Physics 241
Final Exam
May 3, 2004

One (both sides) 8 1/2" x 11" crib sheet is allowed. It must be of your own creation.

$$k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \; \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}$$

$$\varepsilon_0 = 8.85 \times 10^{-12} \; \frac{\text{C}^2}{\text{N} \cdot \text{m}^2}$$

$$\mu_0 = 4\pi \times 10^{-7} \; \frac{\text{N}}{\text{A}^2}$$

$$e = 1.602 \times 10^{-19} \text{ C}$$

$$c = 2.99792458 \times 10^8 \text{ m/s (speed of light)}$$

$$N_{Avogadro} = 6.022 \times 10^{23} \text{ (number of atoms in 12 g of }^{12}\text{C)}$$

m $\Rightarrow 10^{-3}$ $\mu \Rightarrow 10^{-6}$ n $\Rightarrow 10^{-9}$ p $\Rightarrow 10^{-12}$ f $\Rightarrow 10^{-15}$

k $\Rightarrow 10^{3}$ M $\Rightarrow 10^{6}$ G $\Rightarrow 10^{9}$ T $\Rightarrow 10^{12}$ P $\Rightarrow 10^{15}$
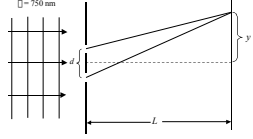
For $ax^2 + bx + c = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

1. Please sign the opscan sheet and print your name on it.
2. Use a #2 pencil to fill in your full name, your student identification number (old one), and finally the answers for problems 1–21.
3. Please be prepared to show your Purdue ID when you hand in your opscan sheet.

1. Consider a double slit interference experiment as shown below.

$\lambda = 750$ nm

If $d = 0.3$ mm and $L = 20$ m, what is y for the third minimum for light of wavelength $\lambda = 750$ nm?

(a) 15.0 cm
(b) 4.8 cm
(c) 12.5 cm
(d) 6.1 cm
(e) none of the above

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2. Consider two concentric conducting spheres as shown below. The outer sphere is hollow and has a total charge of +12 µC on it; its inner radius is $R_2 = 6$ cm and its outer radius is $R_3 = 7$ cm. The inner sphere has a radius of 1 cm, is solid, and has a charge −4 µC on it. What is the magnitude of the electric field at a radius of 5 cm?

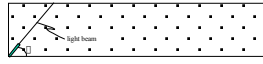(a)   0 V/m
(b)   14.4 MV/m
(c)   28.8 MV/m
(d)   360 MV/m
(e)   none of the above

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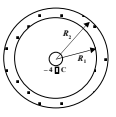
3. A concave mirror has a radius of curvature of 10 cm. A 1 cm high object is placed 4 cm from the mirror. What is the magnification m of the image?

(a) + 5
(b) − 10
(c) + 0.8
(d) − 3
(e) none of the above

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4. A side view of the water in a swimming pool is shown below. A laser pointer in the lower left corner of the pool can be pointed at any angle φ. For what range of φ will there be total internal reflection of the laser light? The index of refraction of the water in the pool is 1.33 and the index of refraction of the air above the water is 1.00029. Assume that the laser and its light beam are all in the plan of the page, and that the pool extends to the right an infinite distance.

light beam

(a) $0^\circ < \phi < 49^\circ$
(b) $0^\circ < \phi < 41^\circ$
(c) $49^\circ < \phi < 90^\circ$
(d) $41^\circ < \phi < 90^\circ$
(e) none of the above

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5. A satellite 160 km above the Earth's surface has a camera with a lens of focal length of 3.6 m. The camera image can barely resolve two point sources of light that are 30 cm apart. What is the minimum effective diameter of the lens as determined from diffraction considerations only? Assume light of wavelength 550 nm is being used.

(a) 3.0×10^{-3} m
(b) 3.6×10^{-3} m
(c) 1.0×10^{-4} m
(d) 2.9×10^{-2} m
(e)   none of the above

6. As shown below, an electron (e^-) is traveling with a velocity of 2.5×10^6 m/s $\hat{i}$ in a uniform electric field of -500 V/m $\hat{j}$. What is the magnitude and direction of a uniform magnetic field that will exactly cancel the electric force on the electron. The mass and charge of an electron are 9.11×10^{-31} kg and -1.60×10^{-19} C.

