5C-F21 Midterm 1 B

CLAIRE HATHAWAY

TOTAL POINTS

31.5 / 40

QUESTION 1

17 pts

1.1 1 / 1

✓ **- 0 pts Correct**

- 1 pts Click here to replace this description.

1.2 0 / 1

- 0 pts Correct

✓ **- 1 pts incorrect**

1.3 1 / 1

✓ **- 0 pts Correct**

- 1 pts incorrect

1.4 1 / 1

✓ **- 0 pts Correct**

- 1 pts Incorrect

1.5 1 / 1

✓ **- 0 pts Correct**

- 1 pts incorrect

1.6 0 / 1

- 0 pts Correct

✓ **- 1 pts incorrect**

1.7 1 / 1

✓ **+ 1 pts Correct**

+ 0.5 pts Fnet = F_CA + F_CB

1.8 1 / 1

✓ **- 0 pts (a)**

- 1 pts incorrect

1.9 0 / 1

- 0 pts Correct

✓ **- 1 pts incorrect**

1.10 1 / 1

✓ **- 0 pts Correct**

- 1 pts incorrect

1.11 1 / 1

✓ **+ 1 pts Correct**

+ 0.5 pts lines drawn correctly

+ 0.5 pts direction is identified

+ 0 pts incorrect

1.12 1 / 1

✓ **- 0 pts Correct**

- 1 pts incorrect

1.13 1 / 1

✓ **- 0 pts Correct**

- 1 pts incorrect

1.14 1 / 1

✓ **- 0 pts Correct**

- 1 pts incorrect

1.15 1 / 1

✓ **- 0 pts Correct**

- 1 pts incorrect

1.16 1 / 1

✓ **- 0 pts Correct**

- 1 pts incorrect

1.17 1 / 1

✓ **+ 1 pts Correct. Plot has the criteria: 1) $$V(x) \rightarrow + \infty$$ at exactly where the charges**

are 2) $$V(x)$$ should go as $$\frac{1}{x}$$ away from each point charge, and 3) $$V(x) \neq 0$$ in between the charges. There should be a noticeable difference between $$V(x)$$ in the region between them and the regions outside the charges ($$V \rightarrow 0$$ as $$x \rightarrow \pm \infty$$)

+ **0.5 pts** includes two of the above criteria

+ **0 pts** missing two or more

QUESTION 2

23 pts

2.1 8 / 12

✓ **- 0 pts Correct $$V$$ Plot: 1) constant (nonzero) inside the sphere, and 2) decreasing as $$\frac{1}{x}$$ outside (both sides, all positive)**

- 1 pts Partially correct $$V$$ plot (at least 1 of the 2 criteria met)

- 2 pts Incorrect $$V$$: Neither of the criteria met

- 0 pts Correct $$U$$ plot: 1) constant inside sphere 2) "increasing" as $$-\frac{1}{x}$$ outside (essentially flipping the $$V$$ upside-down).

✓ **- 1 pts Partially correct $$U$$ (at least 1 of the 2 criteria met)**

- 2 pts Incorrect $$U$$: neither of the criteria met

- 0 pts Correct $$K$$ plot: 1) constant (nonzero) inside sphere 2) decreasing as $$\frac{1}{x}$$ outside (should look very similar to correct $$V$$).

✓ **- 1 pts Partially correct $$K$$ (at least 1 of 2 criteria met)**

- 2 pts Incorrect $$K$$ (neither of the criteria met)

- 0 pts Correct $$v$$ plot: 1) constant (nonzero) inside sphere 2) decreasing as $$\frac{1}{\sqrt{x}}$$ outside. Just has to look similar to $$\frac{1}{x}$$ to count.

✓ **- 1 pts Partially correct $$v$$ (at least 1 of 2 criteria met)**

- 2 pts Incorrect $$v$$ (neither of the criteria met)

- 0 pts Correct $$a$$ plot: 1) $$a = 0$$ inside the sphere (because $$E = 0$$ inside, and thus $$F = 0$$) 2) and decreasing as $$\frac{1}{x^2}$$ outside. Just has to look similar to $$\frac{1}{x}$$ to count.

✓ **- 1 pts Partially correct $$a$$ (at least 1 of 2 criteria met)**

- 2 pts Incorrect $$a$$ (neither of the criteria met)

✓ **- 0 pts Correct $$E_{total}$$ plot: energy is conserved regardless of the position, and thus the plot should look like a straight, horizontal line.**

- 2 pts Incorrect $$E_{total}$$ plot: is not constant all the way through.

