

Final December 16, 2003

Physics 241

1. Please print your name on the top edge of the op-scan sheet.
2. Use a #2 pencil to fill in your full name, your student identification number, your recitation division number, and finally the answers for problems 1-12.
3. One (both sides) 8 1/2" x 11" crib sheet is allowed. It must be hand-written.

Useful equations and constants:

$$F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \quad \vec{E} = \vec{F} / q_0 \quad dE = \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} \quad \epsilon_0 \phi_E = q_{\text{enclosed}}$$

$$V_b - V_a = \frac{W_{ab}}{q_0} = -\int_a^b \vec{E} \cdot d\vec{l} \quad V = \frac{1}{4\pi\epsilon_0} \frac{q}{r} \quad U = Vq \quad E = -\frac{dV}{dl} \quad q = CV \quad V = iR$$

$$d\vec{B} = \frac{\mu_0 i}{4\pi} \frac{d\vec{\ell} \times \vec{r}}{r^3} \quad \oint \vec{B} \cdot d\vec{s} = \mu_0 i_{\text{enc}} \quad \vec{F} = q\vec{v} \times \vec{B} \quad \vec{F} = i\vec{\ell} \times \vec{B} \quad \oint \vec{E} \cdot d\vec{s} = -\frac{d\phi_B}{dt}$$

$$\omega_0 = \sqrt{\frac{1}{LC}} \quad \omega' = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}} \quad \epsilon_m = i_m Z \quad Z = \sqrt{R^2 + (X_L - X_C)^2} \quad X_L = \omega L \quad X_C = \frac{1}{\omega C}$$

$$\tan \phi = \frac{X_L - X_C}{R} \quad P_{\text{av}} = \frac{1}{2} \frac{(\epsilon_m)^2}{Z} \cos \phi \quad \bar{S} = \frac{1}{\mu_0 c} \frac{(E_m)^2}{2}$$

$$I = \frac{1}{2} I_0 \quad I = I_0 \cos^2 \theta \quad n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad \frac{1}{p} + \frac{1}{i} = \frac{1}{f} \quad m = -\frac{i}{p}$$

$$d \sin \theta = m\lambda \quad I = 4I_0 \cos^2 \frac{\phi}{2} \quad \phi = \frac{2\pi d}{\lambda} \sin \theta \quad 2L = \left(m + \frac{1}{2}\right) \frac{\lambda}{n_2}$$

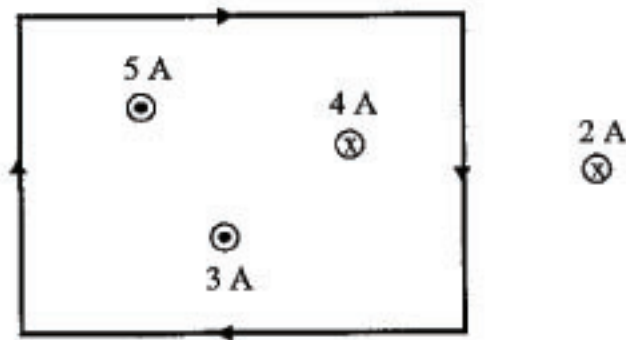
$$I(\theta) = I_m \left(\frac{\sin \alpha}{\alpha}\right)^2 \quad \sin \theta = 1.22 \frac{\lambda}{d} \quad D = \frac{m}{d \cos \theta} \quad y = \frac{1}{2} at^2 \quad f = \frac{c}{\lambda}$$

$$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{N \cdot m^2}{C^2} \quad c = 3.0 \times 10^8 \text{ m/s}$$

$$e = 1.6 \times 10^{-19} \quad m_p = 1.67 \times 10^{-27} \text{ kg} \quad m_e = 9.11 \times 10^{-31} \text{ kg}$$

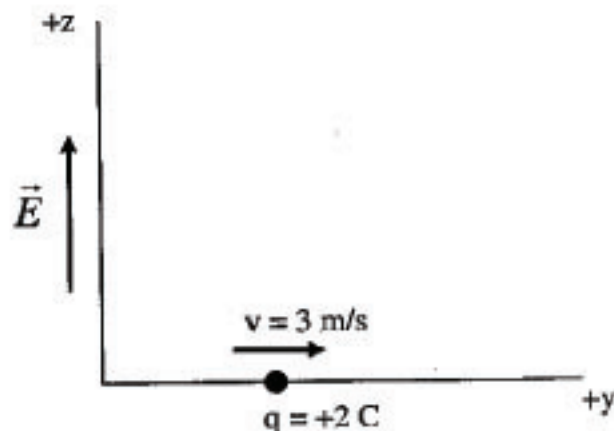
$$\mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m} / \text{A} \quad \epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N \cdot m^2}$$

1. What is the value of $\oint \vec{B} \cdot d\vec{s}$ for the path shown below? (Note that \odot represents a current coming out of the page, and \otimes represents a current going into the page; the arrows indicate the direction of integration).



