Name____________________________________ **Section**___________

University of Maryland
Department of Physics

Physics 122 Dr. David Noyes
Exam 1

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 and section number at the top of every page.**

2. Do your work for each problem on the page for that problem. I will pass around paper so you can do your scratch work on it before starting to write out your answer on the exam. **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. Partial credit will be granted for correct steps shown, even if the final answer is wrong. So be sure to show your work.

4. Write clearly and logically so I can understand what you are doing and can give you as much partial credit as you deserve. I cannot give credit for what you are thinking — only for what you show on your paper.

5. If on a multi-step problem you can't do a particular 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. You are not permitted to have any outside information during this exam. This includes any written information and any relevant information programmed into a calculator. If you are caught using such information, you will be prosecuted and may receive a grade of XF for this course.

7. If there is a formula or constant that is not given, but you think is needed, ask me and if reasonable, I will put it on the board. However I will not tell you which equation is needed for a given problem. Also note that some of the formulas that are given only apply in certain situations, so be sure to take that into account.

8. Take a deep breath, relax, and good luck!

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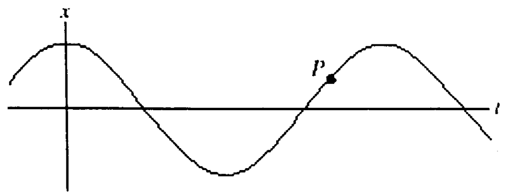
Vibrations and Waves (27 points)

1) **(5 points)** A mass attached to a spring oscillates back and forth as indicated in the position vs. time plot below. At point *P*, the mass has:

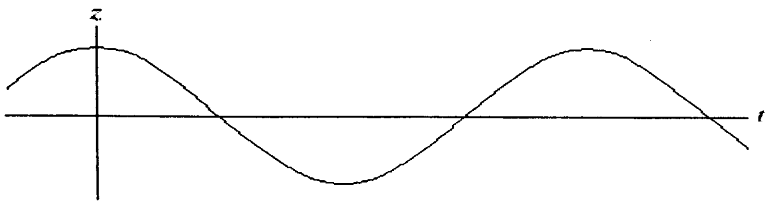


At P, we have positive position, positive velocity, negative acceleration

a. Positive velocity and positive acceleration.
(b.) Positive velocity and negative acceleration.
c. Positive velocity and zero acceleration.
d. Negative velocity and positive acceleration.
e. Negative velocity and negative acceleration.
f. Negative velocity and zero acceleration.
g. Zero velocity but is accelerating (positively or negatively).
h. Zero velocity and zero acceleration.

2) **(5 points)** A mass suspended from a spring is oscillating up and down as indicated. Consider two possibilities:

(i) At some point during the oscillation the mass has zero velocity but is accelerating (positively or negatively).
(ii) At some point during the oscillation the mass has zero velocity and zero acceleration.



At points where velocity is zero, we have maximum displacement and maximum acceleration.

a. Both occur sometime during the oscillation.
b. Neither occurs during the oscillation.
(c.) Only (*i*) occurs.
d. Only (*ii*) occurs.

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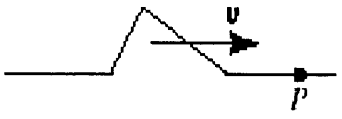
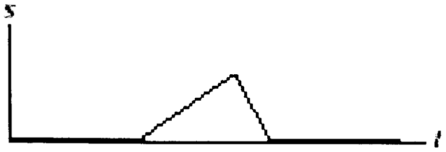
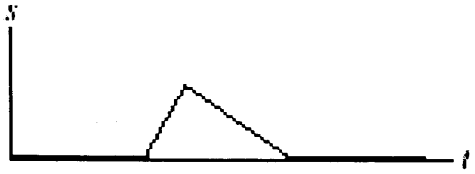
3) (**5 points**) A wave pulse is moving, as illustrated, with uniform speed v along a rope. Which of the graphs below (A or B) correctly shows the relation between the displacement *s* of point *P* and time *t*?



(A)



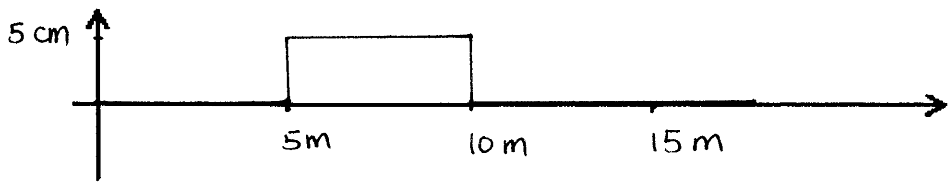
B)



4) (**12 points**) Assume that a wave pulse traveling on a spring is described at time t = 0 as:

$y(x, t = 0) = 5$ cm $5m < x < 10m$
$y(x, t = 0) = 0$ for all other values of x

a) (**3 points**) Construct a graph below that portrays the actual shape of the spring at t=0. Be sure to label the graph.