2.2 3.5 / 4

+ 4 pts Correct

✓ **+ 1 pts Correct Electric field formula**

✓ **+ 1 pts Correct force formula**

✓ **+ 1 pts Correct calculation of charge**

✓ **+ 1 pts Attempted**

✓ **- 0.5 pts Everything else right, but the numbers are wrong**

2.3 4 / 4

+ 4 pts Correct

✓ **+ 2 pts Attempted**

✓ **+ 2 pts Discusses relevant details of the motion other than the oscillatory behavior**

- 0.5 pts Some important detail is mentioned incorrectly

+ 1 pts Only mentions force or field lines or initial direction

2.4 2 / 3

+ 3 pts Correct

✓ **+ 2 pts attempted**

+ 0.5 pts Correctly identified the initial energy/voltage

+ 0.5 pts Correctly calculated the maximum kinetic energy

- 0.5 pts Everything correct but plugged in numbers wrong

+ 0 pts no attempt

Problem 1

(17 points)

(each multiple-choice question has only one correct answer)

U

1. Consider electric charges that have electric potential energy and can move freely. In what direction will charges move?

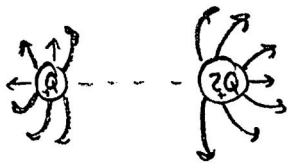
(a) + and - charges move to regions of higher potential energy.

(b) + and - charges move to regions of lower potential energy.

(c) + and - charges move to regions of lower potential.

(d) + and - charges move to regions of higher potential.

2. Consider two positive point charges, Q and 2Q, separated by a short distance. Along the line connecting the two charges the electric field is ...



(a) the largest exactly between the two charges.

(b) zero.

b/c repel?

(c) the largest near the 2Q charge.

3. A balloon is negatively charged by adding 10^6 excess electrons. An electron is placed next to the balloon. Which of the following statement is true?

(a) The electric force on the electron is 10^6 times larger than the force on the balloon.

(b) The electric force on the balloon is 10^6 times larger than the force on the electron.

(c) The electric force on the balloon is zero.

(d) The electric forces on the balloon and the electron have the same magnitude.

Newton 3rd Law

$F_{AB} = F_{BA}$

4. If you charge a plastic rod by rubbing it with a silk cloth, then bring it close to an uncharged conducting ball, what will happen?

(a) Nothing.

uncharged will make dipole

(b) The rod will attract the ball.

which will attract?

(c) The rod will repel the ball.

V constant

5. A parallel plate capacitor is charged with a battery and stays connected to the battery at all times. If you push the plates closer together, what happens to the charge on the plates?

Q

want to relate V, Q, C

(a) Increases.

(b) Decreases.

(c) Stays the same.

$\uparrow C = \varepsilon_0 \frac{A}{d\downarrow}$ =

Could be this

$\uparrow C = \frac{Q}{V}\uparrow$

b/c Q not change C

6. You place a conducting metal sphere with no net charge next to an infinitely large, positively charged sheet without touching it. The conducting sphere will ...

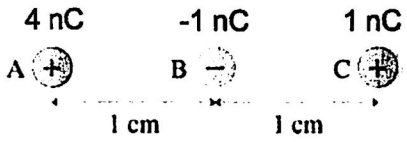
(a) be polarized and attracted by the positive sheet.

(b) be polarized and repelled by the positive sheet.

(c) be polarized but not experience any electric force at all.

(d) not be polarized.

7. What is the force on charge C?



$F_{BC} = \left(9\times10^{9}\ \frac{N m^2}{C^2}\right)\frac{(1\times10^{-9}\ C)(-1\times10^{-9}\ C)}{(0.01)\ m^2}$

$F_{BC} = -9\times10^{-5}\ N$

$F_{AC} = \left(9\times10^{9}\ \frac{N m^2}{C^2}\right)\frac{(1\times10^{-9}\ C)(9\times10^{-9}\ C)}{(0.02)\ m^2}$

$F_{AC} = 9\times10^{-5}\ N$

$F_{BC} + F_{AC} = (-9\times10^{-5}\ N) + (9\times10^{-5}\ N) = 0$

Net force on C = 0 N

8. The electric field at a point on the line between two charges is zero, what do you know about the charges?

(a) The two charges have the same sign. ← repel

(b) The two charges have the opposite sign. ← attract

(c) The sum of the two charges is zero. don't think this matters?

(d) The charges are the same magnitude.

9. Consider two solid conducting spheres (separately). One sphere is small (radius R) and the other sphere is large (radius 2R). If both spheres have exactly the same charge, which sphere has the higher potential relative to a point far away?

