

Unless otherwise stated, use a coordinate system with $+x$ to the right and $+y$ upward, toward the top edge of the page.

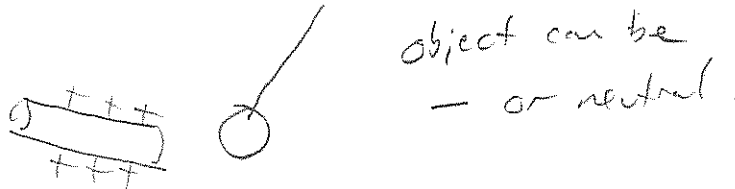
Section 1.

1. With which statement (a-c) do you *disagree*?

- (a) If two charged objects have like charges, they repel. agree
- (b) If two charged objects have opposite charges, they attract. agree
- (c) If two charged objects attract, one of them can be charged (positive or negative) and the other can be neutral. agree
- (d) None. I agree with all of the statements.

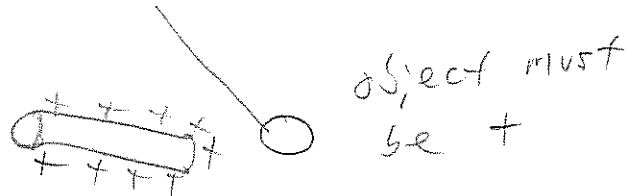
2. A positively charged nylon rod is brought close to, but does not touch, an object hanging from an insulating string. The object is attracted toward the rod. What, if anything, does this tell you about the charge on the object?

- (a) The object has a positive charge.
- (b) The object is neutral.
- (c) The object has a negative charge.
- (d) Both (a) and (b) are possible.
- (e) Both (b) and (c) are possible.



3. A positively charged nylon rod is brought close to, but does not touch, an object hanging from an insulating string. The object is repelled by the rod. What, if anything, does this tell you about the charge on the object?

- (a) The object has a positive charge.
- (b) The object is neutral.
- (c) The object has a negative charge.
- (d) Both (a) and (b) are possible.
- (e) Both (b) and (c) are possible.



Questions 4-5: You have four metal disks with charges: $q_A = -8.0 \mu\text{C}$, $q_B = -2.0 \mu\text{C}$, $q_C = +5.0 \mu\text{C}$, and $q_D = +12.0 \mu\text{C}$.

4. How many excess protons does Disk D have?

- (a) 12 protons
- (b) 7.5×10^{13} protons
- (c) 1.3×10^{14} protons
- (d) 7.5×10^{10} protons
- (e) 1.3×10^{11} protons

$$q_D = 12 \mu\text{C} = 12 \times 10^{-6} \text{C}$$

$$(12 \times 10^{-6} \text{C}) \left(\frac{1 \text{ proton}}{1.6 \times 10^{-19} \text{C}} \right)$$

$$= 7.5 \times 10^{13} \text{ protons}$$

5. Holding them with insulators, you touch disks A and B together. Then you separate them and touch disk B to disk C and separate them. Now the charge of disk C is

- (a) $+5.0 \mu\text{C}$
- (b) $+3.0 \mu\text{C}$
- (c) $+1.5 \mu\text{C}$
- (d) $-5.0 \mu\text{C}$
- (e) zero; it is neutral.

$q_A = -8 \mu\text{C}$
 $q_B = -2 \mu\text{C}$

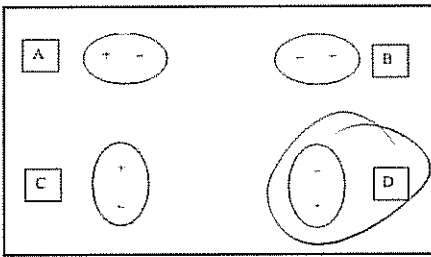
total = $-10 \mu\text{C}$
 separate, then $q_A = -5 \mu\text{C}$
 $q_B = -5 \mu\text{C}$

then, $\text{B} \text{ C} = 0$

6. An electron is near a neutral atom, as shown below.



Which picture below shows the polarization of the neutral atom?



- (a) A
- (b) B
- (c) C
- (d) D
- (e) None of the above.

$\uparrow F_{\text{on electron cloud}}$
 $\rightarrow F_{\text{on electron cloud}}$

$F_{\text{on electron cloud}}$ is away from the electron.

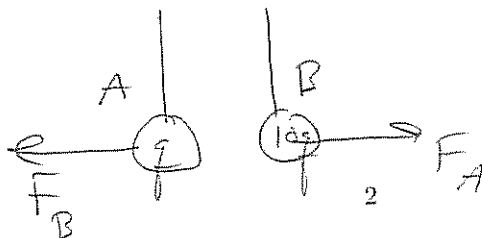
7. Identically charged objects A and B are separated by a distance d . You measure the force F that A exerts on B. If you now separate the objects by a distance $1.4d$, what will be the new force that A exerts on B?

