,

$$\vec{E}_1 = \frac{kq_1}{|\Delta\vec{r}_{11}|^2} \langle -1, 0 \rangle$$

$$\vec{E}_2 = \frac{kq_2}{|\Delta\vec{r}_{21}|^2} \langle 1, 0 \rangle$$

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Solve for where the fields add to zero

We only need to worry about the x-component

$$-\frac{kq_1}{|\Delta r_1|^2} + \frac{kq_2}{|\Delta r_1 + 30|^2} = 0$$

$$\frac{kq_1}{|\Delta r_1|^2} = \frac{kq_2}{|\Delta r_1 + 30|^2}$$

Let's call the position where the field is zero d

$$\frac{(d+30\text{cm})^2}{d^2} = \frac{kq_2}{kq_1}$$

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Solve for where the fields add to zero

$$d^2 + 90 \text{ cm}^2 + 30 d \text{ cm} = \frac{q_2}{q_1} d^2$$

$$d^2 - \frac{q_2}{q_1} d^2 + 30 d \text{ cm} + 90 \text{ cm}^2 = 0$$

$$\frac{d^2(q_1 - q_2)}{q_1} + 30 d \text{ cm} + 90 \text{ cm}^2 = 0$$

We know $q_2 = 2q_1$

$$\frac{d^2(q_1 - 2q_1)}{q_1} + 30 d \text{ cm} + 90 \text{ cm}^2 = 0$$

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Solve for where the fields add to zero

$$-d^2 + 30d \text{ cm} + 90 \text{ cm}^2$$

$$d = 3(5 \pm \sqrt{35}) \text{ cm}$$

We know the zero point must be to the left of the origin

$$d = 3(5 - \sqrt{35})$$

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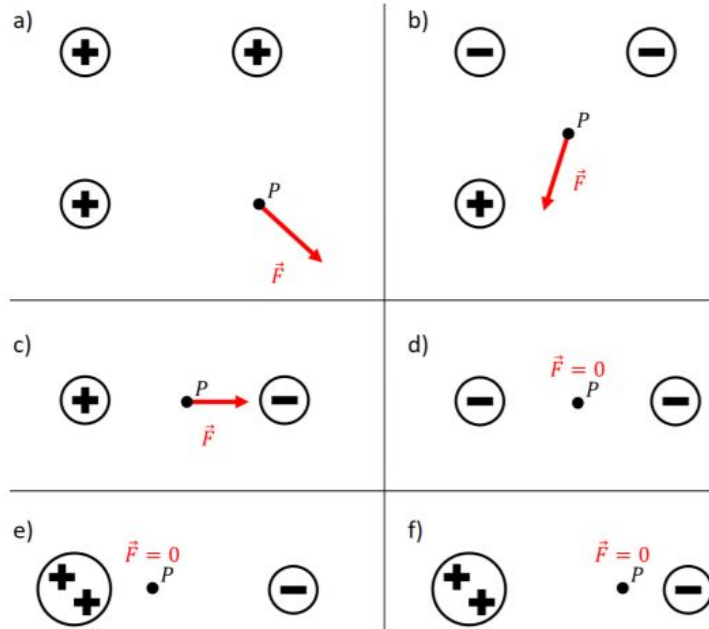
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S18 Midterm 2

4. Which of the following situations correctly depict the force on a negative charge placed at the black dot? (+ and - charges have equal magnitudes, ++ implies twice the charge)

