Name KEY
Exam 1 — 18 questions

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) *X* and *Y* are two uncharged conducting metal spheres on insulating stands, and are in contact with each other. A positively charged rod *R* is brought close to *X* as shown in Figure (a).

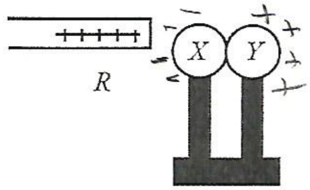


Figure (a)

Sphere *Y* is now moved away from *X*, as in Figure (b).

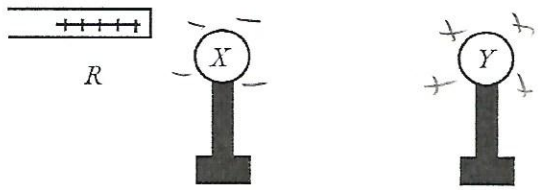


Figure (b)

What are the final charge states of *X* and *Y*?

A) Both *X* and *Y* are neutral.

B) Both *X* and *Y* are negative.

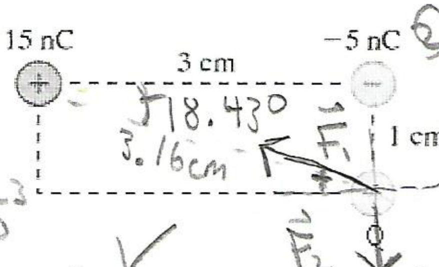
C) *X* is negative and *Y* is positive.

D) *X* is neutral and *Y* is positive.

E) *X* is positive and *Y* is neutral.

See class notes (This was also a class demonstration → hanging foil)

2) The charge in the bottom right corner of the figure is Q =– 45 nC. What is the magnitude of the force on Q?



$\vec{F}_2 = \frac{k(5\times10^{-9})(45\times10^{-9})}{(0.01)^2}\hat{j} = -0.020\,\hat{j}$

$|\vec{F}_1| = k\frac{(15\times10^{-9})(45\times10^{-9})}{(0.0316)^2} = 6.08\times10^{-3}$

$\vec{F}_1 = -6.08\times10^{-3}\cos(18.43°)\,\hat{i} + 6.08\times10^{-3}\sin(18.43°)\,\hat{j}$

$\vec{F}_{TOTAL} = \vec{F}_1 + \vec{F}_2 = -5.77\times10^{-3}\,\hat{i} - 0.0181\,\hat{j}$

A) 2.6×10^{-2} N B) 1.9×10^{-2} N ✓ $|\vec{F}_{TOTAL}|$ C) 3.5×10^{-2} N D) 1.4×10^{-2} N

3) A point charge of -5×10^{-9} coulombs is placed in a region of space that has a constant electric field of 10 N/C in the +x direction. What is the x component of the force on the point charge?

✓ A) -50×10^{-9} N B) $+50 \times 10^{-9}$ N C) $+6.2 \times 10^{-9}$ N D) 0 N

$\vec{F} = q\vec{E} = (-5\times10^{-9})(+10\,\hat{i}) = -50\times10^{-9}\,\hat{i}$

