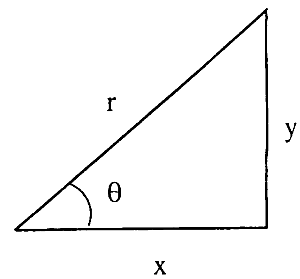
Physics 241 – Final Exam

May 6 **2005**

This exam consists of 24 problems on 15 pages. **Please check that you have them all.** Each problem is worth 8 points unless otherwise noted.

All of the formulas that you will need are given below. You may also use a calculator.

$\sin\theta = y/r$ $\cos\theta = x/r$ $\tan\theta = y/x$



$e = 1.6 \times 10^{-19}$ C $k = 9.0 \times 10^{9}\ \mathrm{N\cdot m^2/C^2}$ $\epsilon_0 = 8.9 \times 10^{-12}\ \mathrm{C^2/(N\cdot m^2)}$

$F = \frac{kq_1q_2}{r^2} = \frac{q_1q_2}{4\pi\epsilon_0 r^2}$ $E = \frac{kq}{r^2}$ $\Phi = \int \vec{E}\cdot d\vec{A} = \frac{q}{\epsilon_0}$ charged plane : $E = \frac{\sigma}{2\epsilon_0}$

$\Delta V = \frac{\Delta U_E}{q} = -\int \vec{E}\cdot d\vec{l}$ $dV = -\vec{E}\cdot d\vec{l}$ point charge : $V = \frac{kq}{r}$ $U_E = q_0V = \frac{kqq_0}{r}$

$E_x = -\frac{\partial V}{\partial x}$ 1 Volt = 1 J / C 1 Volt/m = 1 N / C $U_E = \frac{1}{2}qV$ $C = \frac{q}{V}$

Surface area(sphere) $= 4\pi R^2$ capacitor : $U_E = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}qV = \frac{1}{2}CV^2$ $u_E = \frac{1}{2}\epsilon_0 E^2$

parallel plate capacitor : $C = \frac{\epsilon_0 A}{d}$ isolated spherical capacitor : $C = 4\pi\epsilon_0 R$

capacitors in parallel : $C = C_1 + C_2 + C_3 \ldots$ capacitors in series : $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\ldots$

$C = \kappa C_0$ $I = \frac{\Delta q}{\Delta t}$ $R = \frac{V}{I}$ $R = \rho\frac{L}{A}$ $V = IR$

$$P = IV = I^2R = \frac{V^2}{R} \qquad P = \mathcal{E}I \qquad \text{resistors in series} : R = R_1 + R_2 + R_3 ...$$

$$\text{resistors in parallel} : \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} ... \qquad q(t) = q_0 e^{-t/(RC)} = q_0 e^{-t/\tau}$$

$$I(t) = \frac{V}{R} e^{-t/(RC)} = I_0 e^{-t/\tau} \qquad \tau = RC$$

$$q(t) = C\mathcal{E}(1 - e^{-t/(RC)}) = q_0(1 - e^{-t/\tau}) \qquad I(t) = \frac{\mathcal{E}}{R} e^{-t/(RC)} = I_0 e^{-t/\tau}$$

$$\vec{F_B} = q\vec{v} \times \vec{B} \qquad \vec{F_B} = I\vec{L} \times \vec{B} \qquad \vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

$$\mu_0 = 4\pi \times 10^{-7}\, \mathrm{T \cdot m/A} \qquad d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{\ell} \times \hat{r}}{r^2} \qquad \int \vec{B} \cdot d\vec{\ell} = \mu_0 I \qquad B(\text{center of circular loop}) = \frac{\mu_0 I}{2R}$$

$$B(\text{wire}) = \mu_0 I/(2\pi r) \qquad B(\text{solenoid}) = \mu_0 n I \qquad \mathcal{E} = -\frac{d\Phi_B}{dt} \qquad U_L = \frac{1}{2} L I^2$$

$$V_L = -L\frac{dI}{dt} \qquad L = \mu_0 n^2 A \ell \qquad U_B = \frac{1}{2\mu_0} B^2 (Vol) \qquad u_B = \frac{1}{2\mu_0} B^2$$

$$I = \frac{V}{R}(1 - e^{(-t/\tau)}) \qquad |V_L| = V e^{(-t/\tau)} \qquad \tau = L/R$$

$$\omega = 2\pi f \qquad X_C = \frac{1}{\omega C} \qquad X_L = \omega L \qquad \omega_{resonance} = \frac{1}{\sqrt{LC}}$$