(a) The large sphere.

(b) The small sphere.

(c) Both spheres have exactly the same potential.

higher V b/c same charge but same far away b/c 0? farther distance

10. An electron and a proton accelerate from rest through a potential difference of 5 kV and speed up (they are moving in opposite directions). Which of the following statements is true? (the proton has 1836 times the mass of an electron)

(a) Both particles acquire the same kinetic energy and velocity.

(b) The electron will move faster than the proton.

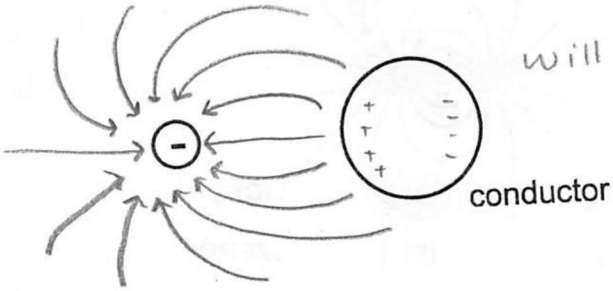
(c) The proton will move faster than the electron.

$q\Delta V = \Delta K = K_f - K_i$

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

↑ set so divided among

11. A solid conducting sphere with no net charge is placed next to an electron as shown. Qualitatively correct sketch the electric field lines around the electron and conductor.



will make a dipole / be polarized?

12. The pointer in an electroscope indicates the presence of an electric charge. Which of the following statements is true?

(a) The net charge on the electroscope is positive.

(b) The net charge on the electroscope is negative.

(c) The net charge on the electroscope could be positive, negative, or zero.

(d) The net charge on the electroscope could be positive or negative but not zero.

13. An insulating sphere with no excess charge is placed close to a negative electric point charge without making physical contact. Which of the following is true?

(a) The insulator is attracted by the point charge.

(b) The insulator is repelled by the point charge.

(c) The insulator does not experience an electric force.

microscopic attraction?

slight attraction, not big but present?

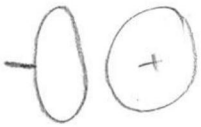
14. An insulator with no net charge is placed next to a large positive charge without making physical contact. If you ground the insulator by touching it briefly with your finger the charge on the insulator will be ...

(a) positive.

(b) negative.

(c) zero.

- for conductor



15. If you double the voltage between the plates of a capacitor, what happens to the capacitance C?

(a) It doubles.

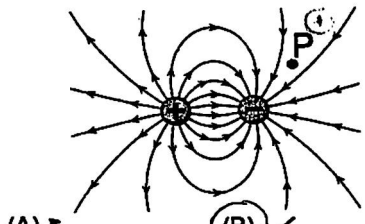
(b) It decreases by a factor of 2.

(c) It stays the same.

$\downarrow C = \frac{Q}{V \uparrow}$

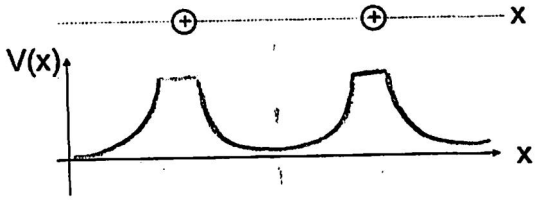
b/c C not dependent on Q & V

16. Which of the arrows best represents the electric force on a proton at point P?



(+) with E on tangent

17. Two identical positive point charges Q are located on the x-axis (dashed line) and separated from each other. Sketch the electric potential V(x) as a function of x along the dashed line, to the left, the right, and in-between the two charges.



Problem 2

(23 points)

A hollow conducting sphere of radius R=20 cm is positively charged to a voltage of 10 kV relative to a point infinitely far away. The sphere has small holes on the left and right. The holes are large enough so that a particle (i.e. test charge) can pass unobstructed but small enough so that they do not disturb the symmetry of the field. A test charge q= - e is placed a distance of d=50 cm to the right from the surface of the sphere and is released from rest.