- (a) $5.03 \times 10^{-6} \text{ T} \cdot \text{m}$
(b) $-5.03 \times 10^{-6} \text{ T} \cdot \text{m}$
(c) $1.51 \times 10^{-5} \text{ T} \cdot \text{m}$
(d) $-1.51 \times 10^{-5} \text{ T} \cdot \text{m}$
(e) $2.51 \times 10^{-6} \text{ T} \cdot \text{m}$

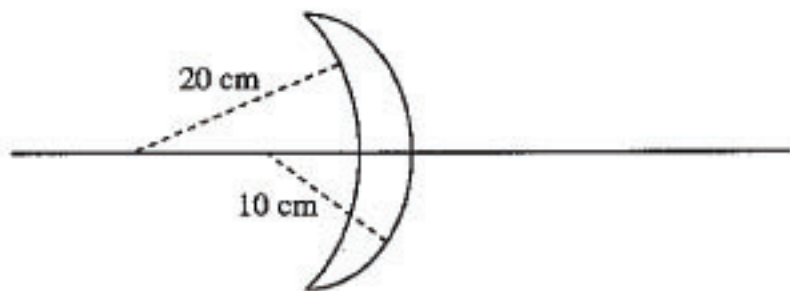
2. A particle with a charge of $+2\text{ C}$ moves with a speed of 3 m/s in the $+y$ direction. It enters a region with a uniform electric field of 6 N/C pointing in the $+z$ direction. What is the direction and magnitude of the magnetic field in this region if the net force on the particle is zero in this region? (Note that in the figure below the $+x$ axis points out of the page).



- (a) $|\vec{B}| = 6\text{ T}$, pointing in the $+z$ direction
(b) $|\vec{B}| = 6\text{ T}$, pointing in the $-z$ direction
(c) $|\vec{B}| = 4\text{ T}$, pointing in the $-x$ direction
(d) $|\vec{B}| = 2\text{ T}$, pointing in the $+x$ direction
(e) $|\vec{B}| = 2\text{ T}$, pointing in the $-x$ direction

3.

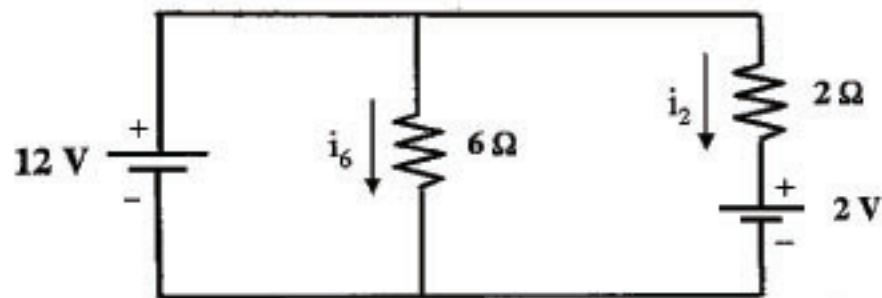
A lens made out of a material having index of refraction 1.5 has sides with radii of curvature 20 cm and 10 cm, as shown below. What is the focal length of the lens?



- (a) -40 cm
- (b) 13.3 cm
- (c) 20 cm
- (d) -20 cm
- (e) 40 cm

4.

What are the currents flowing thru the $6\ \Omega$ and the $2\ \Omega$ resistors in the circuit below?



- (a) $i_6 = 6\ \text{A}, i_2 = 2\ \text{A}$
- (b) $i_6 = 2\ \text{A}, i_2 = 3\ \text{A}$
- (c) $i_6 = 3\ \text{A}, i_2 = 4\ \text{A}$
- (d) $i_6 = 2\ \text{A}, i_2 = 5\ \text{A}$
- (e) $i_6 = 3\ \text{A}, i_2 = 6\ \text{A}$

5. The primary mirror on the Optical Telescope assembly of the Hubble Space Telescope, which orbits 600 km above the Earth, has a diameter of 2.4 m. Assume that the telescope is observing the earth. What is the minimum separation distance between two objects on the ground such that they can still be resolved? Ignore all atmospheric effects and assume that the telescope is receiving light with a wavelength of 550 nm.