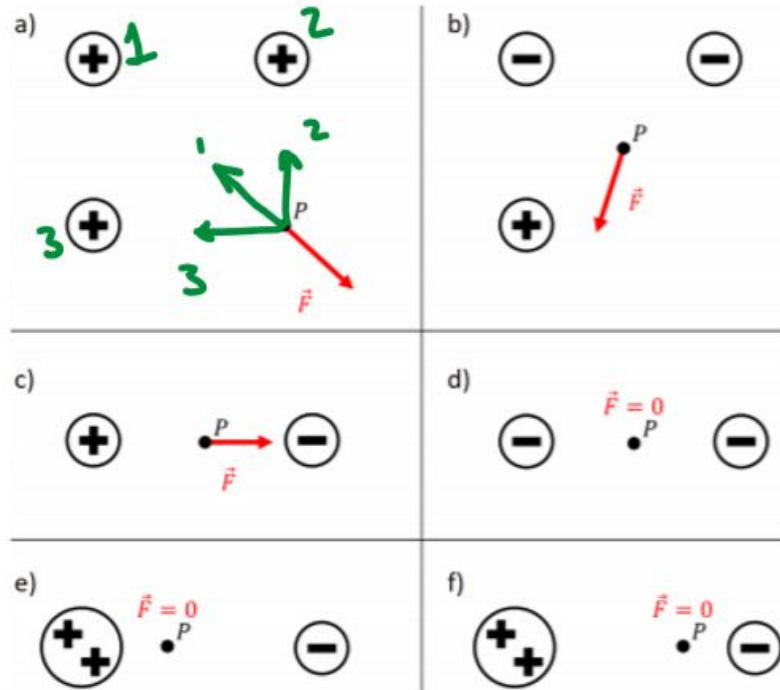
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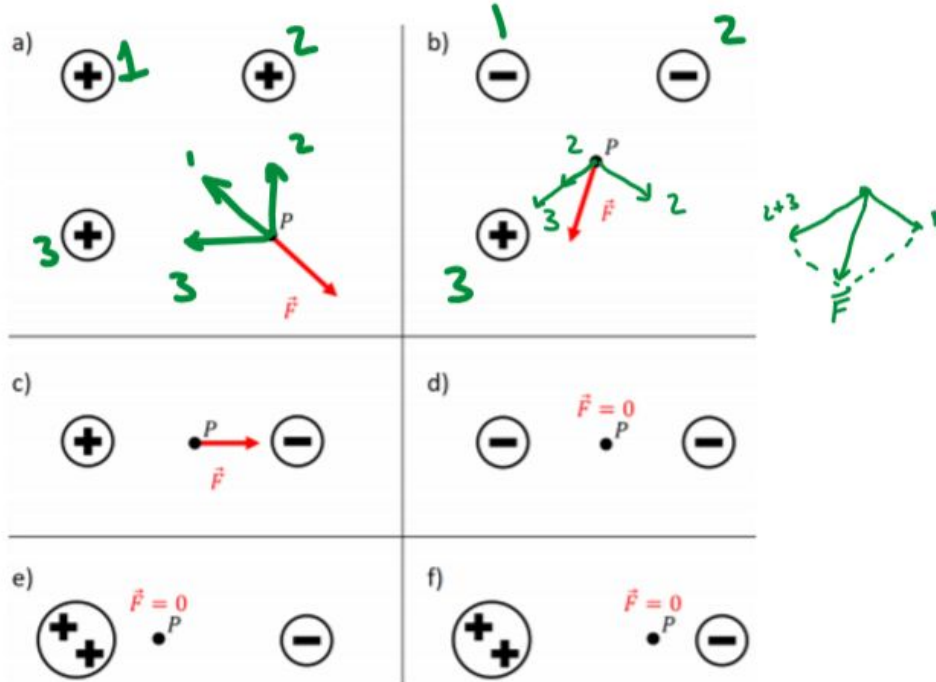
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