(a) 2.0×10^{-4} T $\hat{j}$
(b) -2.0×10^{-4} T $\hat{k}$ (into the page)
(c) -2.0×10^{-4} T $\hat{j}$
(d) 2.0×10^{-4} T $\hat{k}$ (out of the page)
(e) none of the above

7. Charges q_1 and q_2 in the figure below are separated by 1 m. If q_1 and q_2 both have a charge of $+1\mu$C, which of the plots below best describes $V(x)$? The origin is denoted by 0 in all figures.

(a)
(b)
(c)
(d)
(e) none of the above

8. A conducting rod moves along a pair of conducting rails that are 40 cm apart as shown below. A 2 Ω resistor R is connected across the left ends of the rails, completing a circuit made up of the rails, rod, and the resistor. A 1.5 T uniform magnetic field B is directed into the page. If the rod is pulled at a constant velocity $v = 8$ m/s, what is the current in the circuit?

(a)   2.4 A in the counterclockwise direction
(b)   2.4 A in the clockwise direction
(c)   9.6 A in the counterclockwise direction
(d)   9.6 A in the clockwise direction
(e)   none of the above

9. Consider the circuit shown below. What is the voltage across the 10 μF capacitor?

(a)   5.3 V
(b)   18.7 V
(c)   3.8 V
(d)   10.5 V
(e)   none of the above

10. A 24 V dc battery is connected to the primary of a transformer as shown. The transformer primary has $N_1 = 5$ turns and the transformer secondary has $N_2 = 10$ turns. Assuming that the magnetic flux linkage is 100%, what is the voltage across resistor R?

(a) 0 V
(b) 6 V
(c) 48 V
(d) 12 V
(e) none of the above

11. A cube of Cu is 2 cm on a side. The resistivity of Cu is $\rho = 1.68\times10^{-8}\ \Omega$ m. If this cube is extruded (formed) into a wire 100 m long, what is the resistance of the wire?

(a) 105 Ω
(b) 21 Ω
(c) 830 Ω
(d) 68 Ω
(e) none of the above

2

12. In the figure below, initially unpolarized light is sent through three polarizing sheets whose polarizing directions make angles of $\theta_1 = 45°$, $\theta_2 = 30°$, and $\theta_3 = 40°$ with respect to the y-axis. What percentage of the light's initial intensity is transmitted by the system? Note that θ_1 and θ_3 are measured relative to the positive y-axis, but θ_2 is measured with respect to the negative y-axis.

(a) 0.78
(b) 44
(c) 22
(d) 0.39
(e) none of the above

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13. A converging lens has a focal length of 50 mm. An object is located 83 mm from the lens and has a height of 0.6 cm, what is the magnification m of the image?

(a) $+0.66$
(b) -0.89
(c) $+2.75$
(d) -1.52
(e) none of the above

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14. A semicircular nonconducting rod of radius a has a uniform charge $-Q$ along its top half and a uniform charge $+Q$ along its bottom half. What is the direction of the electric field at point P?

(a) in the positive x-direction
(b) no direction because the electric field is zero
(c) in the negative y-direction
(d) in the positive y-direction
(e) none of the above

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15. When the headlights of an automobile are switched on (S_1 closed, S_2 open), an ammeter (A) in series with the headlights reads 10 A and a voltmeter (V) across the lights reads 12 V. When the electric starting motor is turned on (both S_1 and S_2 closed), the ammeter reading drops to 8.0 A and the lights dim somewhat. The circuit is shown below. If the internal resistance r of the car battery is 0.050 Ω, what is the current through the starting motor when the lights are on? Assume that the resistance of the ammeter is zero and the resistance of the voltmeter is infinite.

(a) 12 A
(b) 48 A
(c) 50 A
(d) 58 A
(e) none of the above

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16. A convex lens with a focal length of 100 mm is made of a glass with index of refraction of 1.65. To minimize reflections of light of wavelength $\lambda = 450$ nm in air, the lens is coated with a material with index of refraction 1.40. What is the minimum thickness of the coating that will accomplish this?

