APPC, E & M: Unit A HW 7

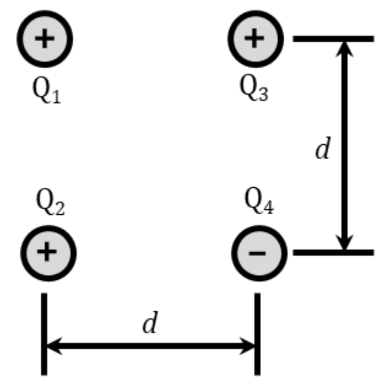
Name: ______________________
Hr: ___ Due at beg of hr on: __________

UA, HW7, P1
Reference Video: "Potential Energy Due to Point Charges"
YouTube, lasseviren1, ELECTRIC POTENTIAL DIFFERENCE (VOLTAGE) playlist

A. Write an equation that shows the relationship between the work done by a conservative force W_{cons} and the change in the potential energy ΔU of a system.

B. Write the equation that gives the potential energy U associated with the configuration of two charges q_a and q_b that are separated from each other by a distance r.

Refer to the figure at right in completing the rest of this problem, which deals with using the principle of superposition to find the total electrical potential energy U of a collection of point charges. We're going to build up the configuration shown from nothing, so see if you can follow the logic...



C. If we have NOTHING (or, said another way, if all our charges are at a distance of ∞), then the total potential energy U stored in the "system" is _______.

D. Now, from ∞ , we bring in charge Q_1. Because there are no other charges around to exert a force on Q_1 as we bring it in, there IS no electric force F_e that applies here, and therefore the amount of work done is _______ and (by your Part A answer) the amount by which the potential energy U has changed is _______, which means that the total potential energy U stored in this one-charge system is now _______.

E. Complete the table.

From ∞, we now bring in charge...	With regard to what is already present, which is...	...the F_e that exists between these two particular charges will have done work W (over the entire distance) having WHICH sign?	And the amount by which the potential energy ΔU of the system will have changed has WHICH sign?	Write the equation (see Part B) for the potential energy U of a system containing just these two charges. Include (+) or (−), use variables from the figure, and show which charges are involved, e.g., U_{12} = ???
Q_2	Q_1			
Q_3	Q_1			
	Q_2			
Q_4	Q_1			
	Q_2			
	Q_3			

F. By the principle of superposition, if you wanted to find the total electrical potential energy U associated with the system shown in the figure, what would you have to do with the quantities in the rightmost column of the table above?

UA, HW7, P2
Reference Video: "Potential, Potential Difference, and Voltage"
YouTube, lasseviren1, ELECTRIC POTENTIAL DIFFERENCE (VOLTAGE) playlist

A. "The magnitude of the electric field E at a given location is the electric force F felt by a particle AT that location…divided by the charge q of the particle." Write an equation (that DOES have a denominator) that illustrates this statement.

B. Based on your Part A answer, why does it makes sense that the electric field E is a vector quantity?

C. "The electric potential V at a given location is the potential energy U possessed by a particle AT that location…divided by the charge q of the particle." Write an equation (that DOES have a denominator) that illustrates this statement.

D. Based on your Part C answer, why does it makes sense that electric potential V is a scalar quantity?

E. Write the no-denominators forms of your answers to Parts A and C.

F. The unit for potential is the volt (V). From your Part C answer, 1 volt must be equal to…

G. Write the equation for determining the potential V at a distance r away from a point charge Q.

UA, HW7, P3
Reference Video: "Potential Difference as a Path Integral (Part I)"
YouTube, lasseviren1, ELECTRIC POTENTIAL DIFFERENCE (VOLTAGE) playlist

A. Potential difference (also called ____________________) is measured using an instrument called a ________________________. When using this instrument, we are always measuring the potential at the ____________ lead with respect to the potential at the ____________ lead.

B. Notation such as V_{YZ} means "the potential at Point Y with respect to the potential at Point Z."
If we let B = black and R = red, write the notation that would apply to your Part A answer.

C. Suppose you would like to determine the potential difference between two points, *O* and *P*. Unfortunately, you don't have an instrument like what you mentioned in your Part A answer ☹. However, you DO happen to know the electric field function $E(r)$ between the two points, i.e., you know how the *E* field behaves at every single step along the path between *O* and *P*.
Write the path integral that you would have to solve, i.e., V_{OP} = ?
(Yes, it will have an integral sign. No, you won't actually solve it.)

D. Suppose now that the electric field along the path between *O* and *P* is constant. Rewrite your Part C answer to reflect this information. (Yes, it still needs an integral sign.)

E. If the length of the path between *O* and *P* is given by the distance *r*, solve now the integral of Part D, i.e., determine V_{OP} = ? (This is easy to do, and your answer is what occurs between the plates of a capacitor, where the *E* field is constant.)

UA, HW7, P4
Reference Video: "Potential Difference as a Path Integral (Part II)"
YouTube, lasseviren1, ELECTRIC POTENTIAL DIFFERENCE (VOLTAGE) playlist

Let's set the stage. Suppose you are given an object's acceleration as a function of time: $a(t) = \frac{4}{t^2}$

A. Change the power on t so that the expression has NO denominator. Write that here.

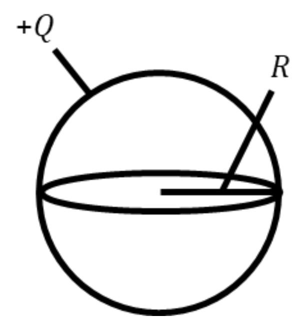
B. Now, write an expression for the velocity of the object as a function of time.