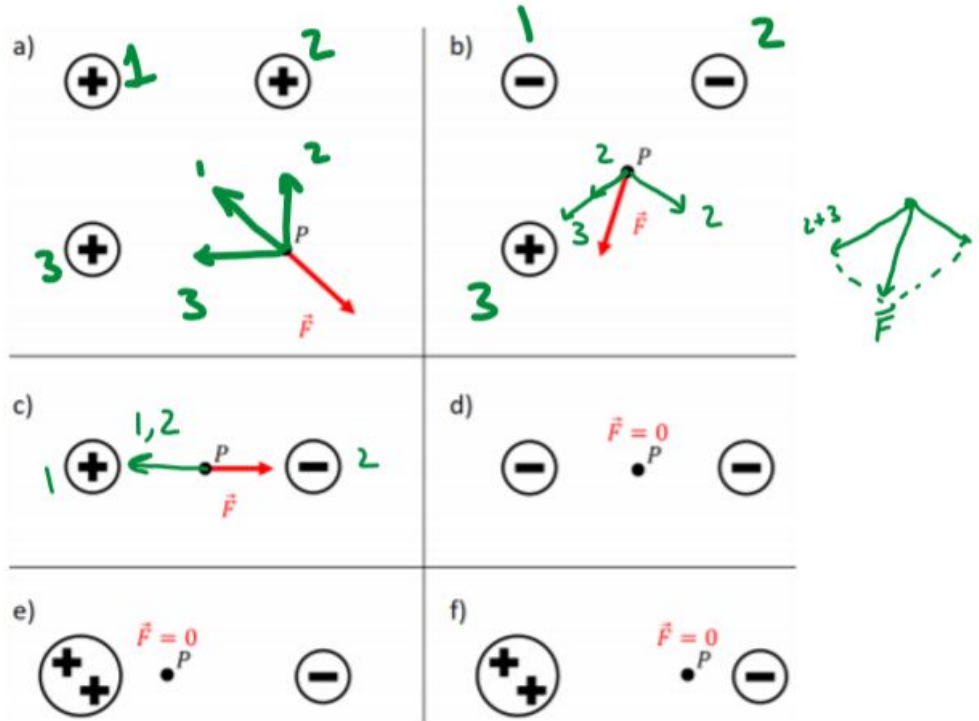
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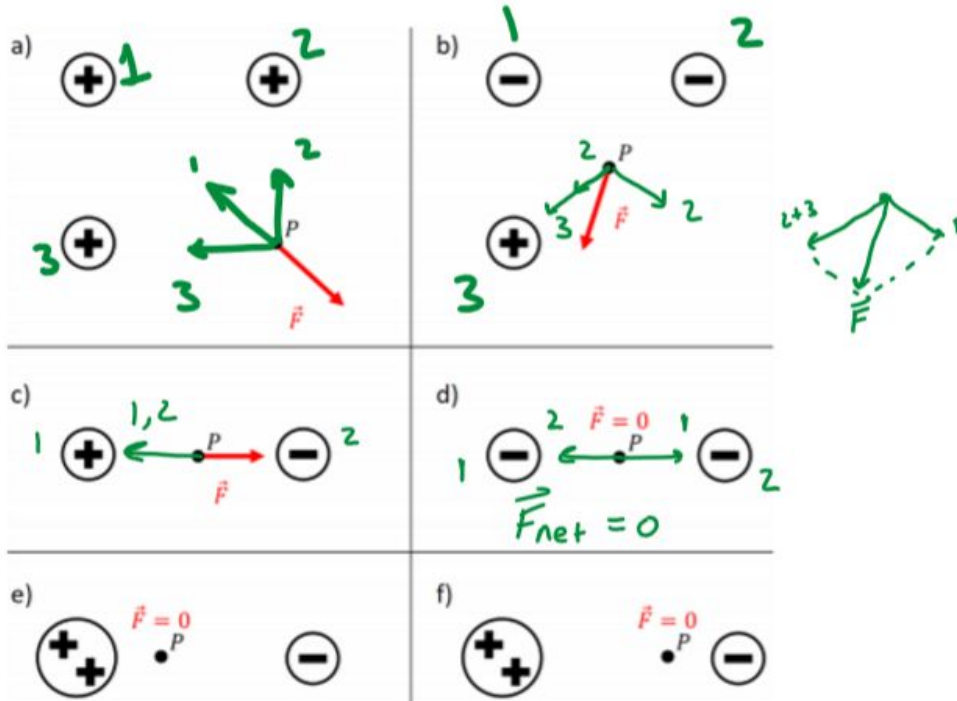
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