PHY2054 General Physics II

Section 590986

Prof. Douglas H. Laurence

Exam 1 (Chapters 19 – 20)

June 14, 2018

Name: SOLUTIONS

Instructions:

This exam is composed of **10 multiple choice questions** and **4 free-response problems**. To receive a perfect score (100) on this exam, 3 of the 4 free-response problems must be completed. The fourth free-response problem **may not be answered for extra credit**. Each multiple choice question is worth 2.5 points, for a total of 25 points, and each free-response problem is worth 25 points, for a total of 75 points. This means that your exam will be scored out of 100 total points, which will be presented in the rubric below. **Please do not write in the rubric below; it is for grading purposes only.**

Only scientific calculators are allowed – do not use any graphing or programmable calculators.

For multiple choice questions, no work must be shown to justify your answer and no partial credit will be given for any work. However, for the free response questions, **work must be shown to justify your answers.** The clearer the logic and presentation of your work, the easier it will be for the instructor to follow your logic and assign partial credit accordingly.

The exam begins on the next page. **The formula sheet is attached to the end of the exam.**

Exam Grade:

Multiple Choice	
Problem 1	
Problem 2	
Problem 3	
Problem 4	
Total	

MULTIPLE CHOICE QUESTIONS

1. Two charges are placed some distance apart, and exert a force F on each other. If the distance between the charges is halved, and each charge is doubled, what would the new force exerted between the charges be?

   (a) $F/16$
   (b) $F/8$
   (c) ~~$8F$~~
   (d) $16F$

$$F = k\frac{q_1 q_2}{d^2} \rightarrow F' = k\frac{(2q_1)(2q_2)}{(d/2)^2} = \underbrace{\frac{2\cdot 2}{1/4}}_{8}\underbrace{\left(k\frac{q_1 q_2}{d^2}\right)}_{F} = \boxed{16F}$$

2. Consider a charge q_A producing an electric field. A second charge q_B feels the electric field with a magnitude E. If the distance between q_A and q_B is doubled, and the charge q_B is halved, what is the new value of the electric field felt by q_B?

   (a) $E/8$
   (b) $E/4$
   (c) $E/2$
   (d) E

$$E = k\frac{q_A}{d^2} \rightarrow E' = k\frac{q_A}{(2d)^2} = \frac{1}{4}\underbrace{\left(k\frac{q_A}{d^2}\right)}_{E} = \frac{1}{4}E$$

3. Which of the following is true for conductors?

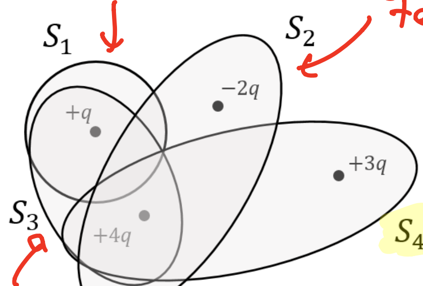
   (a) Charges will spread throughout a conductor and the electric field will be zero within the conductor.
   (b) Charges will move to the surface of a conductor and the electric field will be zero within the conductor.
   (c) Charges will move to the surface of a conductor and the electric field will be non-zero within the conductor.
   (d) Charges will be spread throughout a conductor and the electric field will be non-zero within the conductor.

GAUSS' LAW:

$$\Phi_{tot} = \frac{q_{enc}}{\varepsilon_0}$$

$q_{enc,1} = +q$

$q_{enc,2} = +2q$



$\boxed{q_{enc,4} = +7q}$

$q_{enc,3} = +5q$

LARGEST q_{enc}
$\Rightarrow$ LARGEST Φ

4. Which surface in the above figure has the largest flux passing through it?

   (a) S_1
   (b) S_2
   (c) S_3
   (d) S_4

5. A charge q can be placed at the center of 3 different Gaussian surfaces: Surface A is a cube with a side length L, Surface B is a sphere with a radius L, and Surface C is a cylinder with a height and radius of L. Which surface should the charge be placed inside to produce the maximum flux through the surface?

   (a) A
   (b) B
   (c) C
   (d) All Gaussian surfaces would have the same flux

   $\Phi_{tot} = \frac{q_{enc}}{\varepsilon_0}$

   All q_{enc} are the same, so all Φ_{tot} are the same!

6. A 1C charge moves from point A, which has a potential of 2V, to point B, which has a potential of 6V. What is the gain in the charge's kinetic energy from A to B?