C. The $a(t)$ function has one term: $\frac{4}{t^2}$. When you integrated this, what did the power on t turn into?

D. Why does your Part B answer have two terms, even though the original $a(t)$ function has only one? FYI: Your Part B answer should have two terms. ☺

E. In essence, WHAT did you integrate to obtain the second term (i.e., the one that DOESN'T have a t in it) of your $v(t)$ equation?

Okay, now consider the solid metal sphere shown. The sphere has a net charge $+Q$ and radius R.



F. To review, what is the E field within the sphere, i.e., for $r < R$?

G. Also, recall that the equation for finding the E field at a distance $r \geq R$ away from the center of a metal sphere having net charge Q is the same equation as for finding the E field at a distance r away from a point charge Q. Write that equation here.

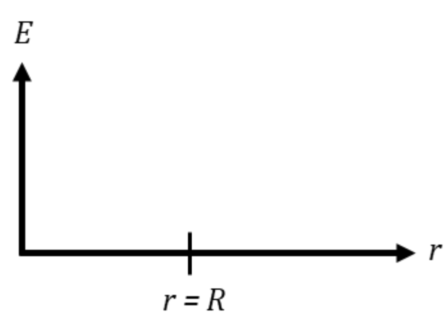
H. Change the power on r in your Part G answer and rewrite the equation without a denominator.

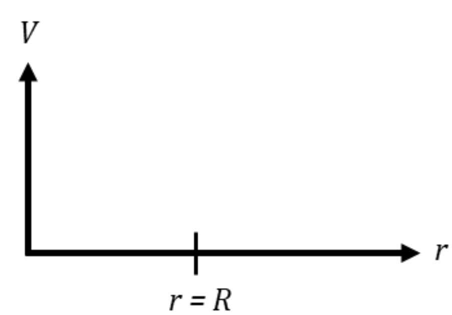
Recall now that a potential V can be obtained by evaluating the path integral of the E field between two points a and b, i.e.,, $V_{ab} = \int_a^b \vec{E} \cdot d\vec{r}$.

I. If you use the path integral equation on your Part F answer, you will get a potential V for our charged sphere, for $r \leq R$. What is that answer, i.e., V = ? FYI: This question connects to your Parts D and E answers.

J. Now, use the path integral on your Part H answer to obtain an expression for the potential V outside the sphere, where $r \geq R$. Hint: The limits of the integral are from r to ∞, i.e., you'll need to evaluate… $V = \int_r^\infty \vec{E} \cdot d\vec{r}$

K. At right, complete the graphs. Above, each distinct portion of each graph, write an expression showing your understanding of how the quantity on the y-axis relates to r .

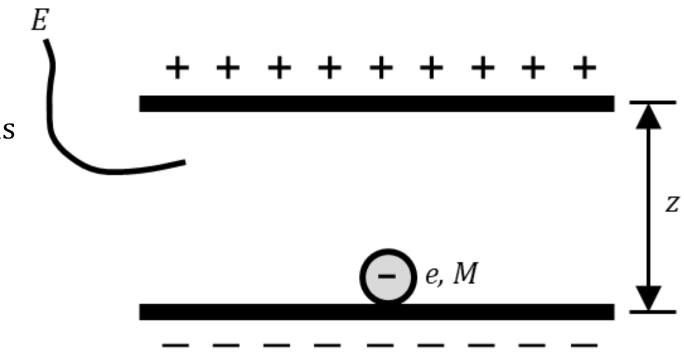




UA, HW7, P5

Reference Video: "Accelerating a Charged Particle Between Two Charged Plates"
YouTube, lasseviren1, ELECTRIC POTENTIAL DIFFERENCE (VOLTAGE) playlist

An electron of mass *M* and charge *e* starts from rest between two equally and oppositely charged plates, as shown in the figure.



A. Draw proper *E* field lines into the figure.

We will first use Newton's laws and kinematics equations for constant acceleration to derive an expression for the final speed v_f of the electron when it hits the (+) plate.

B. Write an expression for the electric force on the electron, while it is in the presence of the *E* field.

C. Your answer to Part B is not only the electric force; it is also the net force on the electron. (Gravity is completely negligible.) Use your Part B answer and Newton's 2nd law to write an expression for the acceleration of the electron, i.e., a = ?

D. Here, we are not interested in the time that the electron takes to make its trip, nor are we given the time of travel (although we could find it, if we wanted). Write some version of the "no-time" equation of kinematics.

E. Combine your Parts C and D answers, along with the quantities given in the figure, to obtain an expression for the final speed v_f of the electron when it hits the (+) plate.

We will now (hopefully) obtain the same expression for v_f using conservation of energy.

F. There is a potential difference *V* between one charged plate and the other. Use the quantities given to write an expression for this potential difference *V*. (If necessary, refer back to your answer to Part E of Problem 3.)

G. The electron has potential energy *U* when it is at its starting location. Use the quantities given and your Part F answer to find an expression for the electron's initial potential energy *U*. (If necessary, refer back to your answer to Part E of Problem 2.)

H. All of the potential energy *U* from your Part G answer is converted into kinetic energy *K* as the electron travels across the gap between the plates. Use this fact to obtain an expression for the final speed v_f of the electron when it hits the (+) plate.

I. Our scenario has the electron experiencing a constant acceleration. Which method (Newton's laws + kinematics <u>OR</u> conservation of energy) will work even if the acceleration ISN'T constant?