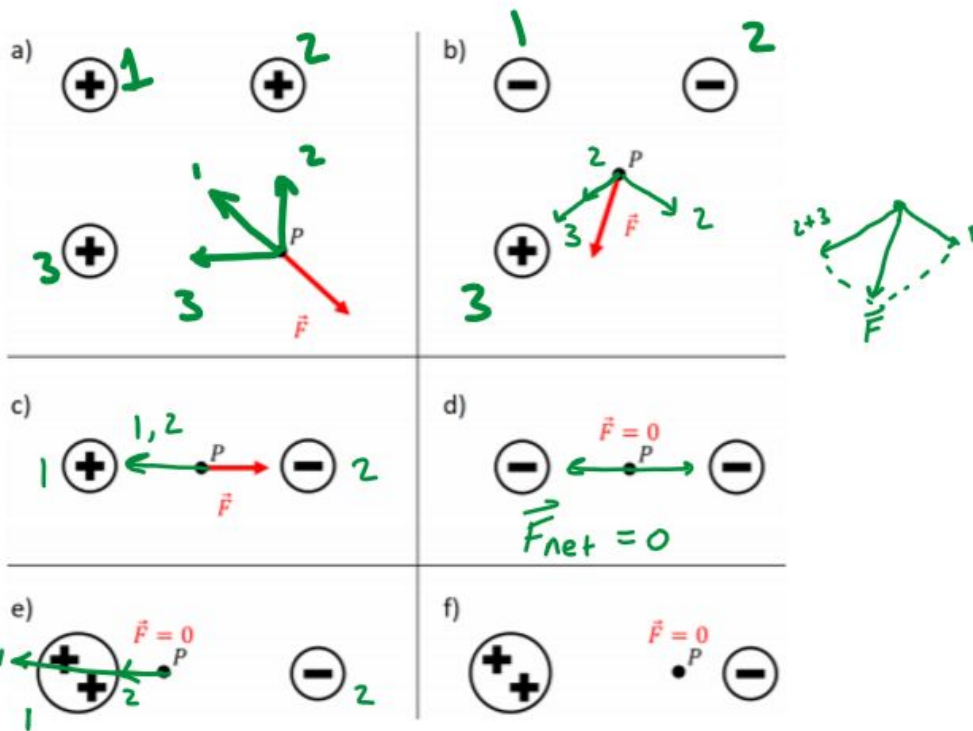
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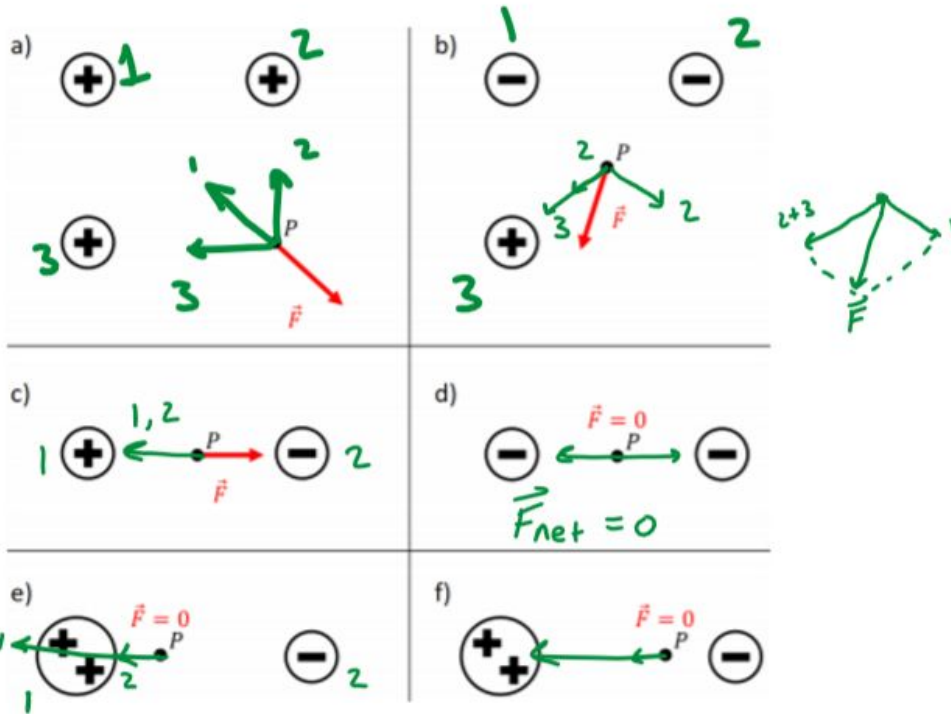
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S18 Midterm 2