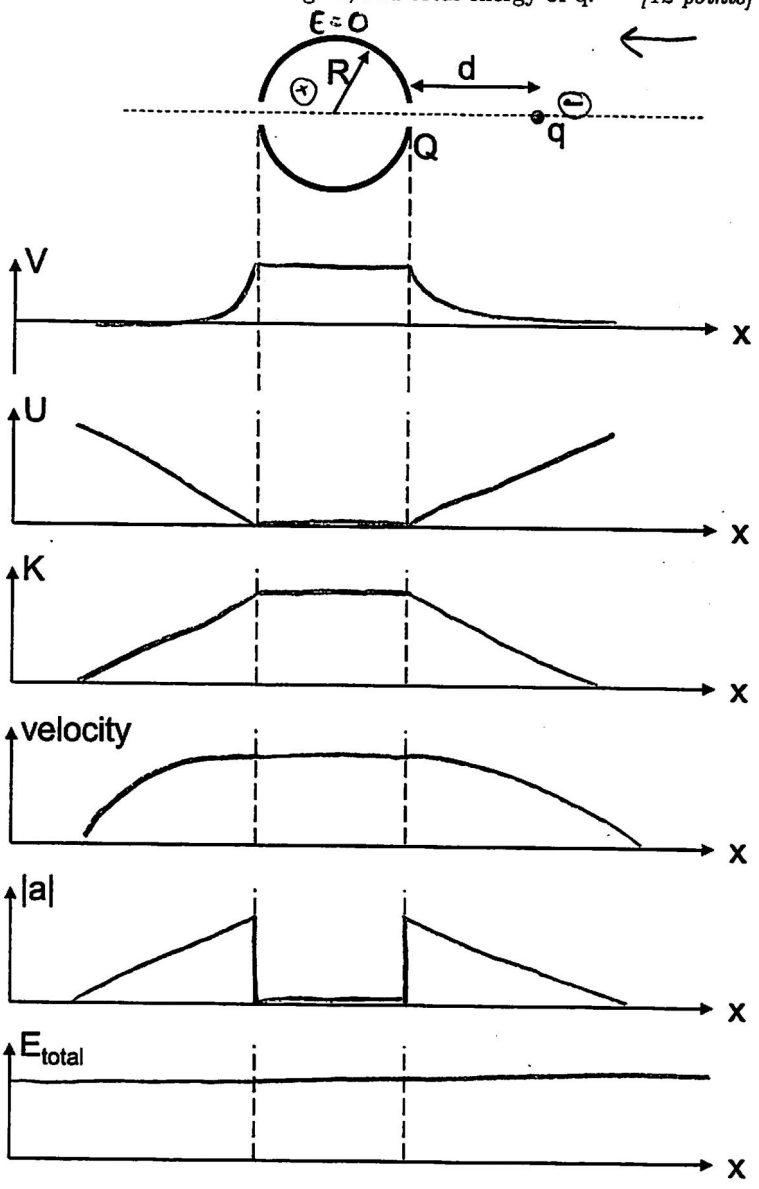
(a) Qualitatively correct sketch the following parameters everywhere inside and outside the sphere: electric potential of sphere, potential energy of the test charge, kinetic energy of the test charge, velocity of the test charge, acceleration of the test charge a, and total energy of q. *[12 points]*

$V = 10\,kV$

$q = -e$

$d = 50$

$K_i = 0$



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$V = 10 \times 10^3$ V $q = -1.6 \times 10^{-19}$ C $d = 0.5$ m $K_i = 0$

$R = 0.2$ m

F

(b) Calculate the force on the test charge at its initial position. *[4 points]*

$V = K\frac{Q}{r} \rightarrow 10\times10^3\ V = (9\times10^9\ \frac{Nm^2}{C^2})\frac{Q}{0.2m} \rightarrow Q = 2.22\times10^{-7}\ C$

$F = K\cdot\frac{qQ}{r^2} = (9\times10^9\ \frac{Nm^2}{C^2})\frac{(-1.6\times10^{-19}C)(2.22\times10^{-7}C)}{(0.5m^2)} = -1.28\times10^{-15}\ N$

$\boxed{F = -1.28\times10^{-15}\ N}$

(b) Describe the trajectory and motion of the test charge in your own words. *[4 points]*

The test charge will quickly speed up to reach the sphere since they are attracted due to their opposite charges. While in the sphere it will maintain a constant speed. Once it leaves the sphere it will slow down as it is unfavorable for opposite charges to be moved away from each other. It will likely move entirely in a straight line against the electric field on the tangent.

K_{max}

(c) Calculate the highest kinetic energy the test charge will acquire. *[3 points]*

$\Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ $\Delta U = q\Delta V = \Delta K = \frac{1}{2}mv_f^2$

$q\Delta V = \Delta K \rightarrow (-1.6\times10^{-19}\ C)(10\times10^3\ V) = -1.6\times10^{-15}\ J$

$\boxed{K_{max} = -1.6\times10^{-15}\ J}$