Instructor(s): *Profs. Korytov, Rinzler*

PHYSICS DEPARTMENT

PHY 2049, Spring 2015 Final Exam April 25, 2015

Name (print): _____ Signature: _____

On my honor, I have neither given nor received unauthorized aid on this examination.

YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

DIRECTIONS

(1) **Code your test number on your answer sheet (use 76–80 for the 5-digit number)**. Code your name on your answer sheet. **Darken circles completely (errors can occur if too light)**. Code your student number on your answer sheet.
(2) Print your name on this sheet and sign it also.
(3) Do all scratch work anywhere on this exam that you like. At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout with scratch work.
(4) Work the questions in any order. Incorrect answers are not taken into account in any way; you may guess at answers you don't know.
(5) If you think that none of the answers is correct, please choose the answer given that is closest to your answer.
(6) **Blacken the circle of your intended answer completely, using a number 2 pencil**. Do not make any stray marks or the answer sheet may not read properly. Completely erase all incorrect answers, or take a new answer sheet.
(7) As an aid to the examiner (and yourself), in case of poorly marked answer sheets, please circle your selected answer on the examination sheet. Please remember, however, that in the case of a disagreement, the answers on the bubble sheet count, NOT what you circle here. Good luck!!!

>>>>>>>>>**WHEN YOU FINISH** <<<<<<<<<
Hand in the answer sheet separately.

Constants: $e = 1.6 \times 10^{-19}$ C $m_p = 1.67 \times 10^{-27}$ kg $m_e = 9.1 \times 10^{-31}$ kg $\epsilon_o = 8.85 \times 10^{-12}$ C^2/N·m^2

$k = 1/(4\pi\epsilon_o) = 9 \times 10^9$ N·m^2/C^2 nano $= 10^{-9}$ micro $= 10^{-6}$ pico $= 10^{-12}$

Sphere: $A = 4\pi R^2$ $V = \frac{4\pi}{3}R^3$ $\mu_0 = 4\pi \times 10^{-7}$ T·m/A

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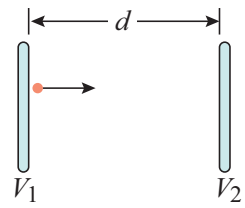
1. Charges $8e$ and $-2e$ are held in place at positions $x = 0$ m and $x = 2$ m, respectively. At what position in x (in m) should a third charge be placed so that it is in equilibrium?

(1) 4 (2) −4 (3) 6 (4) −6 (5) −2

2. A point charge −2 pC is placed at the center of thick conductive shell carrying charge 3 pC. What is the charge on the inner surface of the shell?

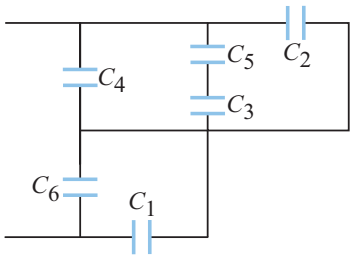
(1) 2 pC (2) −2 pC (3) −1 pC (4) 1 pC (5) 0

3. In the figure an electron is moving rightward between two parallel charged plates separated by distance $d = 8.10$ mm. The plate potentials are $V_1 = -31.0$ V and $V_2 = -34.0$ V. The electron's initial speed is 200 km/s at the left plate. What is its speed just as it reaches plate 2?



(1) the electron will not reach plate 2 (2) 753 km/s (3) 726 km/s (4) 66.7 km/s (5) 61.2 km/s

4. What is the equivalent capacitance C_{eq} of the network of capacitors shown in the figure, if all six capacitors have identical capacitance C_0?

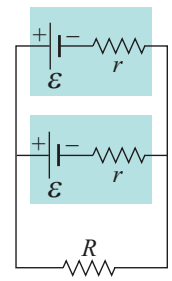


(1) $1.1C_0$
(2) $0.9C_0$
(3) $1.3C_0$
(4) $1.5C_0$
(5) $1.9C_0$

5. A heating element is made by maintaining a potential difference of 81 V across the length of a Nichrome wire that has a diameter of 1.0 mm. Nichrome has a resistivity of $5.0 \times 10^{-7}\,\Omega\cdot$m. If the element dissipates 2500 W, what is its length?