5. For the electric force to do no work on a charge moving through an electric field, the charge must be:

- a) Moving along an electric field line, in the direction of the electric field
- b) Moving along an electric field line, opposite the direction of the electric field
- c) Moving along an equipotential line
- d) Moving along an electric potential vector line
- e) Moving along an electric potential energy vector line

S18 Midterm 2

9. (12 points) A ball with charge $q = -2.3 \text{ C}$ and mass $m = 0.85 \text{ kg}$ is falling due to gravity. A uniform vertical electric field of strength $E = 5.3 \text{ N/C}$ exists between the ground and D meters above the ground. The ball enters the electric field from the top with a downward velocity $\vec{v}_i = 5.0 \text{ m/s}$ and hits the ground with a downward velocity $\vec{v}_f = 4.0 \text{ m/s}$.

a) (2 point) What direction does the electric field point?

- We start with velocity -5 m/s and end with velocity -4 m/s
- The magnitude of the acceleration must be positive
- The force from the electric field must have a greater magnitude than the force from gravity
- The ball has a negative charge
- The field must point down so that there is a force in the positive vertical direction

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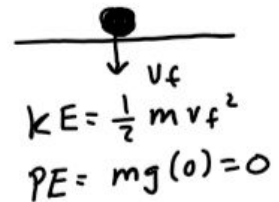
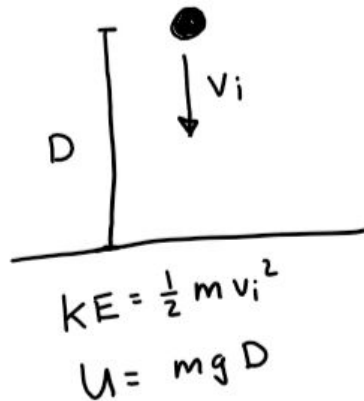
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b) (8 pts) What is the distance D ?

Work done by \vec{E} -field is $W_E = |\vec{F}_E| \Delta x \cos \theta$

We know that the work is a change in energy

$$W_E = \Delta E = E_f - E_i$$



S18 Midterm 2

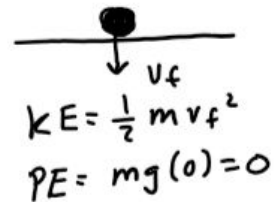
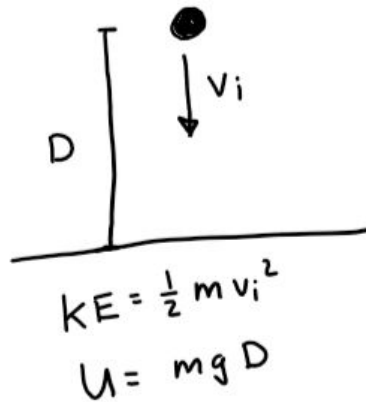
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$$\begin{aligned}W_E &= \left(\frac{1}{2} m v_f^2\right) - \left(\frac{1}{2} m v_i^2 + mgD\right) \\ &= \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 - mgD\end{aligned}$$

$$\begin{aligned}W_E &= |\vec{F}_E| \Delta x \cos \theta \\ &= |\vec{F}_E| (0 - D) \\ &= -|q||E|D\end{aligned}$$

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$$-|q||E|D = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 - mgD$$

$$mgD - |q||E|D = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

$$D(mg - |q||E|) = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

$$D = \frac{\frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2}{mg - |q||E|}$$

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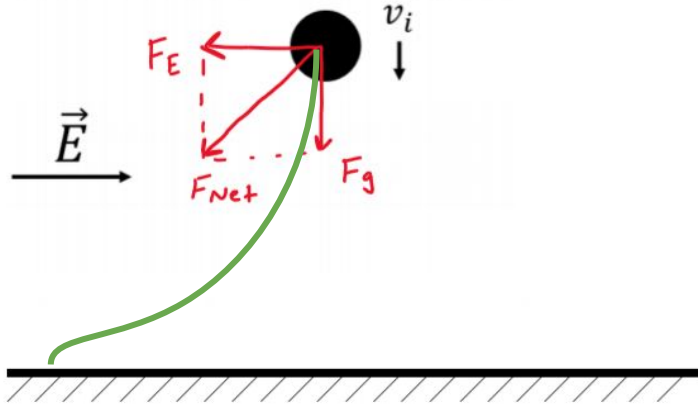
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$$\begin{aligned} D &= \frac{\frac{1}{2} m (v_f^2 - v_i^2)}{mg - |q|E} \\ &= \frac{\frac{1}{2} (0.85) (4^2 - 5^2)}{(0.85)(9.8) - (2.3)(5.3)} \\ &= \boxed{0.99 \text{ m}} \end{aligned}$$

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b) (2 pts) The same situation occurs, except the uniform electric field of strength \mathbf{E} now points horizontally to the right. Sketch the path of the ball as it falls through the electric field.



$$\vec{F}_E = q \vec{E}$$

q is negative

\vec{F}_E points to the left