- (a) $2.0F$
- (b) $1.4F$
- (c) $\frac{1}{2}F$
- (d) $\frac{1}{1.4}F$
- (e) F

$F \propto \frac{1}{r^2}$
 $\frac{1}{1.4^2} = \frac{1}{2}$
 $F_B = \frac{1}{2} F$

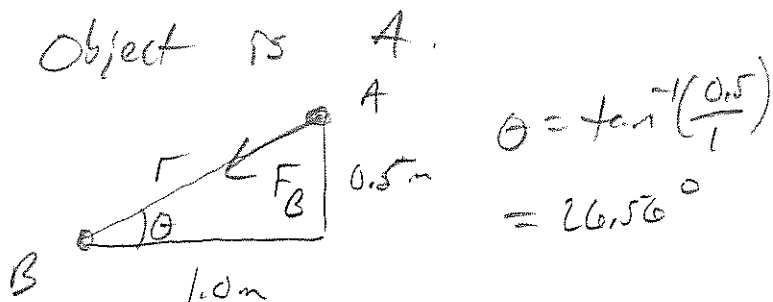
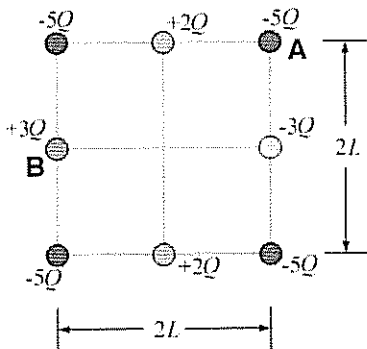
8. Balloon A has charge q , and identical mass balloon B has charge $10q$. You hang them from threads near each other. Which statement is correct?

- (a) The force that A exerts on B is 1/10 the force that B exerts on A.
- (b) The force that A exerts on B is 10 times the force that B exerts on A.
- (c) A and B exert the same magnitude forces on each other.



$F_A = F_B$
 Newt. 3rd law.
 Also, Coulomb's law

Questions 9–11: Eight different charged balls, which we treat as point charges, are arranged in a symmetric pattern around a square. $Q = 2 \times 10^{-6}$ C, and $L = 0.5$ m. The charge at location B is $Q_B = +3Q$. The charge at location A is $Q_A = -5Q$.



9. What is the magnitude of the force by Q_B on Q_A ?

- (a) 1.12 N
- (b) 0.432 N
- (c) 0.144 N
- (d) 0.0864 N
- (e) 0.483 N

$r = \sqrt{1^2 + 0.5^2} = 1.118 \text{ m}$

$$F = \frac{1}{4\pi\epsilon_0} \frac{|q_A q_B|}{r^2} = \frac{(9 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}) (3)(5) (2 \times 10^{-6} \text{ C})^2}{(1.118)^2}$$

$= \boxed{0.432 \text{ N}}$

10. What is the x-component of the force by Q_B on Q_A ?

- (a) -0.305
- (b) +0.386 N
- (c) -0.386 N
- (d) 0.193 N
- (e) -0.193 N

$F_x = F \cos \theta$

$$= 0.432 \text{ N} \cos(26.56^\circ)$$

$= \boxed{-0.386 \text{ N}}$

11. What is the y-component of the force by Q_B on Q_A ?

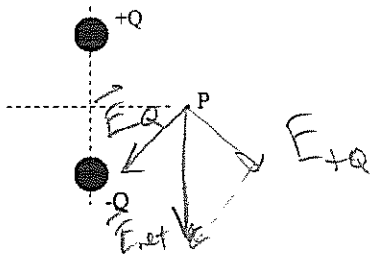
- (a) -0.305
- (b) +0.386 N
- (c) -0.386 N
- (d) 0.193 N
- (e) -0.193 N

$F_y = F \sin \theta$

$$= 0.432 \text{ N} \sin(26.56^\circ)$$

$= \boxed{-0.193 \text{ N}}$

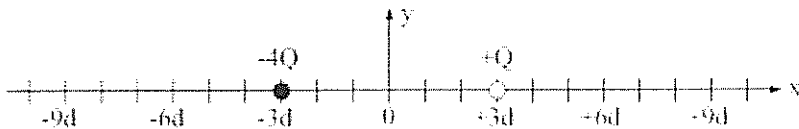
12. Point P is equidistant from equal magnitude, opposite charges as shown below.



What is the direction of the net electric field at point P?

- (a) $+x$ (to the right)
- (b) $-x$ (to the left)
- (c) $+y$ (upward toward the top of the page)
- (d) $-y$ (downward toward the bottom of the page)**
- (e) none of the above, because $E = 0$

Questions 13-14: Two charged objects are arranged as shown below.



