PHYS 2140 Exam 1A Solutions

September 24, 2025

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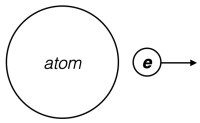
1. **A** If a neutral atom loses an electron, it becomes
A) positively charged **B)** negatively charged



2. Consider a charge $q_A = +5\times10^{-6}$ C which is 0.5 m above a charge $q_B = -3\times10^{-6}$ C.

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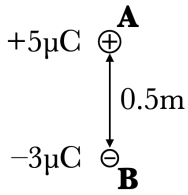
(a) **C** Which charge feels the greater force?
A) charge A **B)** charge B
C) both feel the same force



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(b) **A** In what direction does charge B feel a force?
A) upward **B)** downward

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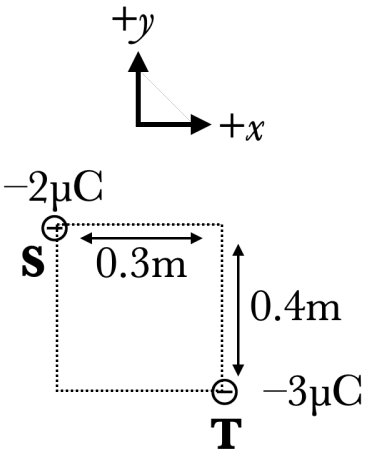
(c) What is the magnitude $|\vec{F}|$ of the force that charge B feels?

$$|\vec{F}| = k\frac{|q_A q_B|}{d^2}$$

$$= (9\times10^9)\frac{(5\times10^{-6})(3\times10^{-6})}{(0.5)^2}$$

$$= \boxed{0.54\,\text{N}}$$

3. Consider a charge $q_S = -2 \times 10^{-6}\,\text{C}$ on the upper-left corner of a 0.3 m by 0.4 m rectangle. A $q_T = -3 \times 10^{-6}\,\text{C}$ charge is on the lower-right corner of the rectangle, as shown. We want to find the force on the charge q_T.



4 (a) **C** Which of these is $\vec{d}$, the vector from the source to the target?

A) $0.3\hat{x} + 0.4\hat{y}$ **B)** $-0.3\hat{x} + 0.4\hat{y}$
C) $0.3\hat{x} - 0.4\hat{y}$ **D)** $-0.3\hat{x} - 0.4\hat{y}$

4 (b) **C** What's the magnitude $|\vec{F}|$ of the force on T?

A) 0.11 N **B)** 0.16 N **C)** 0.22 N **D)** 0.43 N

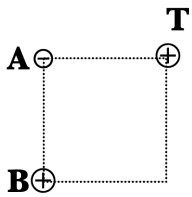
Now $d = |\vec{d}| = \sqrt{(0.3)^2 + (0.4)^2} = 0.5\,\text{m}$.

$$|\vec{F}| = k\frac{|q_S q_T|}{d^2}$$

$$= (9 \times 10^9)\frac{(2 \times 10^{-6})(3 \times 10^{-6})}{(0.5)^2} = \boxed{0.22\,\text{N}}$$

4 4. **B** Consider three charges on a rectangle as shown. If the force on charge T from charge A is $\vec{F}_A = -5\hat{x}$, and the force on T from B is $\vec{F}_B = 3\hat{x} + 4\hat{y}$, what is the magnitude of the net force on T: $|F_T|$. (Hint: don't overthink this!)

A) 0 N **B)** 4.5 N **C)** 8.9 N **D)** 10 N **E)** 12 N



$$\vec{F}_T = \vec{F}_A + \vec{F}_B$$

$$= -5\hat{x} + (3\hat{x} + 4\hat{y})$$

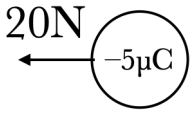
$$= -2\hat{x} + 4\hat{y}$$

$$|\vec{F}_T| = \sqrt{2^2 + 4^2} = \sqrt{20} = 4.5\,\text{N}$$

4

5. **F** A $-5\,\mu$C charge feels a force of 20 N to the left in an electric field. What is the electric field it experiences?