- (a) 3.53 cm
- (b) 13.8 cm
- (c) 16.8 cm
- (d) 21.2 cm
- (e) 32.5 cm

6. A small shiny fish is in the water 1.0 m below the surface. Where does a fisherman looking down into the water see the fish; that is, how far below the surface is the image of the fish? The index of refraction of water is $n = 1.33$.

- (a) 1.77 m
- (b) 0.56 m
- (c) 1.33 m
- (d) 1 m
- (e) 0.75 m

7. Calculate the minimum thickness of a soap bubble film ($n = 1.33$) that will result in constructive interference in the reflected light if the film is illuminated with light whose wavelength in free space is $\lambda = 600 \text{ nm}$

- (a) 113 nm
- (b) 100 nm
- (c) 56.5 nm
- (d) 50 nm
- (e) 150 nm

8. A candle is placed 41 cm in front of a convex spherical mirror of radius 60 cm.
Where is the image ?

- (a) 112 cm in front of the mirror
- (b) 112 cm behind the mirror
- (c) 17.3 cm in front of the mirror
- (d) 17.3 cm behind the mirror
- (e) 129 cm behind the mirror

9. A convex lens of focal length 25 cm is placed at a distance of 10 cm from a printed page. What is the image distance i ? What is the magnification M of the image of the page?

- (a) $i = 7.1$ cm, $M = 1$
- (b) $i = 7.1$ cm, $M = -0.71$
- (c) $i = -7.1$ cm, $M = 0.71$
- (d) $i = 16.7$ cm, $M = -1.67$
- (e) $i = -16.7$ cm, $M = 1.67$

10.

Two narrow slits separated by a distance of 0.12 mm are illuminated with light of wavelength 589 nm from a sodium lamp. If the light is intercepted by a photographic film placed 2.00 m beyond the slits, what is the distance along the film between the central maximum and the first lateral maximum?

- (a) 1.2×10^{-3} m
- (b) 2.45×10^{-3} m
- (c) 9.82×10^{-3} m
- (d) 19.6×10^{-3} m
- (e) 4.9×10^{-3} m

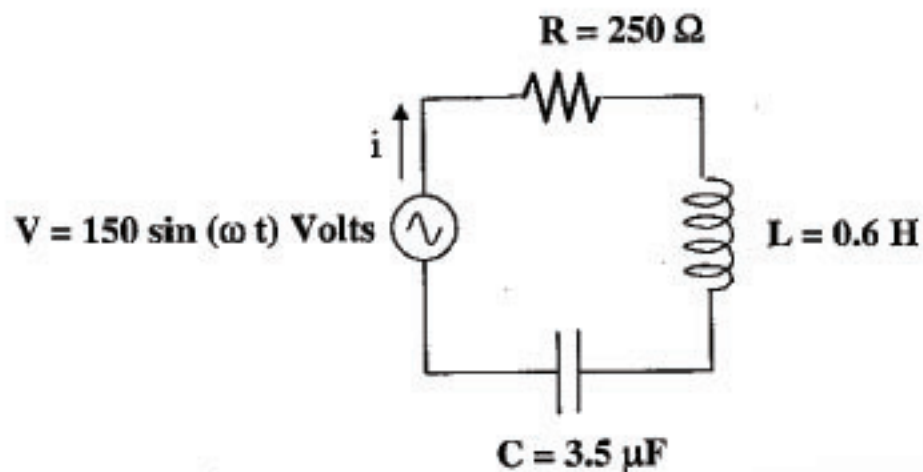
11.

At a distance of 6.0 km from a radio transmitter the amplitude of the oscillating electric field of the radio wave is $E_0 = 0.13$ V/m. What is the total power radiated by the radio transmitter? Assume that the transmitter radiates uniformly in all directions.

- (a) 1 kW
- (b) 0.28 kW
- (c) 1.6 kW
- (d) 2.2 kW
- (e) 10 kW

12.