13. If we use $k = \frac{1}{4\pi\epsilon_0}$, then in terms of k , Q , and d , what is the x-component of the electric field due to the $-4Q$ charge at $x = 0$? Remember that the sign indicates the direction.

- (a) $+\frac{4kQ}{3d^2}$
- (b) $-\frac{5kQ}{9d^2}$
- (c) $-\frac{kQ}{d^2}$
- (d) $+\frac{1kQ}{9d^2}$
- (e) $-\frac{4kQ}{9d^2}$**

$-4Q$
○

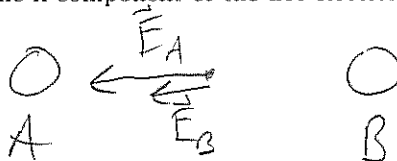


$$E = k \frac{q}{r^2} = \frac{k(4Q)}{(3d)^2} = \frac{4kQ}{9d^2}$$

$$E_x = -\frac{4kQ}{9d^2}$$

14. In terms of Q and d , what is the x-component of the net electric field at $x = 0$? Remember that the sign indicates the direction.

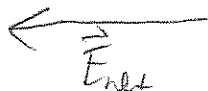
- (a) $+\frac{4kQ}{3d^2}$
- (b) $-\frac{5kQ}{9d^2}$**
- (c) $-\frac{kQ}{d^2}$
- (d) $+\frac{3kQ}{9d^2}$
- (e) $-\frac{4kQ}{9d^2}$



$$E_{Ax} = -\frac{4kQ}{9d^2}$$

$$E_{Bx} = -\frac{kQ}{9d^2}$$

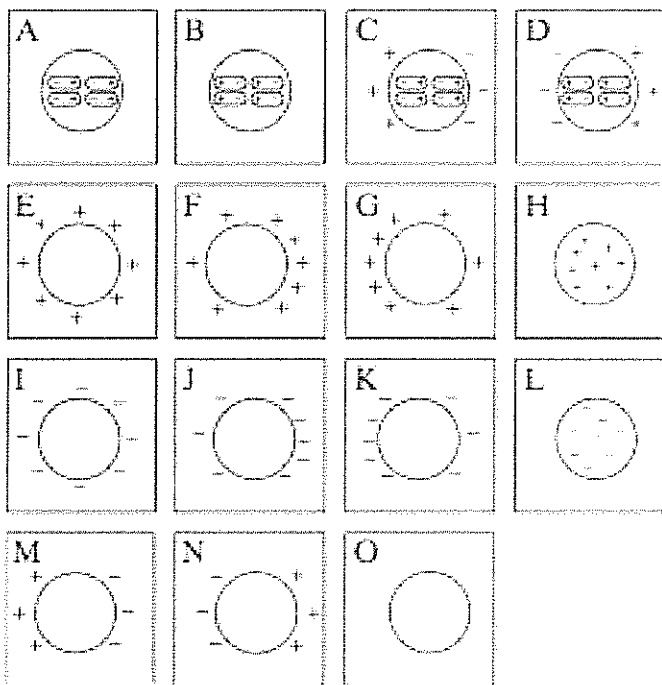
so E_{net} is



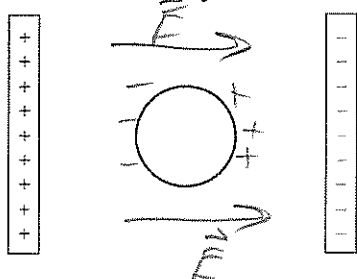
$$E_{net,x} = E_{Ax} + E_{Bx}$$

$$= -\frac{5kQ}{9d^2}$$

Questions 15-17: Use this image to answer each of the following questions.



15. A neutral metal sphere is between two charged plates as shown below.



Which picture shows the polarization of the metal sphere?

- (a) M
- (b) N
- (c) C
- (d) D
- (e) J

\vec{F} on e^- in metal is opposite the applied \vec{E} .

16. The net electric field at a point *inside* the sphere is

- (a) to the right, $+x$
- (b) to the left, $-x$
- (c) zero

$\vec{E}_{net} = 0$ inside a conductor.
 since electrons move until they are in equilibrium.

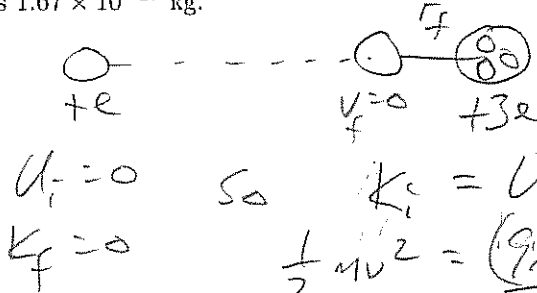
17. If the metal sphere in the previous question is replaced with a neutral plastic sphere (an insulator), which picture shows the polarization of the plastic sphere?