$$I_{rms} = \frac{1}{\sqrt{2}} I_{peak} \qquad I_{rms} = \frac{V_{rms}}{R} \qquad I_{rms} = \frac{V_{rms}}{X_C} \qquad I_{rms} = \frac{V_{rms}}{X_L} \qquad P_{ave} = I_{rms}^2 R$$

$$I_{peak} = \frac{V_{peak}}{R} \qquad I_{peak} = \frac{V_{peak}}{X_C} \qquad I_{peak} = \frac{V_{peak}}{X_L}$$

$$\int \vec{B} \cdot d\vec{\ell} = \mu_0 (I + I_d) \qquad I_d = \epsilon_0 \frac{d\phi_E}{dt} \qquad c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3.00 \times 10^8 \text{ m/s} \qquad E = cB$$

momentum $= U/c$ radiation pressure $= I/c$ intensity $= u_{ave}c$

intensity $= \dfrac{E_0 B_0}{2\mu_0}$ intensity $=$ power/area

$E = hf$ $h = 6.6 \times 10^{-34}$ Js $v = c/n$ $\theta_i = \theta_i'$ $I = \left(\dfrac{n_1 - n_2}{n_1 + n_2}\right)^2 I_0$ $n = c/v$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ $I = I_0 \cos^2\theta$ $\dfrac{1}{s} + \dfrac{1}{s'} = \dfrac{1}{f}$ mirror : $f = r/2$

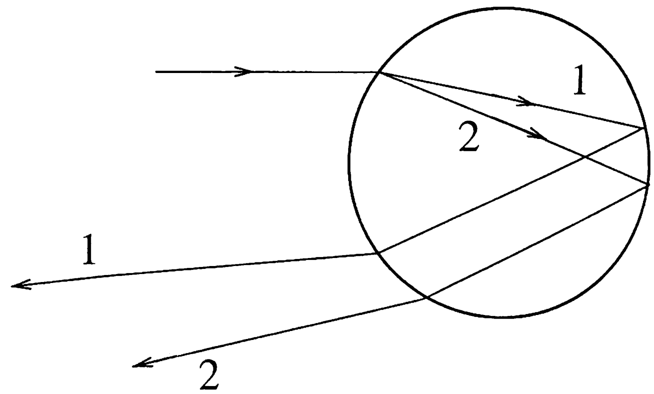
$m = \dfrac{y'}{y} = -\dfrac{s'}{s}$ $\dfrac{n_1}{s} + \dfrac{n_2}{s'} = \dfrac{n_2 - n_1}{r}$ $\dfrac{1}{f} = (n-1)\left(\dfrac{1}{r_1} - \dfrac{1}{r_2}\right)$

phase difference : $\dfrac{\delta}{2\pi} = \dfrac{\Delta r}{\lambda}$ two slits (constructive interference) : $d\sin\theta = m\lambda$

two slits (destructive interference) : $d\sin\theta = (m - \frac{1}{2})\lambda$

single slit (destructive interference) : $d\sin\theta = m\lambda$

1. A rainbow is formed by refraction of light as it passes through a water droplet. In the ray diagram below, which of the following statements *best* explains the origin of a rainbow?



(a) The water drop must be exactly spherical for a rainbow to occur.

(b) Different rays refract at different angles due to their color.

(c) Different rays reflect at different angles due to their color.

(d) The water drop acts like a lens and focuses the light.

(e) Light from the drop is polarized.

2. An object that is 5.0 cm tall is 45 cm in front of a concave mirror with a radius of curvature of 15 cm. Is the image real or virtual, and how big is it?