$|Q_1| = |Q_2|$

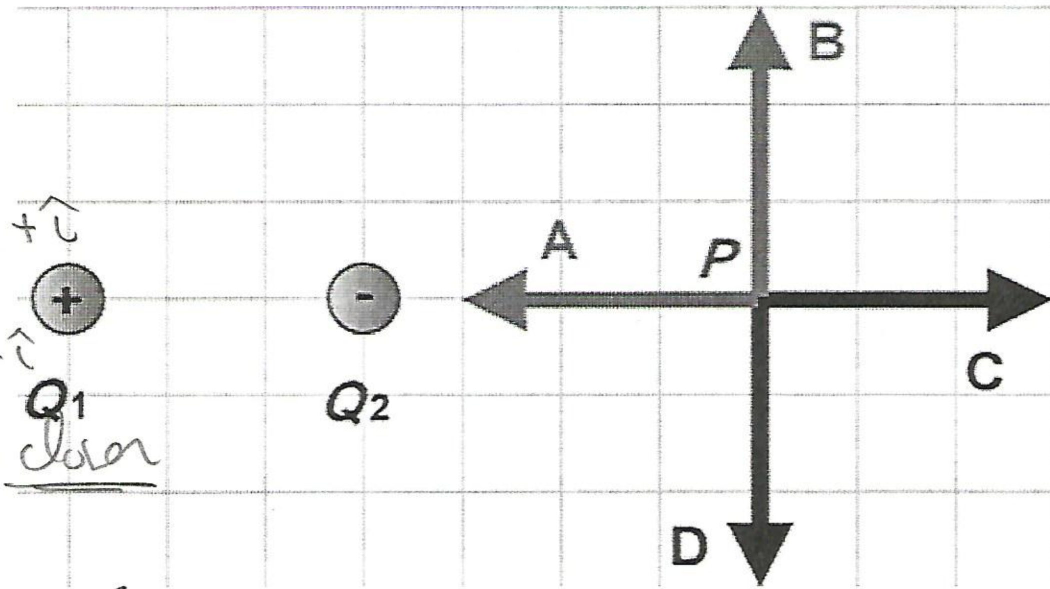
4) Two point charges Q_1 and Q_2 of $\boxed{\text{equal magnitudes}}$ and opposite signs are positioned as shown in the figure. Which of the arrows best represents the net electric field at point P due to these two charges?

$E = \frac{kq}{r^2}$

@P, $\vec{E}_{Q_1}$ is $+\hat{i}$

$\vec{E}_{Q_2}$ is $-\hat{i}$

But, Q_2 is closer



A) A ✓

B) B

C) C

D) D

E) The field is equal to zero at point P.

5) Coulomb's force law was discovered around the year 1785. Michael Faraday propsed the idea of electric fields around the year 1844. Which statement below best charaertizes the relationship between these two ideas?

A) They are the same.

✓ B) Faraday envisioned a charge interacting with a disturbed space, while Coulomb thought about 'action at a distance'.

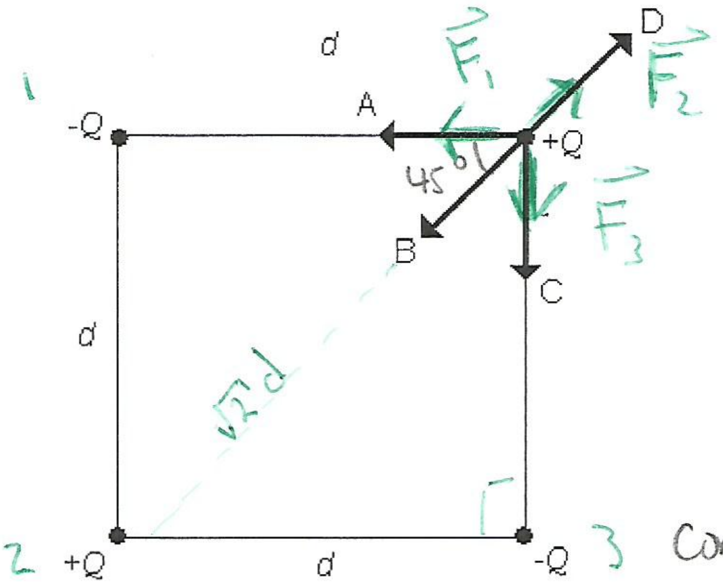
C) They both are good examples what Newton would call 'action at a distance'.

D) The idea of 'action at a distance' only applies to Newton.

CLASS NOTES, I said this several times in several class meetings.

OVER

6) Four point charges of equal magnitude and varying signs are arranged on corners of the square of side d as shown in the figure below. Which of the arrows shown represents the net force acting on the charge at the upper right hand corner of the square?



opposites attract
likes repel.

$|\vec{F}| = \frac{k|Q||Q|}{r^2}$

$|\vec{F}_2| = \frac{1}{2}\frac{kQ^2}{d^2}$

Components of $\vec{F}_1 + \vec{F}_3$ along direction of $\vec{F}_2$ are $\Rightarrow 2 * \left[\frac{kQ^2}{d^2}\right]\cos(45)$
$\Rightarrow 1.4\left[kQ^2/d^2\right]$

A) A B) B C) C D) D

Winner

$\varepsilon = 1 - \frac{293}{1073}$
$\varepsilon = 0.727$
$= \frac{W}{Q_H}$

7) If two uncharged objects are rubbed together and one of them acquires a positive charge then the other one ____.

