University of Maryland
Department of Physics

Physics 122 **Dr. E. F. Redish**

Spring 2009 **Final Exam** **20. May 2009**

(175 points)

Post grades on web? (<u>Initial</u>, please) Yes____ No____

(If you agree, I will post your grades and your detailed scores for each category on our website by the last 4 digits of your student number.)

Instructions:

Do not open this examination until the proctor tells you to begin. Read these instructions while waiting.

1. When the proctor tells you to begin, **write your name at the top of every page that has a place for it including this one (on the back).**
   (This is essential since exam booklets will be separated for grading.)

   The first problem booklet contains the short-answer problems. Do your work for these problems (1-6) on the pages for those problems. Write your answers for those problems in the appropriate boxes on the back of this page. Your work on these problems will not be inspected unless there is an ambiguity in your answer.
2. The second booklet contains long-answer problems. Do your work for each of these (I-V) on the page for that problem. (Work on other pages will not be looked at.) **If part of your answer is on the back, be sure to check the box on the bottom of the page so the grader knows to look on the back!**.
3. On all the problems *except short answers*, your answers will be evaluated at least in part on how you got them. **No credit may be given for answers that do not show how you got them**. Partial credit will be granted for correct steps shown, even if the final answer is wrong.
4. Write clearly and logically so we can understand what you are doing and give you as much partial credit as you deserve. We cannot give credit for what you are thinking – only for what you show.
5. If on a multi-step problem you can't do one part, don't give up. Go on to the next part anyway. If necessary, define a name for the quantity you couldn't find and express your answer in terms of it.
6. If you try one approach and then decide on another, cross out the one you have decided is wrong. If your paper has both correct and incorrect approaches the grader will not choose between them. You will not receive credit when contradictory statements are present, even if one is correct.
7. All calculations should be done to the appropriate number of significant figures.
8. At the end of the exam, write and sign the honor pledge in the space below: "I pledge on my honor that I have not given or received any unauthorized assistance on this examination

*** Good Luck ***

Name________________________________

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Answer sheet for short answer questions: (5 pts each)

1.1

1.2

1.3

1.4

2.1

2.2

2.3

2.4

2.5

3.1

3.2

3.3

3.4

4.1

4.2

5.1

5.2

6.1

6.2

6.3

DO NOT WRITE IN THE SPACES BELOW.

Part I

1.	2.	3.	4.	5.	6.	Total

Part II

I.	II.	III.	IV.	V.	Total

Name____

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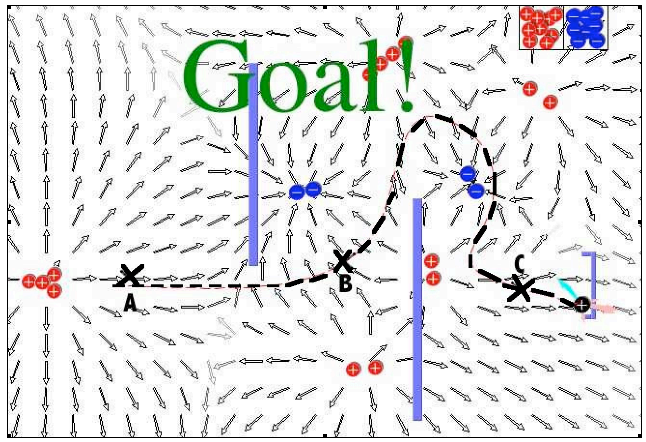
Problems 1-6 are short answer questions. Write the answers in the appropriate box on your answer sheet on the pages of this booklet. No explanations are required for these items. Your work on these pages will only be looked at in case of ambiguity. Give all answers that are correct. If none are correct, write N.

1. (20 pts) In the picture at the right is shown a screen from the web program *Electric Field Hockey*. In this program, your goal is to drive a positive charge around barriers into a goal. The positive charge moves in response to the forces from the positive and negative charges you have placed on the field.

One solution for the second level of difficulty is shown at the right. The path that the charge followed is shown by a dashed line.