(a) 80 nm
(b) 113 nm
(c) 161 nm
(d) 225 nm
(e) none of the above

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17. The series RLC circuit shown below has R = 10 Ω, L = 1.0 H, and C = 1.0 μF. The ac generator is applying a voltage given by $\mathcal{E} = V_{app,\ peak} \sin \omega t$ where $V_{app,\ peak} = 14.14$ V. What is the rms amplitude of the voltage across the inductor at resonance?

(a) 0 V
(b) 1 V
(c) 10 V
(d) 1000 V
(e) none of the above

22 pages total   13

22 pages total   14

22 pages total   15

22 pages total   16

22 pages total   17

22 pages total   18

3

18. In the figure below, charge q_1 is located at the origin of the xy coordinate system and has a charge of 3 μC. Charge q_2 is located at $(x, y) = (0, 3\text{ m})$ and has a charge of 5 μC. What is the electric potential at point P which is located at $(x, y) = (4\text{ m}, 0)$?
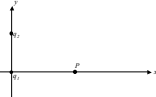
(a) 3.5 kV
(b) 3.1 kV
(c) 16 kV
(d) 14 kV
(e) none of the above

19. Two very long coaxial cylindrical conductors are shown in cross-section below. The inner cylinder has radius $R_1 = 1$ cm and carries a total current of $I_1 = 120$ A in the positive z-direction (pointing out of the page). The outer cylinder has an inner radius $R_2 = 3$ cm, outer radius $R_3 = 6$ cm and carries a current of $I_2 = 300$ A in the negative z-direction (pointing into the page). Assume that the current is uniformly distributed over the cross-sectional area of the conductors. What is the magnitude of the magnetic field at a radius of 0.5 cm?

(a)   0 T
(b)   7.2 x 10⁻³ T
(c)   4.8 x 10⁻³ T
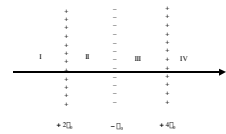(d)   1.2 x 10⁻³ T
(e)   none of the above

20. What is the intensity I of an electromagnetic plane wave with a magnetic field component $B = B_0 \sin(kx - \omega t)$ in which $B_0 = 1.0 \times 10^{-4}$ T? $I = S_{av}$, where S is the magnitude of the Poynting vector.

(a) 4.0×10^{-3} W/m²
(b) 8.0×10^{3} W/m²
(c) 1.2×10^{6} W/m²
(d) 2.4×10^{6} W/m²
(e) none of the above

21. Consider the three infinite charge sheets shown on edge below.

$+ 2\sigma_0 \qquad -\sigma_0 \qquad + 4\sigma_0$

What is value of the electric field in region III?

	magnitude	direction
a)	$\dfrac{\sigma_0}{\varepsilon_0}$	$-x$
b)	$\dfrac{\sigma_0}{\varepsilon_0}$	$+x$
c)	$\dfrac{5\sigma_0}{2\varepsilon_0}$	$+x$
d)	$\dfrac{3\sigma_0}{2\varepsilon_0}$	$-x$
e)	none of the above	

Physics 241
Answer key for blue Final Exam 2
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1. (c) 12.5 cm

2. (b) 14.4 MV/m

3. (a) $+5$

4. (b) $0 < \phi < 41^0$

5. (b) 3.6×10^{-1} m

6. (b) -2.0×10^{-4} T $\hat{k}$, into the page

7. (a)

8. (a) 2.4 A in the counterclockwise direction

9. (a) 5.3 V

10. (a) 0 V

11. (b) 21 Ω

12. (d) 0.39

13. (d) -1.52

14. (d) in the positive y - direction

15. (c) 50 A

16. (a) 80 nm

17. (d) 1000 V

18. (c) 16 kV

19. (d) 1.2×10^{-3} T

20. (c) 1.2×10^{6} W/m^2

21. (d) magnitude : $\dfrac{3\sigma_0}{2\varepsilon_0}$ direction : $-x$