A) acquires a negative charge. See: NOTES B) also acquires a positive charge.
C) may or may not acquire a negative charge. D) remains the same.

$Q_H = \frac{W}{.727}$

8) A Carnot cycle engine operates between a low temperature reservoir at 20°C and a high temperature reservoir at 800°C. If the engine is required to output $\boxed{20.0 \text{ kJ}}$ (W) of work per cycle, how much heat must the high temperature reservoir transfer to the engine during each cycle? Note: 0 C is 273 K

A) 800 kJ B) 20.5 kJ C) 73.2 kJ D) 27.5 kJ ✓ E) 39.2 kJ

$\varepsilon = \frac{W}{Q_H}$

9) A heat engine with an efficiency of 30.0% performs 2500 J of work. How much heat is discharged to the lower temperature reservoir?

A) 750 J B) 8330 J C) 7080 J D) 1350 J E) 5830 J ✓

$\therefore Q_H = \frac{W}{\varepsilon} = 8333$ || 1st Law $Q_H = W + Q_L$ $\therefore Q_L = Q_H - W = 5833$

10) A point charge of -5×10^{-9} coulombs is placed in a region of space that has a constant electric field of 10 N/C in the +x direction. What is the x component of the electric field at a point 'P' that is 2 meters to the right of the point charge? To be clear, the point charge lies on the x-axis at the origin and the observation point 'P' is also on the x-axis, a distance of 2 meters in the +x direction from the point charge.

A) −11.24 N/C B) +1.24 N/C C) −1.24 N/C ✓ D) +11.24 N/C

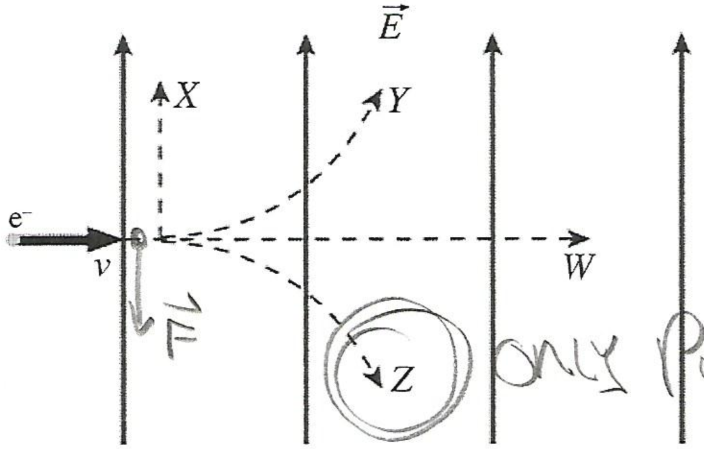
$\vec{E} = \underset{\text{charge}}{\vec{E}_{pt}} + \underset{\text{external}}{\vec{E}} = -\frac{k(5 \times 10^{-9})}{2^2}\hat{i} + 10\hat{i} = -1.24\hat{i}$

negative

11) An electron is initially moving to the right when it enters a uniform electric field directed upwards. Which trajectory shown below will the electron follow?

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

in opposite direction of $\vec{E}$ since q is negative



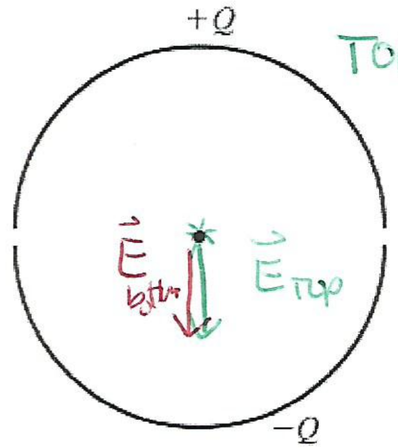
Only Possible Answer.

A) trajectory Z B) trajectory X C) trajectory W D) trajectory Y

12) A circular ring is split into two semi-circles. The top half has a positive charge (Q) evenly distributed, and the bottom half has a negative charge ($-Q$), also evenly distributed. In which direction is the electric field at the point shown (in the center of the ring)?

