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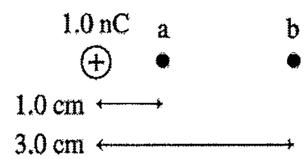
Physics Worksheet
Potentials

Question 1

For the situation shown in the graph, find



a) The potential at points **a** and **b**.

$$V_a = \frac{9\times10^9(1\times10^{-9}C)}{0.01m} = 900V$$

$$V_b = 300V$$

b) The potential difference between points **a** and **b**.

$$\Delta V = V_+ - V_- = 600V$$

c) The potential energy of a proton at points a and b. What about an electron?

$$U_a = (900V)e = 900eV$$

$$U_b = (300V)e = 300eV$$

— the electron-volt is a commonly used unit for energy in physics.

$$1eV = 1.602\times10^{-19}J$$

d) What is the speed at point **a** of a proton that was moving to the left at point **b** with a speed of 4.0×10^5 m/s?

We know that $K_a + U_a = K_b + U_b$ (conservation of energy)

So $K_a = K_b - (U_a - U_b) = \frac{1}{2}mv^2 - 600eV$

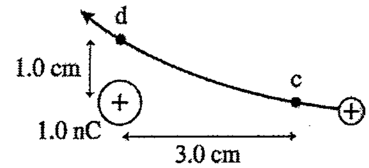
$$= \frac{1}{2}(1.67\times10^{-27}kg)(4.0\times10^5 m/s)^2 - 600eV$$

$$= 1.34\times10^{-16}J - 9.61\times10^{-17}J = 3.8\times10^{-17}J$$

the speed is

$$V = \left(\frac{2(3.8\times10^{-17}J)}{1.67\times10^{-27}kg}\right)^{1/2} = 2.1\times10^5 m/s$$

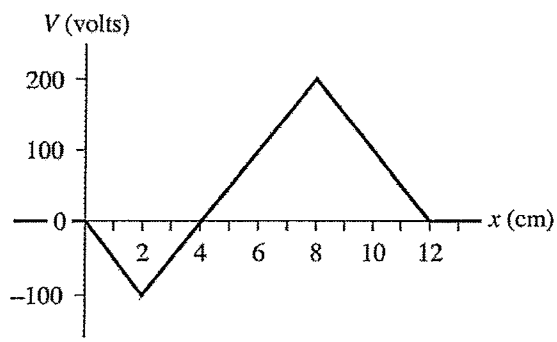
e) For this figure, what is the speed at point **d** of a proton that was moving to the left at point **c** with a speed 4.0×10^5 m/s?

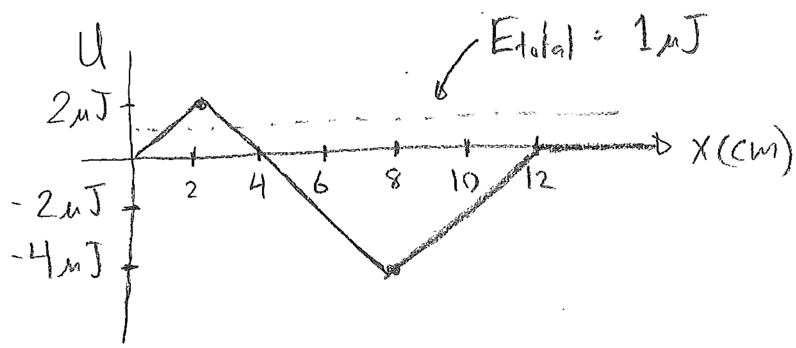


It's the same as d). The change in potential energy is the same, so the speed must be the same.

Question 2

This graph shows the electric potential along the x-axis. In the space beside it, draw the potential energy diagram for a -20 nC charged particle that moves through this potential.





Suppose this charged particle is shot from the right (at x > 12 cm) with a kinetic energy of 1 microjoule.

a) Where is the point of maximum speed?

At 8 cm the potential energy is the lowest, so the kinetic energy is the highest.

b) What is the particle's kinetic energy at this speed?

$E = K + U = 1\mu J \Rightarrow K = 1\mu J + 4\mu J = 5\mu J$

c) Where is the turning point?