The little arrows indicate the direction of the electric field at the base of the arrow. Three points on the path are marked with an "X" and are labelled A, B, and C. Place the answers to the following items in the appropriate boxes on your answer sheet.

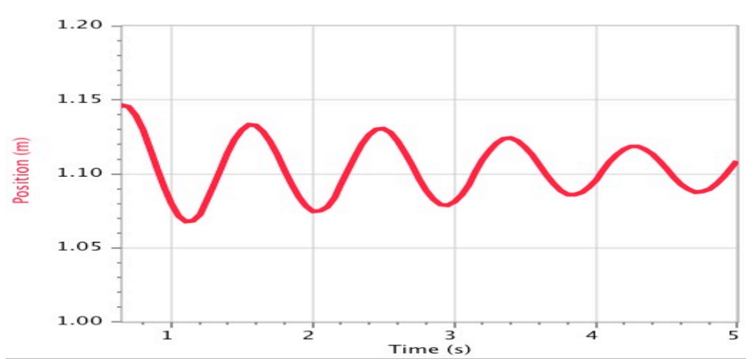
1.1. At which of the three points was the moving charge speeding up?

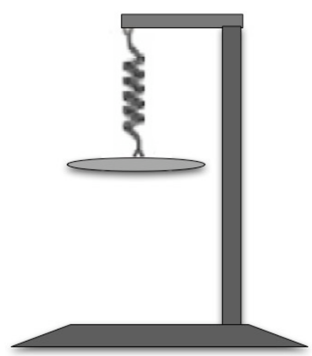
1.2 At which of the three points was the moving charge staying at about the same speed?

1.3 At which of the three points is the electrostatic potential likely to be the lowest?

1.4 At which of the three points is the electrostatic potential likely to be the highest?

2. (25 pts) A large circular wooden disk is hung from a spring as shown at the right below and is pulled down and started oscillating. A sonic ranger placed on the stand below the disk is started at an instant when the disk is at its highest point. It produces the graph on the left below.





2.1. The amplitude of the oscillation is seen to get significantly smaller, even in the first few seconds of observation. Given the setup shown, the most likely reason for this is

(a) Damping (internal friction) in the spring.
(b) Air resistance on the disk.
(c) A moving object naturally wants to come to rest independent of anything acting upon it.
(d) It would not do what is shown; it would maintain its amplitude.
(e) Some other reason. (Explain briefly on your answer sheet.)

2.2. After the first couple of peaks, the period seems fairly stable. A more careful measurement over a longer period of time would show

(a) The period increases (the oscillation slows down) as the amplitude decreases.
(b) The period decreases (the oscillation speeds up) as the amplitude decreases.
(c) The period stays the same as the amplitude decreases.
(d) Something else happens. (Describe what briefly on your answer sheet).
(e) You can't say from the information given. (Explain briefly what you would need to know on your answer sheet.)

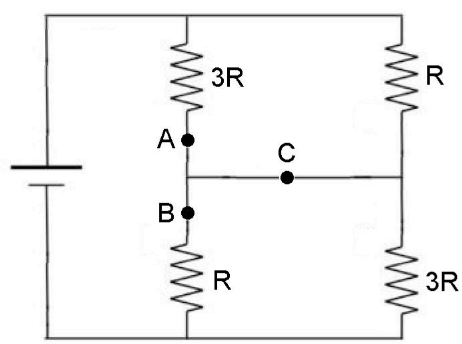
When the disk is oscillating as shown above, for each of the three quantities listed below, select the direction the quantity points by placing one of the following symbols in the appropriate box in your answer sheet: up (↑), down (↓), or zero (0).

2.3. Net force when the disk is moving down and is at its equilibrium position.

2.4. Net force when the disk is moving up and is at its equilibrium position.

2.5. Air resistance force when the disk is at a peak position (maximum).

3. (20 pts) The figure at the right shows a circuit with a single battery (labeled 9 Volts) and four resistors. Two of the resistors have a resistance $R = 3$ Ohms and two of the resistors have a resistance $3R = 9$ Ohms.