Worked semicircle in class. Know from symmetry what $\vec{E}$ looks like.

Out of "+"
In to "-"



A) downward
B) to the left
C) upward
D) to the right
E) The electric field is zero in the center of the ring.

13) From the energy that is input into an engine on each cycle, 500 kJ of mechanical work are produced and 600 kJ of heat are exhausted into the environment. What is the efficiency of the engine?

W Q_L

A) 28.6% B) 90.0% C) 45.5% D) 75.0% E) 83.3%

1st Law: $Q_H = W + Q_L = 1100$ kJ

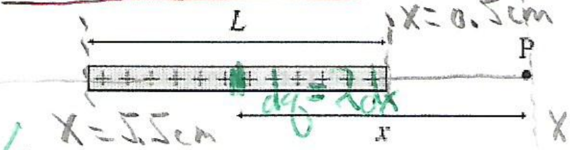
$\varepsilon = \frac{W}{Q_H} = 0.455$

$\lambda = \frac{8.4\times10^{-9}}{0.05}$

Can set up any way we wish! Set it up like class example ☺

14) The figure shows a thin rod of length $L = 5.0$ cm with total charge $Q = 8.4$ nC. What is the magnitude of the electric field E at $x = 3.0$ cm? Note that x is measured from the center of the rod.

$|d\vec{E}| = \frac{k|dq|}{x^2}$



$E = \int_{0.005}^{0.055} \frac{k\lambda dx}{x^2}$

A) 8.4×10^4 N/C
B) 2.7×10^5 N/C
C) 1.8×10^5 N/C
D) 3.7×10^5 N/C

does not look like figure is to scale ☹

15) What is the maximum theoretical efficiency possible for an engine operating between 100°C and 400°C? Note: 0 C is 273 K

A) 65%
B) 75%
C) 45%
D) 55%
E) 25%

$\varepsilon = 1 - \frac{T_L}{T_H} = 1 - \frac{373}{673} = 0.45$

16) A Carnot refrigerator has a coefficient of performance = 2.5. The refrigerator consumes 50 W of power. How much heat is removed from the interior of the refrigerator in 1 hour?

J/s

A) 4.5×10^5 J
B) 72 kJ
C) 1.8×10^5 J
D) 7.5 kJ
E) 7.2×10^5 J

$COP = \frac{Q_L}{W}$ ∴ $Q_L = 2.5 \times 50 = 125 \frac{J}{sec} \times \frac{60 sec}{1 min} \times \frac{60 min}{1 hr} = 4.5\times10^5$ J

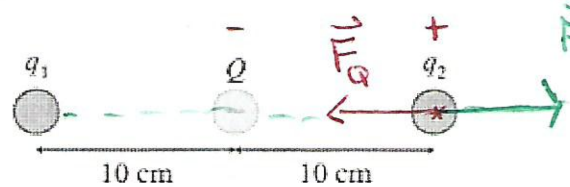
17) The electric field 2.8 cm from a small object points toward the object with a strength of 180,000 N/C. What is the object's charge?

$E = \frac{kq}{r^2}$

A) +16 nC
B) +17 nC
C) −17 nC
D) −16 nC

∴ $q = \frac{(0.028)^2(180000)}{8.99\times10^9} = 1.6\times10^{-8}$ C

18) In the figure, all the charges are point charges and the charge in the middle is $Q = -3.0$ nC. For what charge q_1 will positive charge q_2 be in static equilibrium (zero net force)? Yes, there is enough information to answer this question.



So we see that q_1 must be positive

A) 12 nC
B) 3.0 nC
C) 6.0 nC
D) 25 nC

$= k\lambda\left[-\frac{1}{x}\right]_{0.005}^{0.055}$

$= 8.99\times10^9\left[\frac{8.4\times10^{-9}}{0.05}\right]\left[-\frac{1}{0.055} + \frac{1}{0.005}\right]$

$= 2.74\times10^5$

$|\vec{F}_Q| = |\vec{F}_{q_1}|$

$\frac{k|Q||\cancel{q_2}|}{(0.1)^2} = \frac{k|q_1||\cancel{q_2}|}{(0.2)^2}$

$|q_1| = \frac{(0.2)^2}{(0.1)^2}|Q|$

$|q_1| = 12$ nC