The turning point is where $K = 0$ and $U = 1\mu J$. For a particle coming from the right this happens at $x = 3$ cm

d) What is the electric field at the turning point?

$$E_x = -\frac{dV}{dx} = -\left(\frac{300V}{6\,cm}\right) = -5000\ \frac{V}{m}$$

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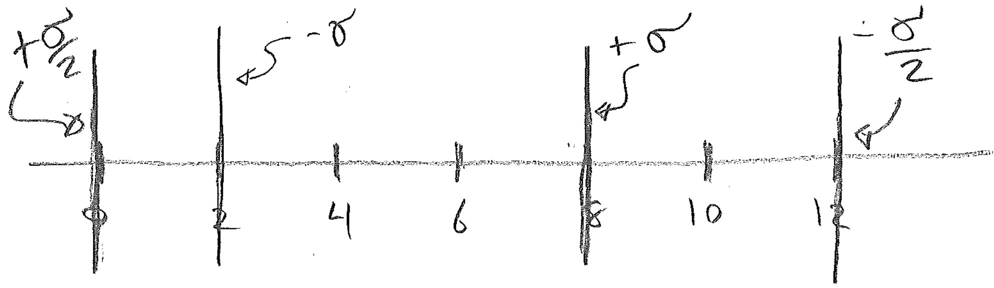
e) What is the force at the turning point?

$$F = -\frac{dU}{dx} = -\left(\frac{-6\mu J}{6\,cm}\right) = \frac{10^{-6}\,J}{10^{-2}\,m} = 10^{-4}\,N$$

f) What charge configuration might be responsible for this potential. Draw is below.

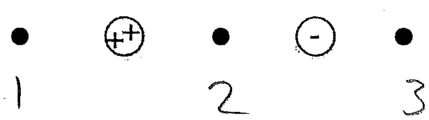


Question 3

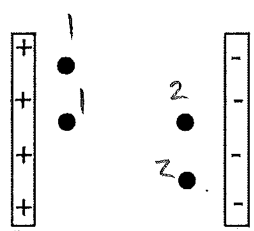
4 planes (nested capacitors)

For each of the following configurations rank the electric potentials at the points from highest to lowest.

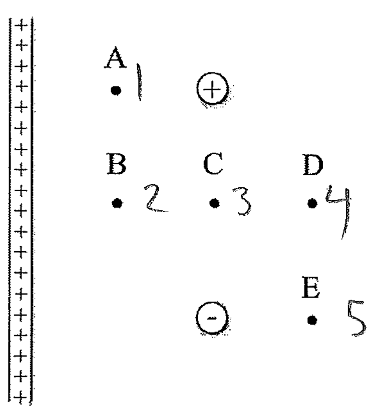
a)



b)



c)