   (a) 2J
   (b) 4J
   (c) 6J
   (d) 12J

   $\Delta K = \Delta U = q\Delta\phi = (1C)(4V) = 4J$

   Kinetic gained / Potential lost

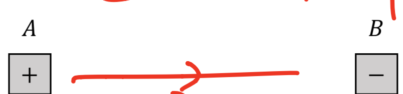
   $\Delta\phi = \phi_A - \phi_B$
   $= 6V - 2V = 4V$

7. Protons will always move towards:

   (a) High potential energy and high potential
   (b) High potential energy but low potential
   (c) Low potential energy but ~~high potential~~
   (d) Low potential energy and low potential

   $\Delta U = q\Delta\phi$
   (−) (+) (−) for protons

   $\boxed{\text{+ charges to low } \phi}$



E from + to −

8. Charges are separated such that all positive charges accumulate at point A and all negative charges accumulate at point B, as shown in the figure above. Which of the following statements is true?

   (a) The electric field points from A to B, with A being the point of low potential
   (b) The electric field points from A to B, with B being the point of low potential
   (c) The electric field points from B to A, with A being the point of low potential
   (d) The electric field points from B to A, with B being the point of low potential

   + → −
   $q > 0$
   + charge to low ϕ!

9. Capacitance is a quantity that should depend upon:

   (a) The charge stored on the capacitor
   (b) The voltage across the capacitor
   (c) The geometry of the capacitor
   (d) Any number of these factors

   Doesn't depend on dynamic variables like Q & V.

10. A capacitor with a capacitance of 4F is connected to a battery outputting a voltage of 2V. What is the charge on the capacitor?

   (a) 2C
   (b) 4C
   (c) 8C
   (d) 12C

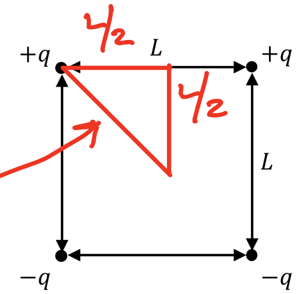
   $Q = CV = (4F)(2V) = 8C$

FREE-RESPONSE PROBLEMS

$r = \sqrt{\left(\frac{L}{2}\right)^2 + \left(\frac{L}{2}\right)^2}$

$= \sqrt{5^2 + 5^2}$

$= 7.1\,\text{cm}$



$q = e = 1.6 \times 10^{-19}$

$L = 10\,\text{cm}$

1. Imagine four charges arranged in the corners of an $L \times L$ square, as shown in the figure above. Consider the case of $q = e$ and $L = 10$cm.

(a) What is the electric field at the center of the square?

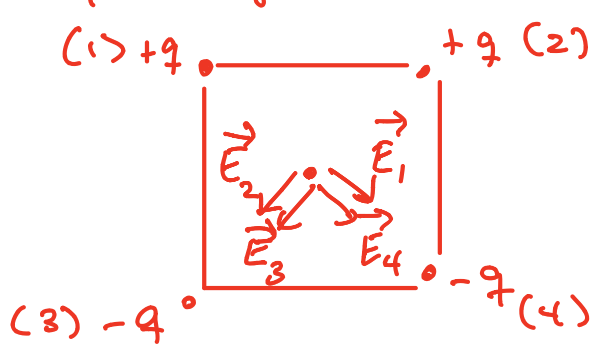
(b) If a fifth charge of $+q$ was placed at the center of the square, what would be the electric force on it?

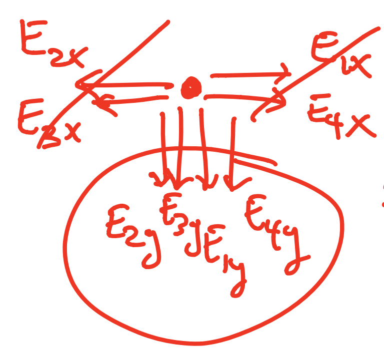
(c) If you could swap any charge at one corner for the charge at another corner – for example, the $+q$ charge in the upper-right corner for the $-q$ charge in the lower-left corner – how would you rearrange the charges so that the force on the fifth charge at the center was zero? *Note: there might be multiple ways to arrange the charges; as long as your answer results in a zero force, it's correct.*

(a) ALL CHARGES HAVE SAME q & r, SO ALL HAVE SAME E:

$$E = k\frac{q}{r^2} = (8.99 \times 10^9)\frac{(1.6 \times 10^{-19})}{(0.071)^2} = \boxed{2.85 \times 10^{-7}\ \frac{N}{C}}$$