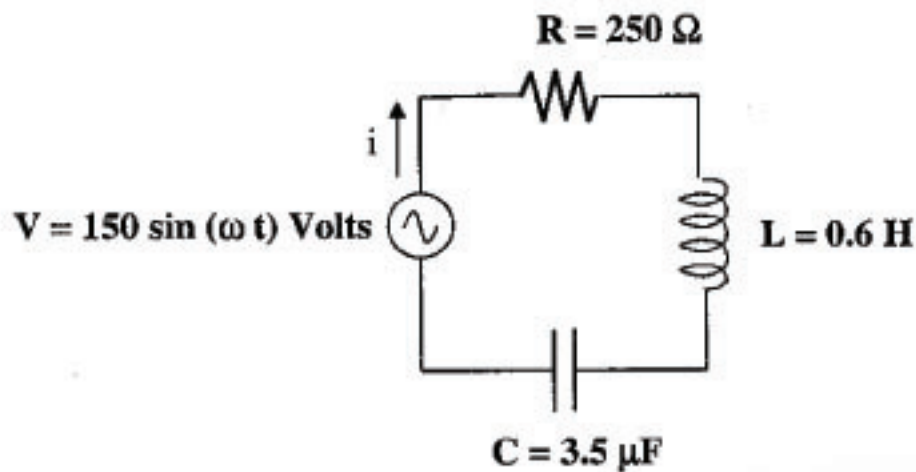
A series RLC circuit with $L=0.6$ H, $C=3.5$ μ F, and $R=250$ Ω is driven by a generator with $V_m=150$ V and variable frequency ω . What is the maximum current I_{\max} when the generator frequency is $\omega=377$ radians/s?



- (a) 0.663 A
- (b) 0.197 A
- (c) 0.255 A
- (d) 0.000 A
- (e) 0.600 A

13.

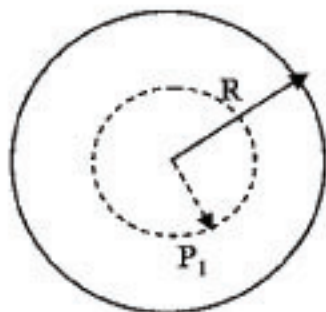
Calculate the average power delivered by the AC voltage source to the series RLC circuit described in problem 8 and shown below



- (a) 11.50 W
- (b) 38.12 W
- (c) 16.29 W
- (d) 19.08 W
- (e) 8.15 W

14.

A cylindrical region of radius $R=3$ cm contains a uniform magnetic field parallel to its axis (i.e. pointing out of the page in the figure below). If the field is changing at a rate of 0.60 T/s, then the magnitude of the electric field at a point P_1 that is at a distance $R/2$ from the axis of the cylinder is:

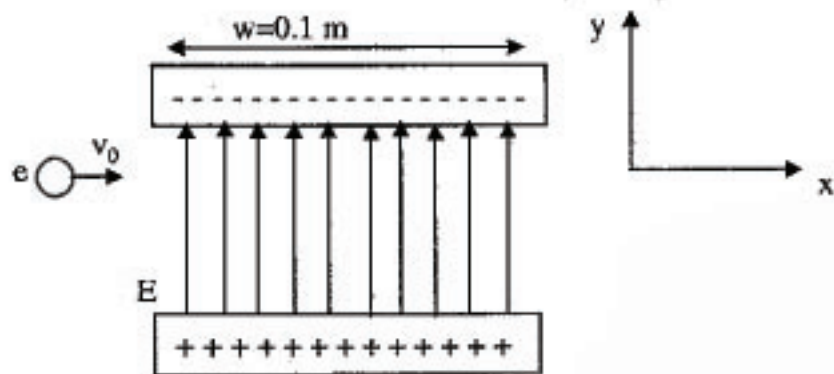


- (a) 0 N/C
- (b) 0.0045 N/C
- (c) 0.0090 N/C
- (d) 0.018 N/C
- (e) None of these

15. A physics instructor in an anteroom charges an electrostatic generator to $25\mu\text{C}$, then carries it into the lecture hall. The net electric flux in Nm^2/C through the walls of the lecture hall is:

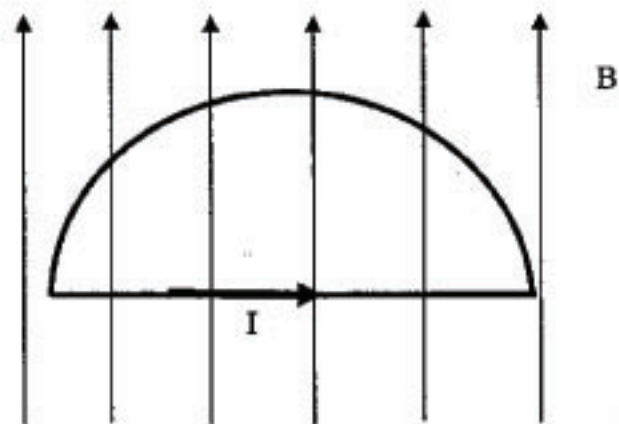
- (a) 0
- (b) 25×10^{-6}
- (c) 2.2×10^5
- (d) 2.8×10^6
- (e) It cannot be calculated since the dimensions of the hall are not given in the problem

16. An electron ($q = -1.6 \times 10^{-19} \text{ C}$) moving with speed $v_0 = 3 \times 10^6 \text{ m/s}$ (parallel to x -axis) enters a region having a uniform electric field $E = 200 \text{ N/C}$, as shown in the figure below. The width of the plates is $w = 0.1 \text{ m}$. Find the change in the vertical displacement y of the electron between the time that it enters and the time that it leaves the electric field. Assume that the initial position of the electron as it enters the electric field is $(0,0)$.



- (a) 3.3 cm
 (b) -1.95 cm
 (c) 1.95 cm
 (d) -3.33 cm
 (e) None of the above

17. A wire bent into the shape of a semicircle of radius $R = 1\text{ m}$ forms a closed circuit and carries a current $I = 10^{-6}\text{ A}$. The circuit lies in the x - y plane and a uniform magnetic field is oriented along the y -axis. Find the net magnetic force on the wire.



- (a) $1.257 \times 10^{-8}\text{ N}$
(b) $6.28 \times 10^{-9}\text{ N}$
(c) $4 \times 10^{-9}\text{ N}$
(d) 0 N
(e) $2 \times 10^{-9}\text{ N}$

18. Consider a series RLC circuit for which $R = 150 \Omega$, $L = 20 \text{ mH}$, $V_{\text{rms}} = 20 \text{ V}$ and $\omega = 5000$ radians/s (V_{rms} gives the rms amplitude of the AC source). Determine the value of the capacitance for which the current attains its peak value.

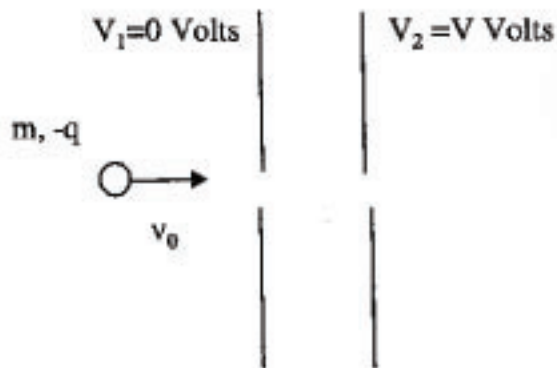
- (a) $C = 80 \text{ nF}$
- (b) $C = 0.25 \times 10^3 \text{ F}$
- (c) $C = 0.25 \times 10^6 \text{ F}$
- (d) $C = 2 \mu\text{F}$
- (e) $C = 0.133 \mu\text{F}$

19. Light of wavelength 589 nm in vacuum passes through a piece of fused quartz ($n=1.458$). Find the frequency of this light in quartz.

- (a) 2.33×10^{14} Hz
- (b) 5.09×10^{14} Hz
- (c) 7.43×10^{14} Hz
- (d) 4.04×10^{14} Hz
- (e) None of the above

20.

A particle (mass m and charge $-q$) is projected with speed v_0 into a region between two parallel plates as shown in the figure below. The potential difference between the two plates is V and their separation is d . The change in kinetic energy of the particle as it traverses this region is:



- (a) $-qV/d$
- (b) $2qV/mv_0^2$
- (c) qV
- (d) $mv_0^2/2$
- (e) None of the above

21. Helium-neon laser light of wavelength 633 nm is passed through a single slit of width 0.10 mm. The diffraction pattern is observed on a screen 3 m away. What is the distance between the two minima on either side of the central maximum?

- (a) 1.9 cm
- (b) 0.0 cm
- (c) 3.8 cm
- (d) 7.6 cm
- (e) None of the above

Form A

1. B
2. D
3. E
4. D
5. C
6. E
7. A
8. D
9. E
10. C
11. E
12. C
13. E
14. B
15. D
16. B
17. D
18. D
19. B
20. C
21. C