

Final Exam
Physics 2102 Fall 2009

December 8th, 2009

Name: _____

Answer all questions and problems (12).

Some questions are multiple choice. You should work these problems starting with the basic equation listed on the formula sheet and write down all the steps. Although the work will not be graded, this will help you make the correct choice and be able to determine if your thinking is correct.

On problems that are not multiple choice, be sure to show all of your work since no credit will be given for an answer without explanation or work. These will be graded in full, and you are expected to show all relevant steps that lead to your answer.

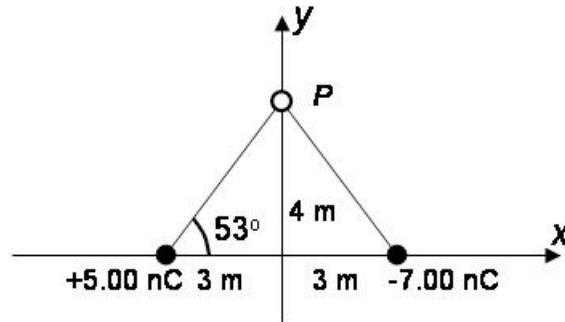
Please use complete sentences where explanations are asked for.

Please be sure that *all* numerical quantities include appropriate units.

The only electronic devices to be used during the exam are standard or graphing calculators.

All cell phones should be turned off and put away. Cell phones are not to be used as calculators.

1) (20 pts) Two point charges, of 5.00 nC and -7.00 nC, respectively, are fixed in place on an xy coordinate plane as shown in the figure. At a point on the plane, P , no charge exists, but there is an electric field due to the presence of the two point charges.

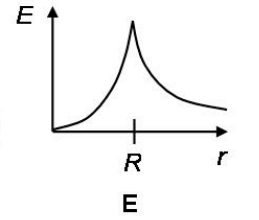
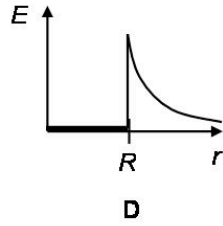
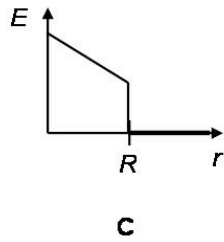
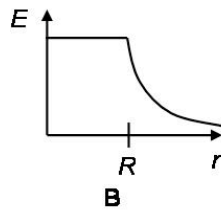
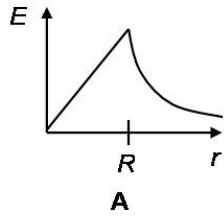


a) (7 pts) Calculate the electric potential at point P , taking the potential at an infinite distance to be zero.

b) (3 pts) At point P on the figure, sketch (and clearly label) three vectors:
the electric field contribution due to the +5.00 nC charge
the electric field contribution due to the -7.00 nC charge
the net electric field

c) (10 pts) Calculate the electric field vector at P in unit vector notation.

2) (16 pts) Consider the following graphs which plot the magnitude of the electric field as a function of r , the distance from the center of a solid sphere of radius R .



i) (4 pts) Which graph represents $E(r)$ for a conducting sphere with an excess charge of $+Q$ on it?

A B C D E

ii) (4 pts) Which graph represents $E(r)$ for an insulating sphere containing a uniform distribution of positive charge?

A B C D E

(Question 2, cont)

Circle the Maxwell equation most directly associated with the following statements.

iii) An alternating emf is induced in a coil that rotates in a uniform magnetic field.

- a) Gauss' Law.
- b) Gauss' Law for magnetic fields (no magnetic monopoles).
- c) Ampere-Maxwell's Law
- d) Faraday's Law.
- e) Snell's Law.

iv) The lines of the magnetic field form concentric circles around a steady current.

- a) Gauss' Law
- b) Gauss' Law for magnetic fields (no magnetic monopoles).
- c) Ampere-Maxwell's 's Law
- d) Faraday's Law.
- e) Snell's Law.

3) (16 pts) A parallel plate capacitor has capacitance C when its plates are separated by an air gap of thickness d . When connected to a battery of potential difference V , an amount of charge Q accumulates on each plate, an electric field of magnitude E exists between the plates, and an amount of energy U is stored.