A) 2.5×10^{-7} N/C $\leftarrow$ **B)** 1×10^{-4} N/C $\leftarrow$ **C)** 4×10^{6} N/C $\leftarrow$
D) 2.5×10^{-7} N/C $\rightarrow$ **E)** 1×10^{-4} N/C $\rightarrow$ **F)** 4×10^{6} N/C $\rightarrow$



$$\vec{E} = \frac{\vec{F}}{q}$$
$$= \frac{20\,\text{N} \leftarrow}{-5 \times 10^{-6}\,\text{C}}$$
$$= -4 \times 10^{6}\,\text{N/C} \leftarrow$$
$$= 4 \times 10^{6}\,\text{N/C} \rightarrow$$

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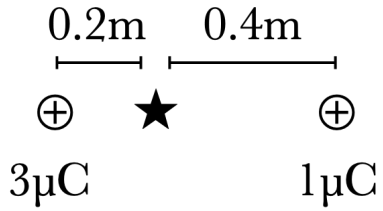
6. What is the electric field at the star between these two charges? Give your answer with at least two significant digits.

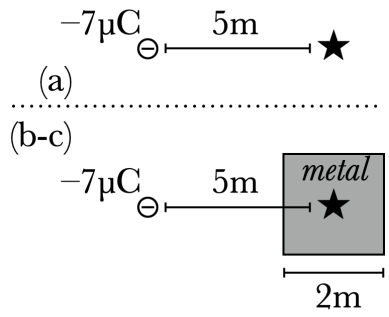


Assume $+\hat{x}$ points to the right.

$$\vec{E} = \vec{E}_L + \vec{E}_R$$
$$= (9 \times 10^{9})\frac{3 \times 10^{-6}}{(0.2)^2}(+\hat{x}) + (9 \times 10^{9})\frac{1 \times 10^{-6}}{(0.4)^2}(-\hat{x})$$
$$= 6.75 \times 10^{5}\hat{x} - 0.562 \times 10^{5}\hat{x}$$
$$= \boxed{6.2 \times 10^{5}\,\text{N/C} \rightarrow}$$

7. Consider a $-7\,\mu$C source charge.

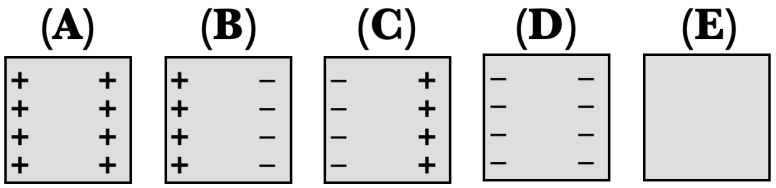
4 (a) What is the electric field at the star, 5 meters away? Include magnitude AND direction (i.e. left, right, etc)



$$\vec{E} = (9 \times 10^9)\frac{-7 \times 10^{-6}}{(5)^2} \rightarrow$$

$$= \boxed{2520\,\text{N/C} \leftarrow}$$

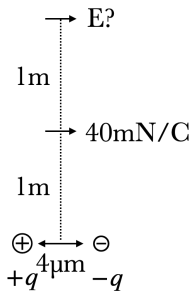
2 (b) **B** Now suppose a neutral metal cube with a side of 2 meters is centered on the star. How does charge distribute itself on the surface of the cube?



2 (c) **D** Compared to your answer in part (a), the electric field at the star inside the cube

A) is stronger **B)** is the same
C) is weaker but not zero **D)** is zero

8. Consider two charges, $+q$ and $-q$, which are 4 microns apart. The electric field a distance 1 meter above the center of these charges is 40 mN/C. (Yes, a meter is much larger than a micron.)



4 (a) **A** What is the electric field 2 meters above the center of these charges?

A) 5 mN/C **B)** 10 mN/C **C)** 20 mN/C **D)** 40 mN/C **E)** 80 mN/C

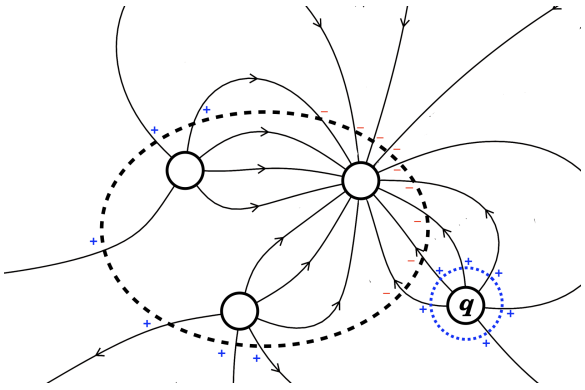
The electric field of a dipole (two equal and opposite charges) dies away as $1/d^3$.