(1) 4.1 m (2) 16 m (3) 8.2 m (4) 2.1 m (5) 1.0 m

6. In the figure the two identical batteries of emf $\mathcal{E} = 8.00$ V and internal resistance $r = 0.250\,\Omega$ are connected to an external resistor of $1.00\,\Omega$. The current through the external resistor is?

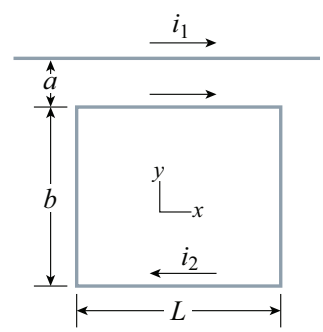


(1) 7.11 A
(2) 14.2 A
(3) 10.7 A
(4) 3.56 A
(5) 12.8 A

7. A *negative* ion with charge $-e$ and mass of 1.33×10^{-25} kg moves along the z-axis with a velocity of 204 m/s in the $\hat{z}$ direction. The ion enters a region where a magnetic field of magnitude 10 mT directed in the $-\hat{x}$ direction is switched on. This causes the ion to execute a circular orbit. That orbit is in either the $+y$ or the $-y$ half plane and has period of motion (in ms) of?

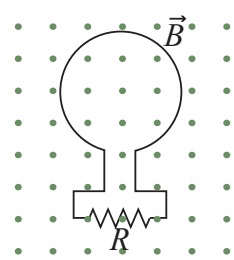
(1) $+y$, 0.5 (2) $-y$, 0.5 (3) $+y$, 1.0 (4) $-y$, 1.0 (5) $-y$, 2.1

8. In the figure, a long straight wire carries a current $i_1 = 30.9$ A and a rectangular loop carries current $i_2 = 17.4$ A. Take $a = 1.44$ cm, $b = 6.39$ cm, and $L = 33.8$ cm. What is the magnitude of the net force on the loop due to i_1?



(1) 2.06×10^{-3} N
(2) 1.96×10^{-3} N
(3) 2.99×10^{-3} N
(4) 3.09×10^{-3} N
(5) 3.31×10^{-3} N

9. In the figure, the magnetic field strength increases according to the relation $B = 60.0t$, where B is in mT and t is in seconds. The area of the loop is 25 cm^2. What is the magnitude of the *emf* induced in the loop when $t = 1.8$ s?



(1) 150 μV
(2) 270 μV
(3) 83 μV
(4) 45 μV
(5) 540 μV

10. Consider an RLC circuit with driving *emf* of amplitude $\mathcal{E}_m = 12$ V, resistance $R = 10\ \Omega$, inductance $L = 1.1$ H, and capacitance $C = 0.8\mu$F. Find the amplitude of the voltage across the inductor at the resonance frequency of the circuit.

(1) 1.4 kV (2) 1.1 kV (3) 0.73 kV (4) 0.51 kV (5) 0.37 kV

11. When a permanent magnet is strongly heated:

(1) it loses its magnetism.
(2) nothing happens.
(3) it becomes an induced magnet.
(4) its magnetism increases.
(5) its polarity reverses.