Now, ***while still connected to the battery***, the plates are pulled apart until they are separated by an air gap of thickness $4d$.

The capacitance is now

- a) $C/4$
- b) C
- c) $4C$
- d) none of these

The amount of charge on each plate is now:

- a) $Q/4$
- b) Q
- c) $4Q$
- d) none of these

The energy stored is now

- a) $U/4$
- b) U
- c) $4U$
- d) none of these

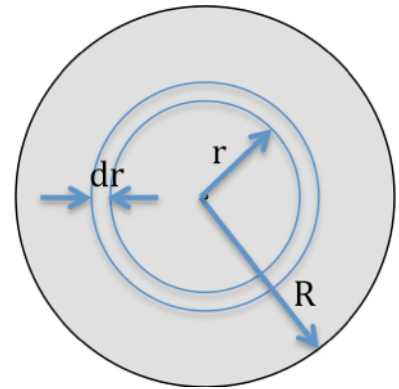
The electric field is now

- a) $E/4$
- b) E
- c) $4E$
- d) none of these

4. (20 points) The figure shows a cross-section of a long cylindrical conductor with radius R . The conductor carries a current with a non-uniform current density that depends on the distance to the axis of the cylinder, r , as $J(r)=J_0 r/R$, where J_0 is a constant.

a) (3 points) At what distance from the center is the current density maximal? Explain briefly.

b) (4 points) Write the current di carried by the part of wire of thickness dr at distance r from the axis of the wire such that $0 < r < R$.

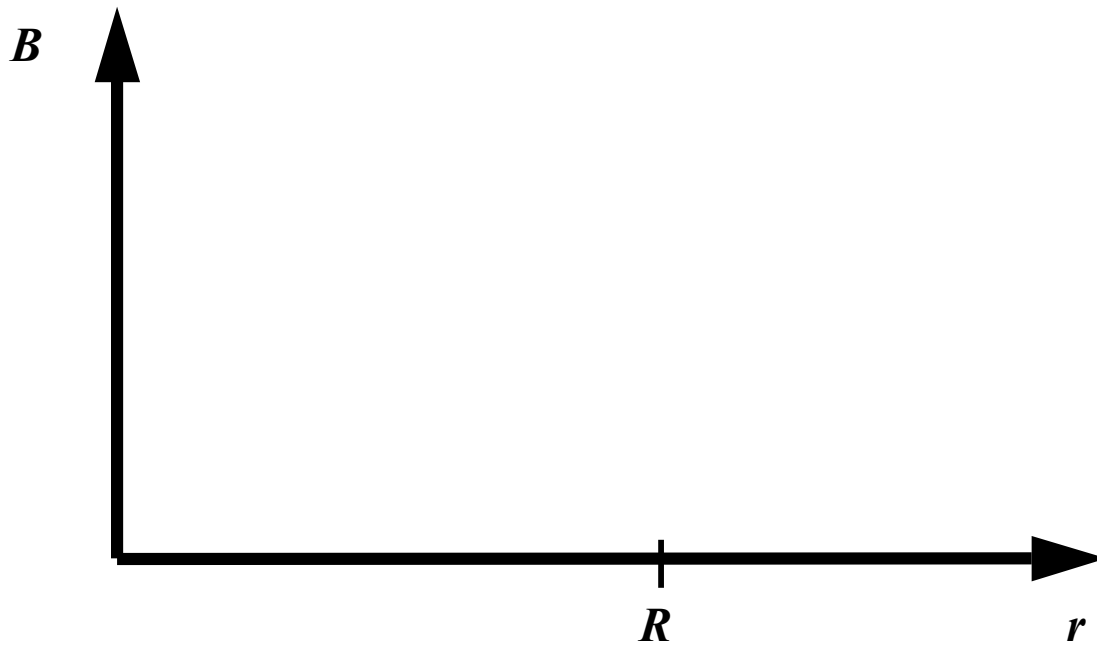


c) (4 points) Determine the current enclosed in the part of the wire that is closer than some fixed distance $r_0 < R$ to the axis of the wire.