The letters A, B, and C indicate points on the wires. (They are not devices – just points on the wires.) The network is carrying current in a steady state. For the following four statements select the best answer (or answers) and put it (or them) on your answer sheet.

3.1 What can you say about the voltage at the points A, B, and C?

(a) The magnitudes of the voltages at A and B add up to the magnitude of the voltage at C.
(b) The sum of the magnitudes of the voltages at two of the points adds up to the magnitude of the voltage at the third (but we can't say which).
(c) The magnitude of the voltages at all three points are equal.
(d) There is not enough information to draw any of the above conclusions.
(e) Something else. (Explain briefly on your answer sheet.)

3.2 What can you say about the currents at the points A, B, and C?

(a) The magnitudes of the currents flowing through A and B add up to the magnitude of the current flowing through C.
(b) The sum of the magnitudes of the currents at B and C add up to the magnitude of the current through A.
(c) The sum of the magnitudes of the currents at A and C add up to the magnitude of the current through B.
(d) The magnitude of the currents flowing through all three points are equal.
(e) There is not enough information to draw any of the above conclusions.
(f) Something else. (Explain briefly on your answer sheet.)

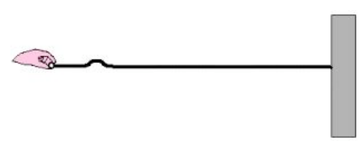
3.3 In what direction is the current at point C flowing?

(a) To the left.
(b) To the right.
(c) It is zero.
(d) There is not enough information to draw any of the above conclusions.
(e) Something else. (Explain briefly on your answer sheet.)

3.4 What can you say about the voltage at the point C given that we take the voltage at the bottom of the battery to be 0?

(a) It is zero.
(b) It 9 Volts.
(c) It is 3 Volts.
(d) It is 4.5 Volts.
(e) There is not enough information to draw any of the above conclusions.
(f) Something else. (Explain briefly on your answer sheet.)

4. (10 pts) A demonstrator is showing how to create a pulse on a long taut spring. She moves her hand up and down quickly to create a pulse as shown. (Is is moving to the right).



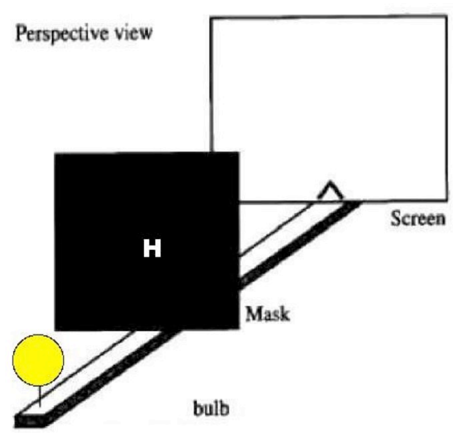
4.1 If she wants to make a wider pulse of the same height she should

(a) Move her hand faster – up to a greater height and down but in the same amount of time.
(b) Move her hand slower –up to a lesser height and down but in the same amount of time.
(c) Move her hand slower – up to the same height and down in a longer time.
(d) Move her hand faster – up to the same height and down in a shorter time.
(e) There is nothing she can do to make this happen by just moving her hand up and down differently.
(f) Something else.

4.2 If she wants to make a the pulse reach the wall in a shorter time she should

(a) Move her hand faster – up to a greater height and down but in the same amount of time.
(b) Move her hand slower –up to a lesser height and down but in the same amount of time.
(c) Move her hand slower – up to the same height and down in a longer time.
(d) Move her hand faster – up to the same height and down in a shorter time.
(e) There is nothing she can do to make this happen by just moving her hand up and down differently.
(f) Something else.

5. (10 pts) A large spherical bulb is supported in front of a black mask with a hole in it shaped like an H as shown in the figure at the right (approximately to scale).



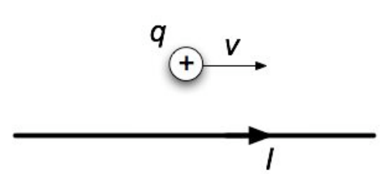
5.1 If the system is in the dark and the bulb is lit, what do you think the pattern on the screen would look like?