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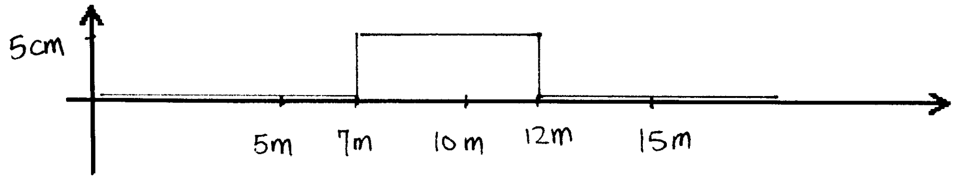
b) **(3 points)** If the pulse is traveling to the right with a velocity of 1 m/s, draw the shape of the spring at time t = 2 s. Again be sure to label everything.



c) **(3 points)** If the spring that wave pulse is traveling on has a linear mass density of 0.05 kg/m, what is the tension in the spring?

$$v = \sqrt{T/\mu} \Rightarrow v^2 = T/\mu \Rightarrow T = v^2\mu$$
$$= \left(1\ \tfrac{m}{s}\right)^2 \left(0.05\ \tfrac{kg}{m}\right) = 0.05\ N$$

d) **(3 points)** Describe what you could do to increase the speed of the wave pulse.

We can increase the tension in the spring.

Electric Fields and Forces (28 points)

5) **(5 points)** Three pithballs are suspended from thin threads. Various objects are then rubbed against other objects (nylon against silk, glass against polyester, etc.) and each of the pithballs is charged by touching them with one of these objects. It is found that pithballs 1 and 2 repel each other and that pithballs 2 and 3 repel each other. From this we can conclude that:

a. 1 and 3 carry charges of opposite sign.
(b.) 1 and 3 carry charges of equal sign.
(c.) All three carry the charges of the same sign.
d. One of the objects carries no charge.
e. We need to do more experiments to determine the sign of the charges.

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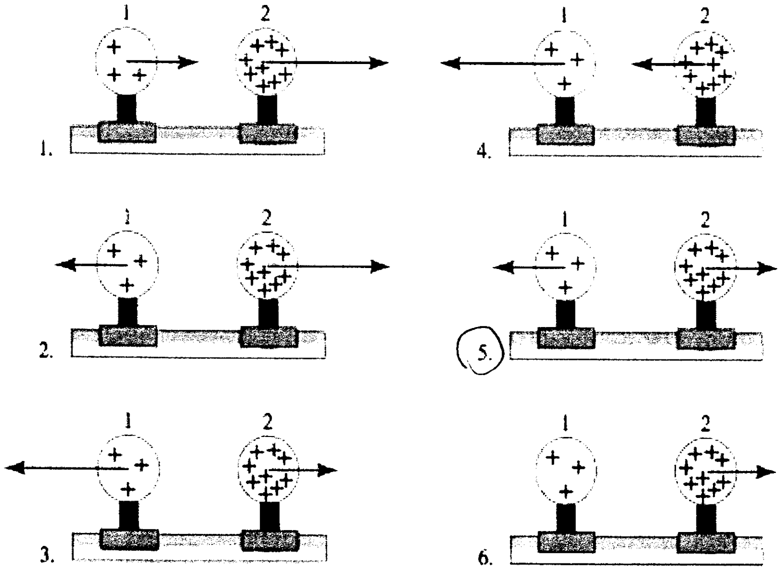
6) (**5 points**) Two uniformly charged spheres are firmly fastened to and electrically insulated from frictionless pucks on an air table. The charge on sphere 2 is three times the charge on sphere 1. Which of the 7 force diagrams correctly shows the magnitude and direction of the electrostatic forces? Explain your reasoning.



7. none of the above

Diagram 5. The two charges should repel because they are both positively charged. The magnitudes are equal by Newton's Third Law.

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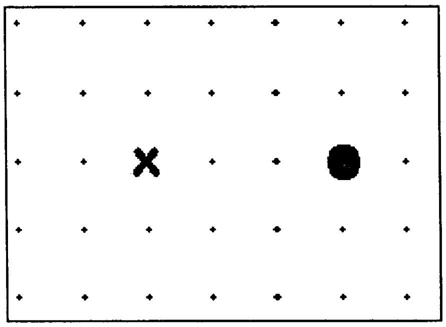
7) (**6 points**) In the figure at the left is shown a fixed charge (specified by a circle) and a location (specified by the x). A test charge is placed at the x in order to measure the electric effect of the fixed charge.