(Problem 4, cont)

d) (4 points) Using Ampere's law, determine the magnitude of the magnetic field at that distance, r_0 . If you could not compute the net current in part c) above, you can use i and express your answer in terms of i for partial credit.

e) (5 points) Sketch the magnetic field as a function of the distance from the axis of the wire.



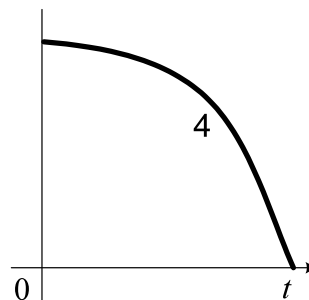
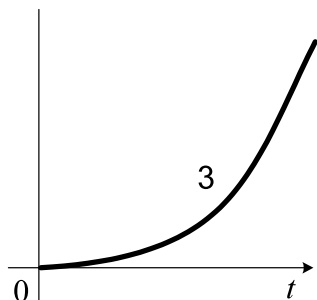
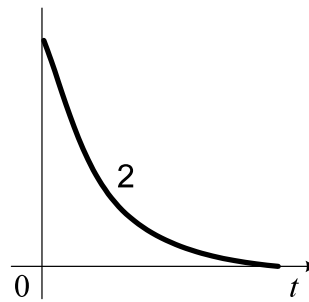
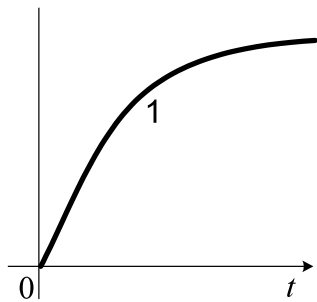
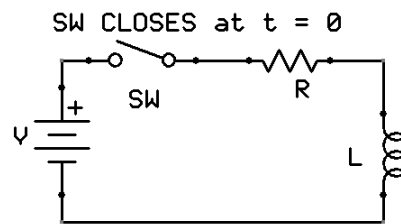
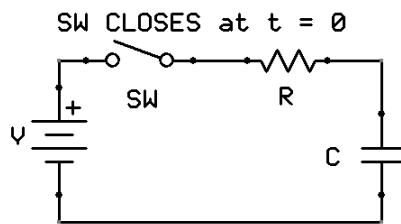
5) (12 points) Choose the graph shape that best represents the *magnitudes* of...

For the RC circuit in the figure below:

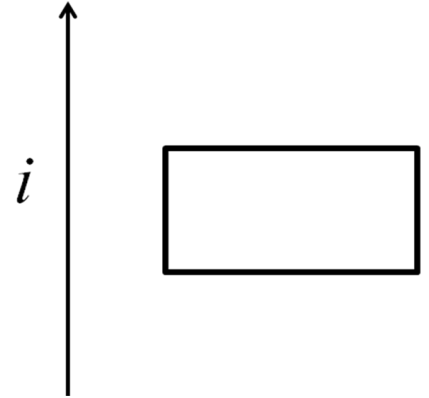
- a) Current through R vs t after the switch is closed _____
- b) Voltage across C vs t after the switch is closed _____
- c) Voltage across R vs t after the switch is closed _____

For the RL circuit in the figure below:

- d) Current through R vs t after the switch is closed _____
- e) Voltage across L vs t after the switch is closed _____
- f) Voltage across R vs t after the switch is closed _____



6) (15 points) A long straight wire is in the plane of a rectangular conducting loop. The straight wire carries a constant current i , as shown.



i) (4 pts) While the wire is being moved away from the loop, the induced current in the loop is:

- (a) Clockwise
- (b) Counterclockwise
- (c) Into the page
- (d) Out of the page
- (e) Zero

ii) (6 pts) The direction of the net force on the rectangular loop as the long straight wire is being moved away from the loop is:

- (a) To the right
- (b) To the left
- (c) Into the page
- (d) Out of the page
- (e) Zero

iii) (5 pts) Now the wire is held in place, and the current i is turned off. While the current is being turned off, the induced current in the loop is:

- (a) Clockwise
- (b) Counterclockwise
- (c) Into the page
- (d) Out of the page
- (e) Zero

7) (20 points) A laser has a beam power 60.0 mW at a wavelength of 650.0 nm. The laser beam is then focused to a circular spot whose diameter is equal to 2.0 wavelengths.

i) (5 pts) Calculate the intensity of the focused beam.