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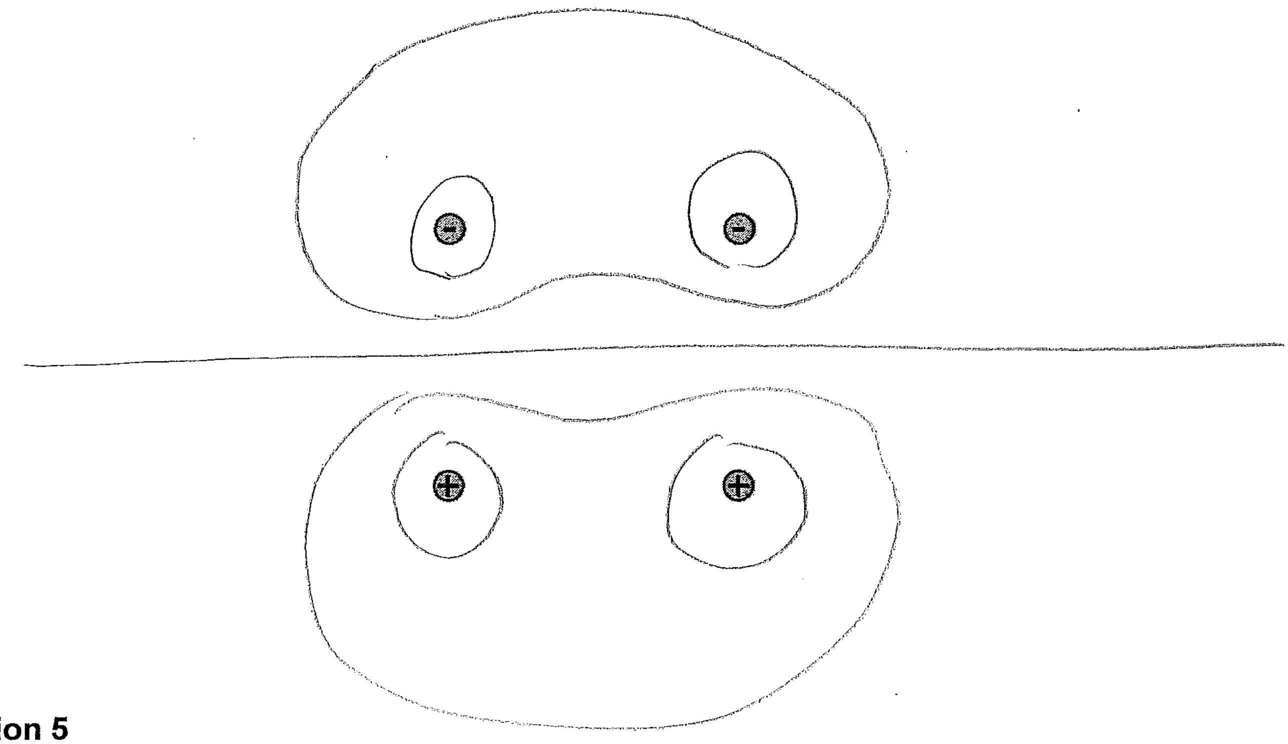
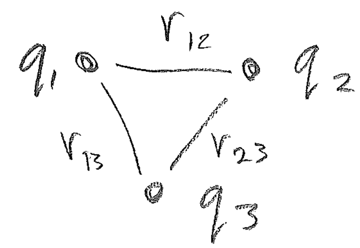
Question 4

Draw the equipotentials for the charge configuration below. Be sure to label the V = 0 equipotential. Also plot equipotentials that circle one and two charges. Are there ones that circle three?



Question 5

The potential energy between two charges q_1 and q_2 is given by $U = kq_1q_2/r^2$. What is the expression for the potential energy of three charges? Think of the work is would take to construct a system of charges. How many terms in the potential energy are there is there are 4 charges? What about n charges?



$$U = \frac{kq_1q_2}{r_{12}^2} + \frac{kq_1q_3}{r_{13}^2} + \frac{kq_2q_3}{r_{23}^2}$$

For 4 charges we need to add 3 more terms

$$U = \frac{kq_1q_2}{r_{12}^2} + \frac{kq_1q_3}{r_{13}^2} + \frac{kq_2q_3}{r_{23}^2}$$

$$+ \frac{kq_1q_4}{r_{14}^2} + \frac{kq_2q_4}{r_{24}^2} + \frac{kq_3q_4}{r_{34}^2}$$