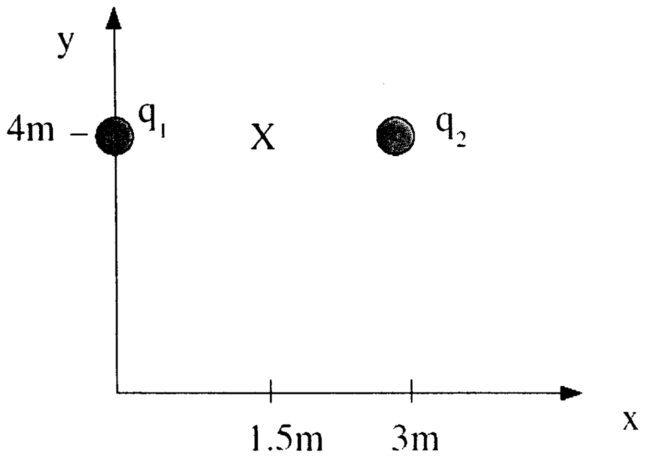


Complete the two statements below as quantitatively as you can. (For example, if the result is larger by a factor of three don't say "increases" say "triples" or "is multiplied by three".) Each statement is meant to be compared with the original situation. (The changes don't cumulate.)

a. (**3 points**) If the test charge is replaced by one with half the amount of charge, then the electric field it sees will _be the same .

b. (**3 points**)If the fixed charge is replaced by one with twice the amount of charge, then the electric field seen by the test charge will __double

8) (**12 points**) For the charge configuration shown below q1 = 1nC, q2 = 5nC. Assume that q1 and q2 are held in place and cannot move.



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a) **(3 points)** Find the electric field (magnitude and direction) at the point X, whose coordinates are (x,y) = (1.5m, 4m).

$$\vec{E}_1 = k_e \frac{q_1}{r_1^2}(+\hat{x})$$

$$\vec{E}_2 = k_e \frac{q_2}{r_2^2}(-\hat{x})$$

$|r_1| = |r_2|$, so E total is

$$\vec{E}_{tot} = \frac{k_e}{r^2}(q_1 - q_2)(\hat{x})$$

$$= \frac{9\times10^9}{(1.5)^2}(-4\times10^{-9})\ N/C\ (\hat{x}) = -16\ \frac{N}{C}\ \hat{x}$$

b) **(3 points)** If a charge q0 = 1nC was placed at the point X, what would the magnitude and direction of the Coulomb force on this charge be?

$$\vec{F}_{\text{felt by } q0} = q_0 \vec{E}_{tot}$$

$$= (1\times10^{-9} C)(16\ \tfrac{N}{C})(-\hat{x})$$

$$= 16\times10^{-9}\ N\ (-\hat{x})$$

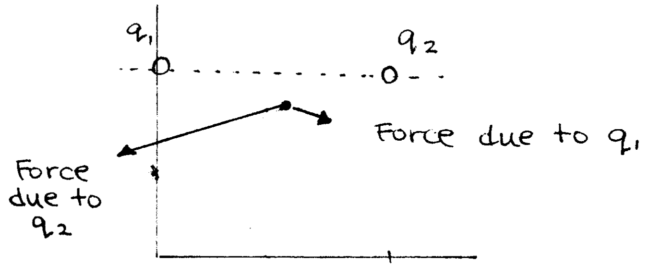
The force points to the left.

c) **(3 points)** Qualitatively describe the motion of q0 if it was placed at X and the charges q1 and q2 are still fixed in place.

It will move to the left ($-\hat{x}$ direction) because the repulsion due to q_2 is stronger.

d) **(3 points)** If instead of placing q0 at exactly (x,y) = (1.5m,4m) it was placed at (x,y) = (1.5 m, 3.9 m), how would the motion of q0 be different.

It will still move to the left, but ~~with~~ now there is also a downward acceleration.



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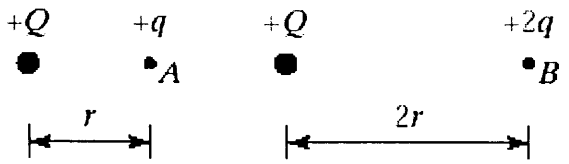
Electric Potential Energy, Electric Potential, and Capacitance (28 points)

9) **(5 points)**Two test charges are brought separately into the vicinity of a fixed charge $+Q$. First, test charge $+q$ is brought to point A a distance r from $+Q$. Next, $+q$ is removed and a test charge $+2q$ is brought to point B a distance $2r$ from $+Q$. Compared with the electrostatic potential of the charge at A, that of the charge at B is



a. Greater.
(b) Smaller.
c. The same.