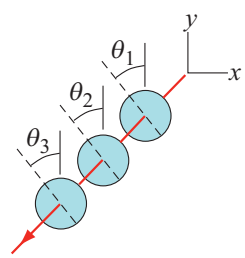
12. If the magnetic field in a plane electromagnetic wave is along the y axis and its component is given by $B_m \sin(kx - \omega t)$ in SI units, then the electric field is along the z axis, and its component is given by:

(1) $-(cB_m)\sin(kx - \omega t)$
(2) $-(cB_m)\cos(kx - \omega t)$
(3) $(cB_m)\sin(kx - \omega t)$
(4) $B_m \sin(kx - \omega t)$
(5) $(cB_m)\cos(kx - \omega t)$

13. A laser beam with intensity $4.3 \times 10^6 \mathrm{W/m^2}$ and wavelength 632.8 nm is aimed vertically upward. What is the maximum radius in nm of a spherical particle (density 4100 $\mathrm{kg/m^3}$) that can be supported by the laser beam against gravity ($g = 9.8$ $\mathrm{m/s^2}$)? Assume that the particle is totally absorbing.

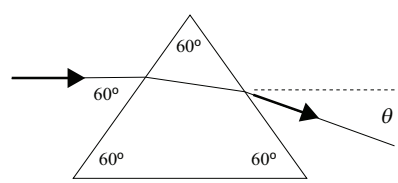
(1) 270 (2) 490 (3) 1070 (4) 120 (5) 190

14. A beam of initially unpolarized light is sent along the z-axis into a stack of three polarizing sheets placed perpendicularly to the z-axis, as shown in the figure. The angles θ_1, θ_2, and θ_3 of the polarizing directions are measured counterclockwise from the positive direction of the y-axis. What percentage of the light's initial intensity is transmitted by the system when $\theta_1 = 60°$, $\theta_2 = 45°$, and $\theta_3 = 15°$?



(1) 35% (2) 42% (3) 12% (4) 18% (5) 24%

15. A light ray traveling in the horizontal direction is incident onto a prism as shown in the figure. At what angle relative to horizontal does the light ray emerge from the second face of the shown prism if the prism has an index of refraction of 1.5 and is surrounded by air? The cross section of the prism is in the shape of an equilateral triangle.



(1) 47° (2) 20° (3) 77° (4) 0° (5) 5°

16. A concave mirror has a radius of curvature of $R = 8$ m. An object is placed 5 m in front of the mirror. Is the image real or virtual, upright or inverted, larger or smaller than the object?

(1) real, inverted, larger
(2) real, inverted, smaller
(3) virtual, upright, larger
(4) virtual, upright, smaller
(5) virtual, inverted, smaller

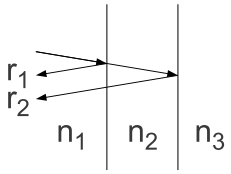
17. Two identical converging lenses with a focal distance of $f = 8$ cm are separated by a distance 16 cm. An object of 1-cm height is placed 2 cm in front of the two-lens package. What is the absolute value of the image height formed by the two lenses?

(1) 1 cm (2) 0.7 cm (3) 1.4 cm (4) 0.5 cm (5) 2 cm

18. A double slit arrangement produces interference fringes for 465 nm laser light that are 4.4 mm apart on a screen located 2.5 m from the slits. What is the separation of the slits?

(1) 0.26 mm (2) 2.5 mm (3) 0.12 mm (4) 5.8 mm (5) 1.06 mm

19. Light is incident perpendicularly on a thin layer of material 2 that lies between materials 1 and 3. The waves of rays r_1 and r_2 interfere. (The rays are tilted only for clarity.) The indexes of refraction are $n_1 = 1.0$, $n_2 = 1.6$, and $n_3 = 1.4$, and the thickness of layer 2 is 200 nm. What is the wavelength of the incoming light (in media 1) in the visible region, $400 \leq \lambda \leq 700$ nm, for which there is completely destructive interference?



(1) 640 nm (2) 430 nm (3) 400 nm (4) 560 nm (5) 480 nm

20. What is the smallest object on the Moon that can be resolved with the Hubble Space Telescope whose diameter is 2.4 m? The typical light wavelength is 500 nm. The distance between the Earth and the Moon is 400,000 km. Neglect the fact that the telescope is at 600 km above the Earth.

(1) 100 m (2) 10 m (3) 1 m (4) 10 cm (5) 1 cm