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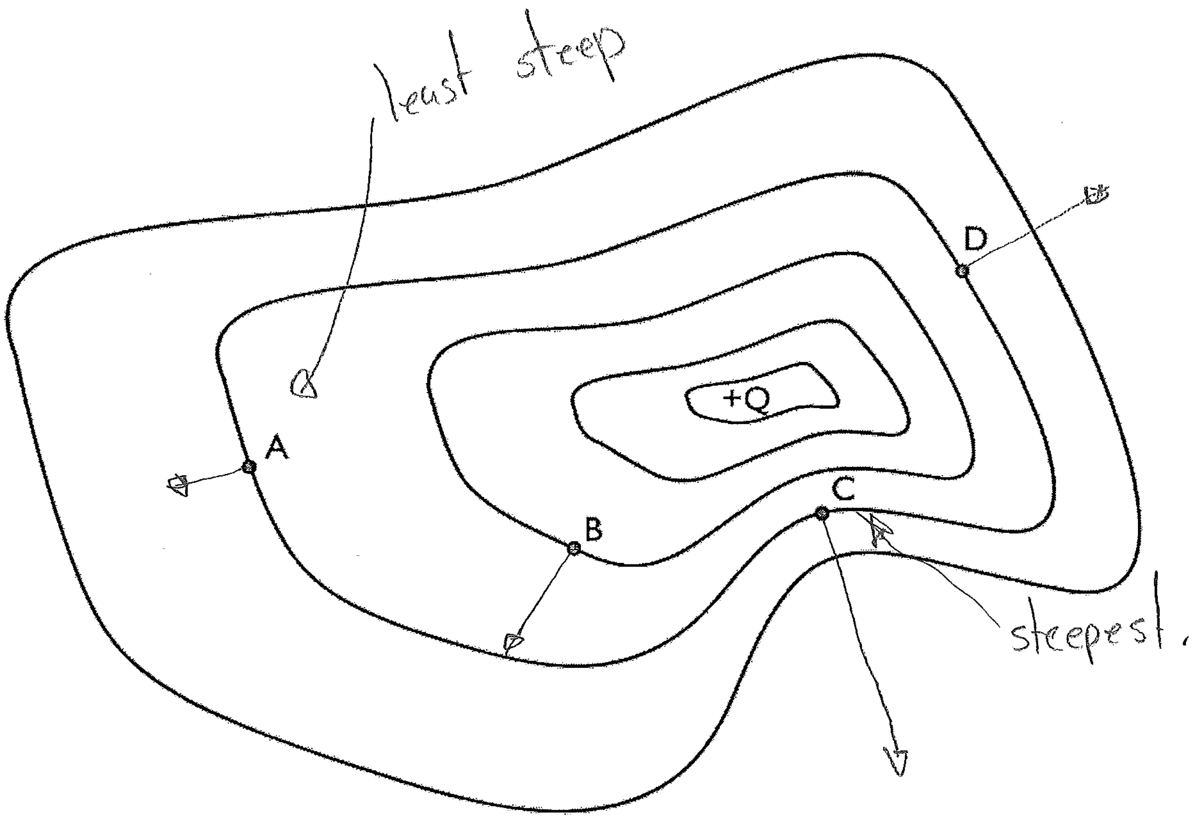
Question 6: Field and Potential

A bizarre, non-uniformly charged rock creates the equipotentials plotted below. The object has a positive charge +Q. Plot the electric field at points A-D. Take care to get the direction and magnitude correct.

It may help to remember that $E_s = - dU/ds$.



The electric field is strongest where the equipotential lines are the closest.

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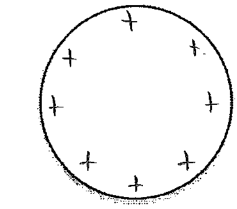
Extra Stuff: For Fun?

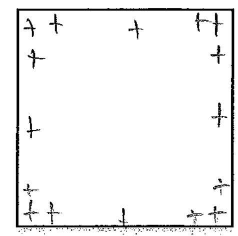
Question 7

a) In a charged conductor the charges arrange themselves in a lowest energy configuration. Based on what you know about forces of charges, draw how the charges are arranged in the spherical conductor below.



b) Now consider a square conductor. How are the charges arranged? Are they spread out uniformly? Pay special attention to the corners and the forces acting on the charges. Explain your reasoning.

bunches near corners.



Question 8

TRIUMF houses one of the world's largest cyclotrons. A cyclotron uses a potential difference to accelerate charged particles, and a magnetic field to guide them in a circle. The TRIUMF accelerator uses a 90 kV potential to accelerate H^- ions to a kinetic energy of 520 MeV.

a) We can crudely model the electric field in the accelerating gap as being uniform. What is the electric field if the gap is 2 cm?

b) How many individual accelerations does a H^- ion go through until it's finally shot out of the cyclotron?

c) In order to do this the potential must oscillate at 23 MHz, which means there are 46 million accelerations ever second. How long does it take to accelerate the H^- ion up to 520 MeV?

Question 10

Using the integral

$$\Delta U = -q \int_a^b \vec{E} \cdot d\vec{r}$$

calculate the potential energy of a dipole and charge q lying a distance r away on the dipole's axis. Let E be the electric field of the dipole. Assume that the charge starts at a point infinitely far away from the dipole and is brought towards a point a distance r away from the charge.