(a) a real image, 7.5 cm tall

(b) a real image, 9.0 cm tall

(c) a real image, 5.0 cm tall

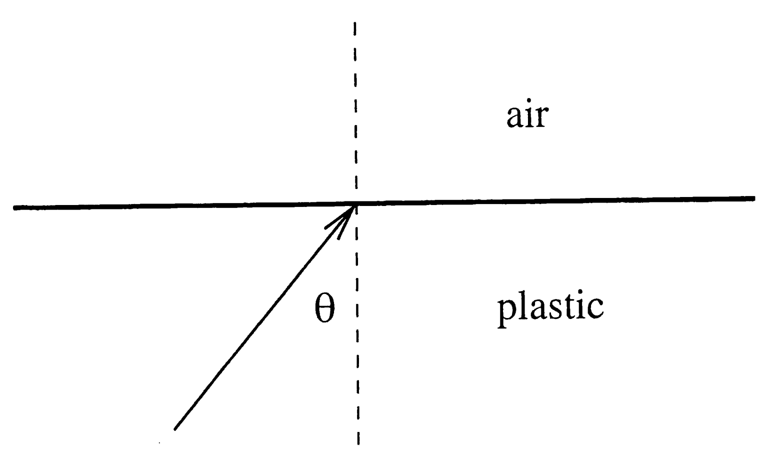
(d) a virtual image, 6.4 cm tall

(e) a real image, 1.0 cm tall

3. The energy carried by 300 photons is 2.5×10^{-16} J. What is the frequency of one of these photons?

(a) 1.3×10^{15} Hz
(b) 3.8×10^{17} Hz
(c) 7.9×10^{14} Hz
(d) 2.4×10^{15} Hz
(e) 6.6×10^{14} Hz

4. A light beam is traveling in a flat plate of plastic as shown. This plate is sitting in air. The critical angle for total internal reflection is measured, and found to be 55°. What is the index of refraction of the plastic? ($n_{air} = 1.00$.)



(a) 1.00
(b) 0.88
(c) 1.50
(d) 1.33
(e) 1.22

5. An object that is 5 cm tall is 25 cm in front (on the left) of a converging lens with a focal length of 40 cm. Where is the image?

(a) 67 cm to the left of the lens

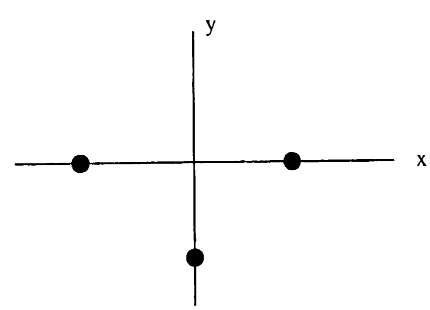
(b) 25 cm to the right of the lens

(c) 15 cm to the right of the lens

(d) at infinity

(e) 40 cm to the left of the lens

6. Three very long wires are directed perpendicular to the plane of the drawing below. The wires are all a distance of 3.3 m from the origin, all carry a current of 2.5 A, and the currents are all directed out of the plane. Find the magnetic field at the origin.



(a) 4.5×10^{-7} T directed along $-x$

(b) 3.0×10^{-7} T directed along $-x$

(c) 5.0×10^{-7} T directed along $-x$

(d) 1.5×10^{-7} T directed along $-x$

(e) 1.5×10^{-7} T directed along $+x$

7. Consider an electromagnetic wave in which $\vec{E}$ points along $-z$ and $\vec{B}$ points along $-y$. What is the propagation direction?

(a) at a 45° angle in the $x - y$ plane

(b) $+y$

(c) $-y$

(d) $+x$

(e) $-x$

8. In air the light from a laser pointer has a wavelength of 630 nm. If the wavelength of this light in plastic is 400 nm, what is the index of refraction of the plastic?

(a) 1.58

(b) 0.63

(c) 1.50

(d) 1.33

(e) 2.50

9. A very thin sheet of glass ($n = 1.55$) floats on the surface of water ($n = 1.33$). When illuminated with white light at normal incidence the reflected light consists predominatly of the wavelengths 560 nm and 400 nm. How thick is the glass?

(a) 600 nm

(b) 450 nm

(c) 390 nm

(d) 530 nm

(e) 250 nm

10. Two narrow slits are used to produce a double slit diffraction pattern with monochromatic light. The slits are separated by 0.90 mm, and the diffraction pattern is projected onto a screen that is 9.5 m away. If the distance between two nearby dark fringes is 5.0 mm, what is the wavelength of the light?

(a) 250 nm

(b) 630 nm

(c) 400 nm

(d) 950 nm

(e) 470 nm

11. Light from a blue laser pointer has a wavelength of 450 nm. What is its frequency?

(a) 1.5×10^{14} Hz

(b) 4.5×10^{14} Hz

(c) 6.7×10^{14} Hz

(d) 5.0×10^{14} Hz

(e) 3.0×10^{8} Hz

12. What is the electric field amplitude at a distance of 0.75 m from a 100 W light bulb? Assume that all of the power of the bulb goes into light of a single color with $\lambda = 500$ nm and that the bulb produces a spherical wave.

(a) 1.4 V/m

(b) 73 V/m

(c) 100 V/m

(d) 140 V/m

(e) 1000 V/m

13. When doing ray tracing to find the image produced by a lens, we suggested that one should always draw a ray that goes through the focal point – we called this the focal ray. Which of the following statements gives the most accurate description of this ray?

(a) The focal ray passes through the center of the lens.

(b) The focal ray always leaves the lens parallel to the axis of the lens.