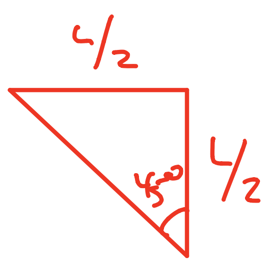
BY SYMMETRY, THE HORIZONTAL COMPONENTS CANCEL:





SUM OF 4 y-COMPONENTS

BREAK $\vec{E}$ INTO ITS y-COMPONENT, THEN MULTIPLY BY 4 (SINCE $E_{1y} = E_{2y} = E_{3y} = E_{4y}$):



$$E_y = E\cos(45°) = (2.85 \times 10^{-7})\cos(45°)$$

$$= \boxed{2.02 \times 10^{-7}\ \frac{N}{C}}$$

So, $\sum E_x = 0$

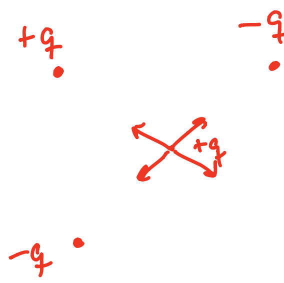
& $\sum E_y = 4E_y = 4(2.02 \times 10^{-7})$

$\Rightarrow \sum E_y = 8.08 \times 10^{-7} \frac{N}{C}$

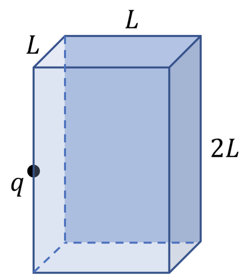
$\boxed{\sum E = 8.08 \times 10^{-7} \frac{N}{C}}$

(b) $F = qE = (1.6 \times 10^{-19})(8.08 \times 10 \frac{N}{C}) = \boxed{1.29 \times 10^{-25} N}$

(c)



All F's cancel $\Rightarrow \boxed{\sum F = 0}$



2. A charge q is placed on an edge of a rectangular prism, halfway along the edge, as shown in the figure above.

(a) Show that Gauss' law doesn't apply to this charge. *Hint: draw the electric field lines this charge emits and convince me that not all of them produce flux through the surface that q is on.*

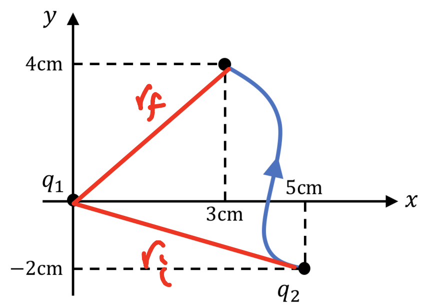
(b) Using multiple blocks (of the same size $L \times L \times 2L$ as shown in the figure), build a uniform geometry that the charge q actually lies at the center of, so that Gauss' law will apply. Explain how this new, bigger surface that you've built will allow Gauss' law to apply – that is, how it fixes the problem from part (a).

(c) What is the total flux through this bigger surface, the one built up of multiple blocks.

(d) What, then, is the total flux through the original $L \times L \times 2L$ block in the figure?

$r_i = \sqrt{2^2 + 5^2} = 5.4\,\text{cm}$

$r_f = \sqrt{3^2 + 4^2} = 5\,\text{cm}$



3. A charge $q_1 = 2.5\mu\text{C}$ is placed at the origin of an x, y-coordinate system. A second charge, $q_2 = -3.7\mu\text{C}$, is moved from its initial position to a final position along the path shown in the figure, while q_1 remains fixed in place. How much work is done by the electric force on q_2 along the path taken? Consider the same set up as for the previous problem. If the charge q_2 has a mass $m_2 = 1.7 \times 10^{-10}$ kg, and was initially at rest, what is the speed of q_2 after it travels along its path?

(a) What is the force between the two charges when q_2 is at its initial position?

(b) What is the work done by the electric force on q_2 as it moves from its initial point to its final point, along the path shown in the figure?

(c) If q_2 starts from rest, what is its speed at the end of the path taken?

(d) Check the sign of your answer for part (b). Does it make sense that it has that sign? That is, should the work be positive or negative? Why?