10) **(5 points)** For the same situation as above, compared with the electrostatic potential energy of the system with the charge at A, that of the system with the charge at B is

a. Greater.
b. Smaller.
(c) The same.

11) **(5 points)** You are given 2 parallel plate capacitors each with a capacitance of 1 nF when there is only air between the two plates. If the two capacitors are connected in series, which has the higher equivalent capacitance:

a. The two capacitors with only air between the plates
(b) One capacitor with air between the plates, and the other with a dielectric between its plates with a dielectric constant of 2.
c. The equivalent capacitance is the same in both cases.

(a) $\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C} \Rightarrow C_{eq} = C/2$

(b) $\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{2C} \Rightarrow C_{eq} = \frac{2}{3} C$

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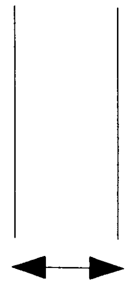
12) **(13 points)** Two parallel plates with charge +Q on plate B and -Q on plate A create a uniform, constant electric field between them. The potential difference between the plates is $\Delta V = V_B - V_A = 10V$.



d = 0.02 m

a) **(3 points)** A charged object with charge q = -10 μC and mass m = 0.02 kg is placed between the plates, just next to plate A with 0 initial velocity. This object is then released and moves toward plate B. What is the change in the potential energy of the charge in moving from A to B?

$U = q\,\Delta V$

$= q\,(V_B - V_A) = -10\,\mu C\,(10\,V) = -100\,\mu J$

b) **(3 points)** What is the velocity of the object just before it strikes plate B?

The charge loses potential energy that is converted into kinetic energy.

$100\,\mu J = \frac{1}{2} m v^2 \Rightarrow v = \sqrt{\frac{200\,\mu J}{m}} = \sqrt{10000 \times 10^{-6}\,\frac{m^2}{s^2}} = 0.1\,\frac{m}{s}$

c) **(3 points)** What is the value of the constant electric field between the plates?

$|\vec{E}| = \Delta V / d = 10V / 0.02m = 500\,N/C$

d) **(4 points)** What is the magnitude of the Coulomb force on the charge q at point A? What is it at point B?

$|\vec{F}| = |q|\,|\vec{E}| = (10\,\mu C)(500\,N/C) = 5 \times 10^{-3}\,N$

This is for both points A and B.

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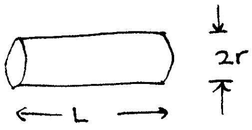
Current and Resistance (17 points)

13) **(12 points)** You are given three conducting wires made of the same material, each with a length L and radius r. For each wire you measure L and r and find:

Wire 1: L = 10m, r = 1mm
Wire 2: L = 10m, r = 10mm
Wire 3: L = 1m, r = 1mm



a) **(6 points)** What is the resistance of each wire if the resistivity is $\rho = 1 \times 10^{-8}\ \Omega$ m?

$$R = \rho\, l/A = \frac{\rho l}{\pi r^2}$$

Wire 1 : $R_1 = (1\times10^{-8}\ \Omega m)(10\ m)/\pi(1\times10^{-3} m)^2$
$= \frac{1\times10^{-1}}{\pi}\ \Omega$

Wire 2 has 100 times larger cross-section area, so $R_2 = \frac{1\times10^{-3}}{\pi}\ \Omega$

Wire 3 is 1/10 as long as wire 1, so $R_3 = \frac{1\times10^{-2}}{\pi}\ \Omega$

b) **(6 points)** If each where connected to identical batteries, rank from smallest to largest the current in each wire.

$R_2 < R_3 < R_1$

And since $I = V/R$, for the same batteries, we have

$I_1 < I_3 < I_2$

14)**(5 points)** Give a qualitative description of the flow of current in a conductor. Include the concept of drift speed as well as the sources of resistance in the conductor.

As electrons flow through a conductor, they bump into the fixed protons of the conductor and scatter. The path is not straight in the microscopic level, and the drift speed is the average speed with which electrons move forward. The scattering is the source of resistance. Without the scattering, the electrons would simply accelerate under the electric field.

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Extra Credit (5 points)

Describe in a few sentences one of the demos that we did in class. Credit will only be given if the relevant physical principles are described. You can draw a picture if that will help you describe the demo. Use the back if this page.