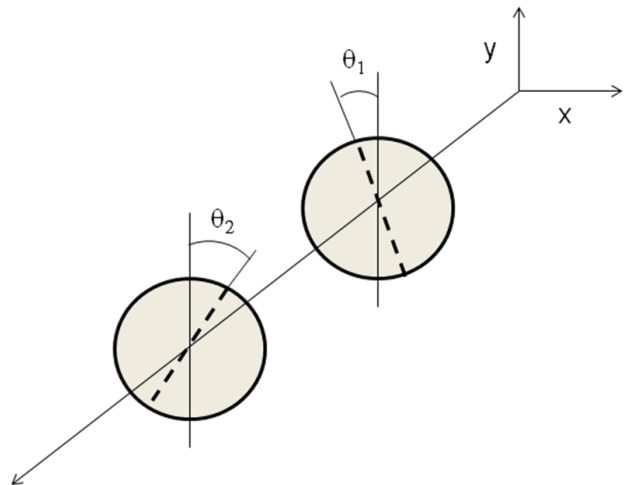
ii) (5 pts) Calculate the radiation pressure exerted on a tiny, perfectly absorbing disk whose diameter is equal to 2.0 wavelengths.

iii) (4 pts) Calculate the force exerted on this disk.

iv) (6 pts) Calculate the number of absorbed photons per unit time.

8) (15 points) A beam of unpolarized light, with intensity 140.0 W/m^2 , is sent into a system of two polarizing sheets with polarizing directions at angles of $\theta_1 = 15^\circ$ and $\theta_2 = -35^\circ$ with respect to the y-axis as shown in the figure.

i) (5 points) Calculate the intensity of light after passing through the first polarizing sheet.



ii) (5 points) Calculate the intensity of light after passing through the second polarizing sheet.

iii) (5 points) Now suppose a third polarizing sheet, with polarization direction of $\theta_3 = +35^\circ$ with respect to the y-axis, is inserted **between** the two sheets shown above. What is the **polarization direction** of light with respect to y-axis after passing through all three sheets?

- (a) 0°
- (b) 15°
- (c) 35°
- (d) 50°
- (e) -35°

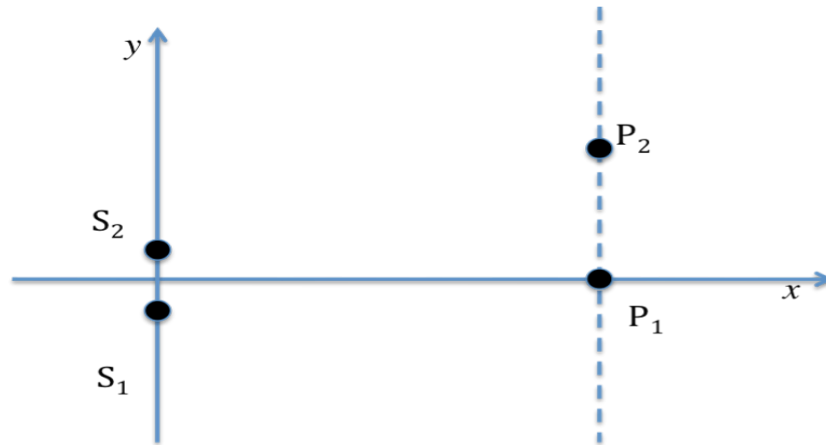
9) (15 points) When coherent light goes through a circular aperture, a diffraction pattern is observed on a screen.

- i) If the size of the aperture is increased, the diameter of the central bright spot ...
 - a. Increases
 - b. Decreases
 - c. Stays the same
 - d. Not enough information

- ii) If the light is switched from red to blue, the diameter of the central bright spot ...
 - a. Increases
 - b. Decreases
 - c. Stays the same
 - d. Not enough information

- iii) If the speed of light was larger than c , the diameter of the central bright spot would...
 - a. Increase
 - b. Decrease
 - c. Stay the same
 - d. Not enough information

10) (20 points) Two isotropic point sources S_1 and S_2 emit light at wavelength $\lambda=550$ nm. The sources are located on the y -axis at $(0,-0.10$ mm) and $(0,+0.10$ mm). A screen is set up at $x=20$ cm where an interference pattern is observed, as shown in the drawing (not to scale).



a) Do rays arriving at point $P_1=(20$ cm, $0)$ at the center of the screen have constructive interference, destructive interference, or something in between? Explain your answer.