(a) A sharp letter H.
(b) A sharp circle.
(c) Somewhat like an H but fuzzy or a bit distorted.
(d) Somewhat like a circle but fuzzy or a bit distorted.
(e) Something else.
(Explain briefly on your answer sheet.)

5.2 If the large bulb is replaced by a tiny (compared to the size of the H) but bright LED bulb, what do you think the pattern on the screen would look like?

(a) A sharp letter H.
(b) A sharp circle.
(c) Somewhat like an H but fuzzy or a bit distorted.
(d) Somewhat like a circle but fuzzy or a bit distorted.
(e) Something else. (Explain briefly on your answer sheet.)

6. (15 pts) A small electric (test) charge, q, is near a wire carrying a current I, at the point shown and is moving with a speed v in the direction shown by the arrow. Calling it a "test charge" just means that you can ignore the forces that it exerts on all other charges in the world. For the following three items, choose the best answer or answers.



6.1 Does the charge experience an electric force from the wire?

(a) Yes. An attraction because the wire is carrying a positive current.
(b) Yes. A repulsion because the current carriers in the wire are electrons.
(c) No. Because the wire is neutral.
(d) Yes for some other reason. (Explain briefly on your answer sheet.)
(e) No for some other reason. (Explain briefly on your answer sheet.)
(f) You cannot tell from the information given.

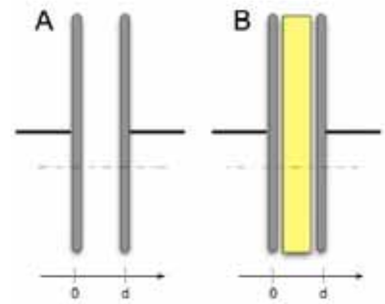
6.2 Is there a magnetic field at the position of the charge?

(a) No. Because there are no bar magnets.
(b) Yes. A magnetic field pointing up due to the current.
(c) Yes. A magnetic field pointing to the right due to the current.
(d) Yes. A magnetic field pointing out of the page due to the current.
(e) No. For some other reason. (Explain briefly on your answer sheet.)
(f) Yes. For some other reason. (Explain briefly on your answer sheet.)

6.3 Is there a magnetic force on the charge?

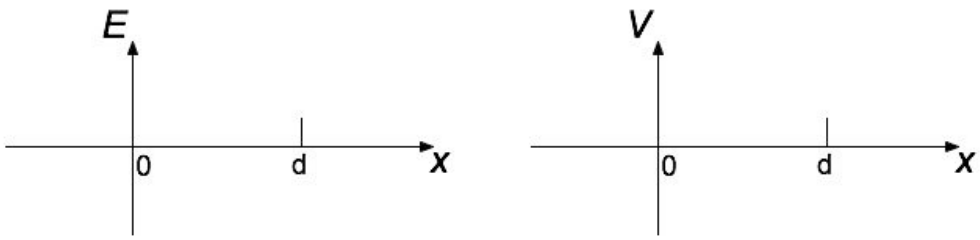
(a) Yes. Along the direction the charge is moving.
(b) Yes. Upward, away from the wire.
(c) Yes. Perpendicular to the page.
(d) No. Since there is no magnetic field.
(e) No. Because of the directions of the velocity and the magnetic field.
(f) Yes. But in some other direction.
(g) No. For some other reason. (Explain briefly on your answer sheet.)

I. (25 points) One of the most important current problems in converting to "green energy" is storage. Lots of renewable energy resources – solar, wind – are intermittent and the times they are available don't necessarily match when the energy is needed. One method of storage uses batteries but they are inefficient (a lot of the energy is lost) and expensive. An alternative being considered is the capacitor. This stores electrical energy in the electric fields between charges. Let's consider how this works and where the energy is.



Two capacitors are shown in the figure at the right. In case A, the gap between the plates is air (which can be ignored). In case B, the gap is filled with a plastic insulator with dielectric constant κ (with κ > 1). This means that when both capacitor are charged to the same value *Q*, the electric field in between the plates in case B is reduced by a factor of κ compared to case A.