2 (b) What is the name of this charge configuration?

dipole

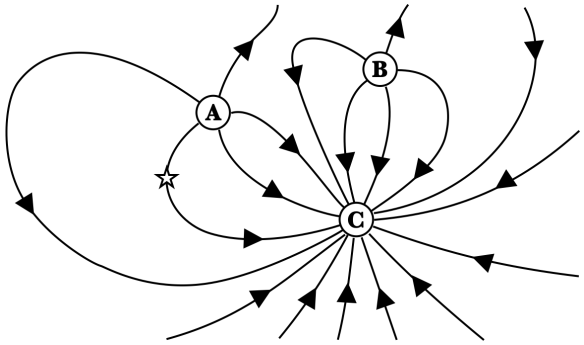
4 9. **D** The figure shows some field lines created by the charges shown. A Gaussian (i.e. imaginary) surface is drawn on the figure. If the charge q in the figure is equal to $+6\,\mu$C, then the total charge inside the Gaussian surface is

A) $+3\,\mu$C **B)** $+6\,\mu$C **C)** $+18\,\mu$C
D) $-3\,\mu$C **E)** $-6\,\mu$C **F)** $-18\,\mu$C



A circle around q has a flux $\Phi = +6$. The black circle has $\Phi = +6 - 9 = -3$. The charge inside a circle is proportional to the flux through it, and since the charge inside the blue circle is $+6\,\mu$C, the charge inside the black circle is $-3\,\mu$C.

10. Consider the field lines created by these three charges: A, B, and C.



4 (a) C Which charge or charges are negative?

A) A **B)** B **C)** C
D) A&B **E)** A&C **F)** B&C
G) All of them **H)** None of them

4 (b) C Which charge has the largest magnitude $|q|$?

A) A **B)** B **C)** C

4 (c) E In which direction does the electric field at the star point?

A) ↑ **B)** ↗ **C)** → **D)** ↘ **E)** ↓

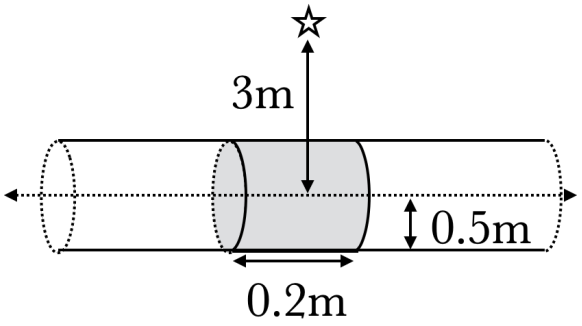
Tangential to the field line

4 (d) C The total charge of these three charges is

A) positive **B)** zero **C)** negative

More field lines are coming from off-screen than going off-screen

11. This figure shows an infinite solid cylinder with a charge density of $4\,\mu\text{C/m}^3$ and a radius of $R = 0.5\,\text{m}$



2 (a) C What symbol should we use to represent this charge density?

A) λ **B)** σ **C)** ρ

Solid cylinders include their interior

4 (b) B What is the total charge of a section of the cylinder that is 0.2 m wide with a volume of $0.157\,\text{m}^3$?

A) 39 nC **B)** $0.63\,\mu\text{C}$ **C)** $6.1\,\mu\text{C}$ **D)** $26\,\mu\text{C}$

$$Q = \rho V = (4\,\mu\text{C/m}^3)(0.157\,\text{m}^3) = 0.63\,\mu\text{C}$$

3 XC (c) What is the electric field at the star, a distance of 3 m from the axis of the cylinder? Include magnitude AND direction.

The linear charge density of the grey cylinder is $\lambda = \frac{Q}{L} = \frac{0.63\,\mu\text{C}}{0.2\,\text{m}} = 3.15\,\mu\text{C/m}$.

$$E = \frac{2k\lambda}{r}$$
$$= \frac{2(9\times10^9)(3.15\times10^{-6})}{3} = \boxed{1.9\times10^4\,\text{N/C}\uparrow}$$