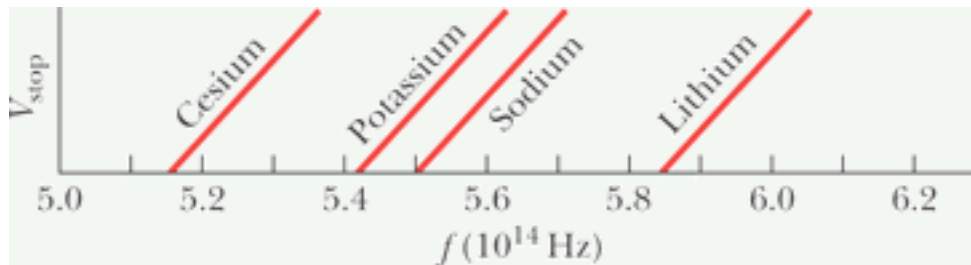
b) What is the y -coordinate of the second dark fringe?

(Problem 10, cont)

c) What is the path length difference for beams arriving at point $P_2=(20 \text{ cm}, 0.50 \text{ mm})$? Express your answer as fraction of wavelength.

d) What is the phase difference for beams arriving at point $P_2=(20 \text{ cm}, 0.50 \text{ mm})$? Express your answer in radians.

11) (15 points) The figure shows data obtained in a photoelectric effect experiment, for the voltage needed to stop the current, V_{stop} , versus the frequency of the incident light. The data is shown for targets of cesium, potassium, sodium, and lithium.



- (i) What is the ranking of the work functions?
- $\Phi_{\text{Cesium}} > \Phi_{\text{Potassium}} > \Phi_{\text{Sodium}} > \Phi_{\text{Lithium}}$
 - $\Phi_{\text{Cesium}} < \Phi_{\text{Potassium}} < \Phi_{\text{Sodium}} < \Phi_{\text{Lithium}}$
 - $\Phi_{\text{Cesium}} = \Phi_{\text{Potassium}} = \Phi_{\text{Sodium}} = \Phi_{\text{Lithium}}$
 - There is not enough information in the plot.
- (ii) If the experiment uses light of wavelength $\lambda=550$ nm, which targets will **not** emit **any** electrons?
- Cesium
 - Cesium and Potassium
 - Sodium and Lithium
 - Lithium
 - It depends on the intensity of the beam used in the experiment.
- (iii) Assume a Cesium target is used in the experiment, like in the leftmost plot in the figure. If the incident light beam's intensity is doubled, the slope of the curve in the figure will...
- Increase
 - Decrease
 - Not change
 - The answer depends on the wavelength of the light

12) (16 points)

- i. A monochromatic light beam with larger intensity than another light beam of the same color:
- has the same number of photons, each with more energy
 - has more photons, each with the same energy and momentum
 - has the same number of photons, each with more momentum
 - has more photons, each with more momentum
- ii. Which of the following can produce interference and diffraction patterns?
- A beam of photons
 - An electromagnetic wave
 - A beam of electrons
 - All of the above
 - None of the above
- iii. Which of the following have the longest deBroglie wavelength?
- A 2 keV electron
 - A 2 keV proton
 - A 2 keV photon
 - All have the same deBroglie wavelength
- iv. Imagine playing baseball in a universe (not ours!) where the Planck constant is huge: $h = 3.14 \times 10^{-3}$ J-s, and quantum uncertainties are an everyday problem. What would be the minimum uncertainty in the position of a 0.5 kg baseball that is moving at 25 m/s along an axis if the uncertainty in the speed is 0.5 m/s?
- 0.5 mm
 - 2.0 mm
 - 4.0 mm
 - It depends on the size of the ball.