(a) $F = k\dfrac{q_1 q_2}{r_i^2} = (8.99\times10^9)\dfrac{(2.5\times10^{-6})(3.7\times10^{-6})}{(0.054)^2} = \boxed{28.5\,\text{N}}$

(b) $U_i = k\dfrac{q_1 q_2}{r_i} = (8.99\times10^9)\dfrac{(2.5\times10^{-6})(-3.7\times10^{-6})}{(0.054)}$

$= -1.54\,\text{J}$

$U_f = k\dfrac{q_1 q_2}{r_f} = (8.99\times10^9)\dfrac{(2.5\times10^{-6})(-3.7\times10^{-6})}{(0.05)}$

$= -1.66\,\text{J}$

$W = -\Delta U = U_i - U_f = -1.54 - (-1.66)$

$= \boxed{0.12\,\text{J}}$

(c) $W = \Delta K = K_f - \cancel{K_i}^{\,0} = \frac{1}{2}mv^2$

$\Rightarrow v = \sqrt{\dfrac{2W}{m}} = \sqrt{\dfrac{2(0.12)}{(1.7\times10^{-10})}} = \boxed{37{,}574\,\text{m/s}}$

(d) Yes, A + work means K GAINED ($\Delta K > 0$).

4. A parallel plate capacitor has an area $A = 2.5 \times 10^{-4}$ m^2 and a plate separation $d = 0.7$mm. This capacitor is then connected to a voltage source of $V = 5$V.

(a) What is the capacitance of this capacitor? *Note: you only need to use the formula for capacitance, you don't need to prove it.*

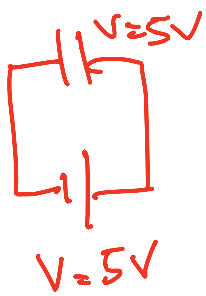
(b) What would the potential difference across the capacitor plates be? Make sure to include a justification for why you know this to be true.

(c) What is the charge stored by the capacitor?

(d) What is the electric field between the capacitor plates?

(a) $C = \varepsilon_0 \frac{A}{d} = (8.85\times10^{-12}) \frac{(2.5\times10^{-4})}{(0.7\times10^{-3})} = 3.16\times10^{-12}\,F$

(b) IF VOLTAGE SOURCE IS 5V, THEN V = 5V FOR CAPACITOR.



LOOP RULE! BOTH ELEMENTS HAVE THE SAME VOLTAGE!

(c) $Q = CV = (3.16\times10^{-12})(5) = 1.58\times10^{-11}\,C$

(d) $E = \frac{Q}{A\varepsilon_0} = \frac{(1.58\times10^{-11})}{(2.5\times10^{-4})(8.85\times10^{-12})} = 7141\,\frac{N}{C}$

FORMULA SHEET

- Vectors:

$$\vec{A}\cdot\vec{B} = AB\cos\theta = A_xB_x + A_yB_y + A_zB_z$$

$$\left|\vec{A}\times\vec{B}\right| = AB\sin\theta$$

- Physics I Formulae:

$$\sum \vec{F} = m\vec{a}$$

$$W = \vec{F}\cdot\Delta\vec{x}$$

$$W_{tot} = \Delta K$$

$$W_{cons} = -\Delta U$$

$$K = \frac{1}{2}mv^2$$

$$K_i + U_i = K_f + U_f$$

- Electric Forces and Fields:

$$e = 1.6\times 10^{-19}\ \mathrm{C}$$

$$\left.\begin{aligned} k &= 8.99\times 10^{9}\ \frac{\mathrm{Nm}^2}{\mathrm{C}^2} \\ \epsilon_0 &= 8.85\times 10^{-12}\ \frac{\mathrm{F}}{\mathrm{m}}\end{aligned}\right\}\ k = \frac{1}{4\pi\epsilon_0}$$

$$Q = Ne$$

$$F = k\frac{q_1q_2}{r^2}$$

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

$$E = k\frac{q}{r^2}$$

$$\Phi_E = \vec{E}\cdot\vec{A}$$

$$\Phi_{tot} = \frac{q_{enc}}{\epsilon_0}$$

$$\lambda = \frac{Q}{L} \quad \text{or} \quad \sigma = \frac{Q}{A} \quad \text{or} \quad \rho = \frac{Q}{V} \quad \text{(charge densities)}$$

- Electric Potential Energy and Electric Potential:

$$U = k\frac{q_1q_2}{r}$$

$$\phi = k\frac{q}{r}$$

$$U = q\phi \quad \text{and} \quad \Delta U = q\Delta\phi$$

$$E_{av} = \frac{\Delta\phi}{\Delta x}$$

$$V = \Delta\phi$$

- Capacitance and Dielectrics:

$$Q = CV$$

$$\left.\begin{aligned} C &= \epsilon_0 \frac{A}{d} \\ E &= \frac{\sigma}{\epsilon_0} \end{aligned}\right\} \text{ Parallel plate capacitors}$$