A. In the two graphs below, sketch the electric field and the electrostatic potential that would be measured along the dotted line for capacitor A. (10 pts)



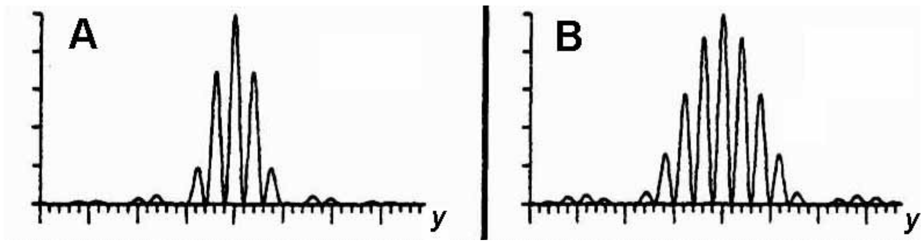
B. The capacitor in A is connected across a battery for some time and then disconnected. The insulating slab is slid in between the plates as shown in B. How would the charge on the two plates of the capactior change and how would the potential between the two plates change? Explain. (5 pts)

C. Capacitors A and B are now connected across identical batteries. How would the voltage differences and the charges compare for the two cases? Explain your reasoning. (5 pts)

C. When both capacitors are charged to the same potential difference, Δ*V*, which one would store more energy? Explain why. (5 pts)

☐ Grader: There is work on the back of this page.

II. (25 points) The interference lab you did this semester can be done more accurately using an expensive CCD to measure the intensity of the light. Two experiments using the same laser, screen, and positions produce the results shown below and are labeled A and B. The only difference between the experiments is the card containing the two slits. The intensity of light is plotted as a function of y, the position along the screen. The large ticks on the axis are measured in cm.



A. Can you tell in which case the slits on the card are farther apart? If you can, say how they compare quantitatively (e.g., “the separation of the slits in case B is 0.7 times the separation of the slits in case A”) give the ratio and explain how you know. (10 pts)

B. Can you tell whether the two slits in case A have the same width? Explain your answer. (5 pts)

C. Assuming the slits in case A have the same width, and the slits in case B have the same width, can you tell in which case the slits are larger? If you can, say how they compare quantitatively (e.g., “the width of the slits in case B is 0.7 times the width of the slits in case A”) give the ratio. Explain. (10 pts)

☐ Grader: There is work on the back of this page.

III. (15 points) We know that within the limits of measurement, the magnitudes of the negative charge on the electron and the positive charge on the proton are equal. Suppose, however, that the magnitude of the charge on the proton was bigger than that on the electron by 1 part in a million. Estimate with what force two copper pennies, placed one m apart, would then repel each other. You may (or may not) find some of the following parameters useful.

k_C (Coulomb's constant) ~ 9 x 10^9 N-m^2/C^2
e (charge on proton) ~ 1.6 x 10^{-19} C
m_e (mass of electron) ~ 9 x 10^{-31} kg
m_p (mass of proton) ~ 1.7 x 10^{-27} kg
m_{Cu} (mass of a copper atom) ~ 10^{-25} kg.
Number of electrons in a copper atom = 29

Be sure to clearly state your assumptions and how you came to the numbers you estimated, since grading on this problem will be mostly based on your reasoning, not on your answer.

☐ Grader: There is work on the back of this page.

Name____Points_____

IV. (10 points) In this class, one of the important goals is *understanding mechanism*. Pick one of Kirchoff's rules for direct current circuits; state the rule clearly and completely. Then discuss the mechanism behind the rule and describe whether an understanding of mechanism has been relevant to your use of the rule. *Note: This is an essay question. Your answer will be judged not solely on its correctness, but for its depth, coherence, and clarity.*

☐ Grader: There is work on the back of this page.

Name____Points_____

V. (5 points – extra credit) Have you learned anything in this class that you think will be of any use to you in five years? If so, what? If not, why not? Any thoughtful answer will receive full extra credit points. (Don't do this until you have completely finished the rest of the exam.)