- (a) A
- (b) B
- (c) C
- (d) D
- (e) O, it is not polarized

for a neutral atom in the plastic, \vec{F} on electron cloud is to the left due to the applied \vec{E} .

18. A proton with initial speed v (when it is very far away) is fired directly towards a He^{3+} nucleus whose charge is $+3e$. The nucleus is firmly held in place, so that it will not undergo any type of motion. What initial speed v is needed if the proton's closest distance of approach during the collision is 1×10^{-15} m? The mass of a proton is 1.67×10^{-27} kg.

- (a) 2.1×10^7 m/s
- (b) 4.5×10^7 m/s
- (c) 3.7×10^7 m/s
- (d) 1.4×10^7 m/s
- (e) 2.9×10^7 m/s

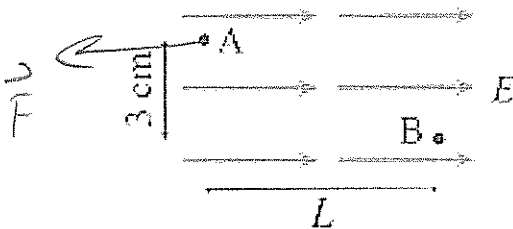


this is Li, not He!

$r_i = \infty$
 $r_f = 1 \times 10^{-15}$ m
 $v_i = v$
 $v_f = 0$

so $K_i = U_f$
 $\frac{1}{2} m v^2 = \frac{(9 \times 10^9) (e) (3e)}{(1 \times 10^{-15} \text{ m})}$
 $= 6.912 \times 10^{-13} \text{ J}$
 $v = \sqrt{\frac{2(6.91 \times 10^{-13} \text{ J})}{1.67 \times 10^{-27} \text{ kg}}} = \sqrt{2.9 \times 10^7 \frac{\text{m}}{\text{s}}}$

Questions 19-20: In the figure below, the electric field is uniform throughout the region. $E = 1000$ V/m and $L = 5$ cm.



\vec{E} points toward lower potential,
 $V_B < V_A$

19. If an electron is at point A, what is the direction of the force on the electron?

- (a) upward, $+y$
- (b) downward, $-y$
- (c) to the left, $-x$
- (d) to the right, $+x$
- (e) The force is zero.

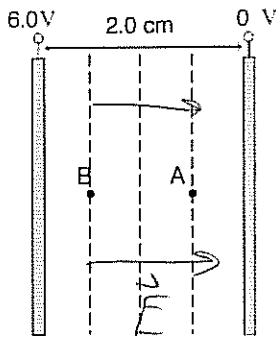
$\vec{F} = q \vec{E}$ so \vec{F} opp. \vec{E} for an electron.

20. What is $|\Delta V|$ between point B and point A?

- (a) 58 V
- (b) 5000 V
- (c) 30 V
- (d) 3000 V
- (e) 50 V

$\Delta V = -E_x \Delta x$
 $= -1000 \frac{\text{V}}{\text{m}} (0.05 \text{ m})$
 $V_B - V_A = -50 \text{ V}$
 $|\Delta V| = 50 \text{ V}$

Questions 21-25: Two plates are 2 cm apart with 6.0 V across the plates as shown below. The dotted lines are equally spaced across the plates.



21. What is the magnitude of the electric field between the plates?

- (a) 1200 V/m
- (b) 12 V/m
- (c) 3 V/m
- (d) 300 V/m

$$E = \frac{\Delta V}{d} = \frac{6V}{0.02m} = 300 \frac{V}{m}$$

22. Which plate is positively charged?

- (a) the left plate
- (b) the right plate

high V plate since \vec{E} is
 \vec{E} and \vec{E} points
 away from +Q.

23. What is the electric potential V at point B?

- (a) 0 V
- (b) 1.5 V
- (c) 3.0 V
- (d) 4.5 V
- (e) 6.0 V

V decreases linearly.
 Since B is $\frac{75\%}{100}$ of the distance, it is
 $\frac{75\%}{100}$ of 6V = $\boxed{4.5V}$

24. If an electron travels from the left plate to the right plate, it

- (a) gains 6 eV of electric potential energy
- (b) loses 6 eV of electric potential energy
- (c) has a constant potential energy

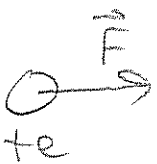
\vec{F} \vec{V}
 $-e$ so e^- slows
 down.

25. If a proton travels from the left plate to the right plate, it

- (a) gains 6 eV of electric potential energy
- (b) loses 6 eV of electric potential energy
- (c) has a constant potential energy

ΔK is - so
 ΔU is +.

Also $\Delta U = q \Delta V$
 $= -e(0 - 6V)$
 $= 6eV$



proton speeds up.

ΔK is + so ΔU is -.

Also, $\Delta U = q \Delta V$
 $= +e(0 - 6V)$
 $= -6eV$