(c) The focal ray always leaves the object parallel to the axis of the lens.

(d) The focal ray always passes through a virtual image.

(e) There are two focal rays, one for each focal point.

14. Consider a solid sphere of radius $R = 0.55$ m that is uniformly charged with $\rho = +2.5\ \mathrm{C/m^3}$. What is the electric potential a distance 2.5 m from the center of the sphere?

(a) 6.3×10^9 V

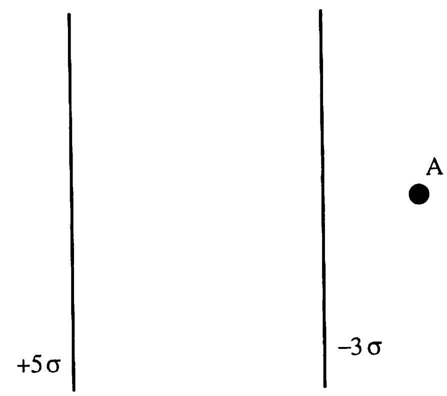
(b) 3.4×10^8 V

(c) 2.3×10^{10} V

(d) 9.0×10^9 V

(e) 2.5×10^9 V

15. Two infinite charged planes have charge densities of $+5\sigma$ and -3σ as shown. What is the electric field at point A?



(a) $\sigma/(2\epsilon_0)$ directed to the left

(b) $3\sigma/(2\epsilon_0)$ directed to the left

(c) $2\sigma/\epsilon_0$ directed to the right

(d) σ/ϵ_0 directed to the right

(e) $\sigma/(2\epsilon_0)$ directed to the right

16. 55 electrons are located at the center of a cubical box of edge length 1.8 m. What is the electric flux through one face of the box?

(a) 1.8×10^{-8} Vm

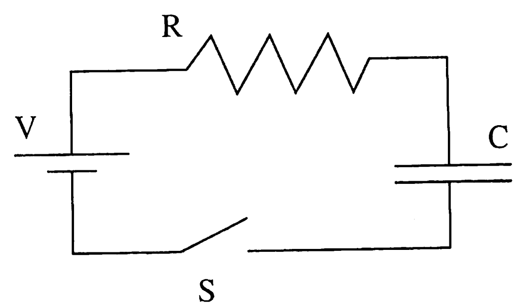
(b) 8.8×10^{-18} Vm

(c) 1.6×10^{-19} Vm

(d) 1.6×10^{-7} Vm

(e) 9.9×10^{-7} Vm

17. Consider the RC circuit shown below. Suppose that $R = 4500\ \Omega$, $C = 4.5\ \mu$C, and $V = 9.0$ V, and that the switch is closed at $t = 0$. What is the charge on the capacitor a long time after the switch is closed?



(a) 4.1×10^{-5} C

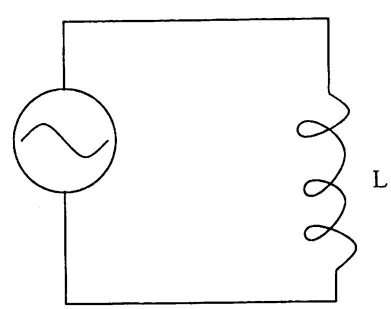
(b) 5.0×10^{-7} C

(c) 4.5×10^{-6} C

(d) 2.0×10^{6} C

(e) 9.0×10^{-6} C

18. Consider the AC circuit shown below. The amplitude of the voltage source is 3.5 V, while the frequency is 350 Hz. If the amplitude of the current through the inductor is 0.0045 A, find L.



(a) 2.2 H

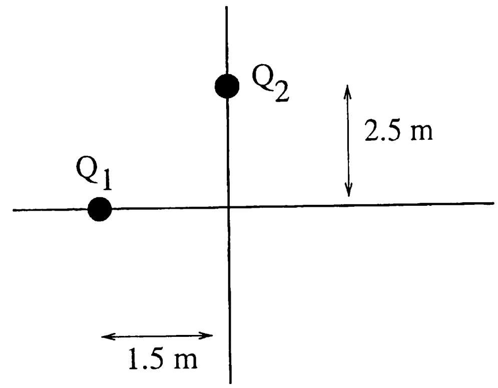
(b) 0.35 H

(c) 7.8 mH

(d) 3.5 mH

(e) 1.4 H

19. Two charges with $Q_1 = +3.5$ C and $Q_2 = -4.5$ C are located as shown. What is the force on an electron at the origin?



(a) 1.0×10^{-9} N along the $-x$ direction
2.2×10^{-9} N along the $-y$ direction

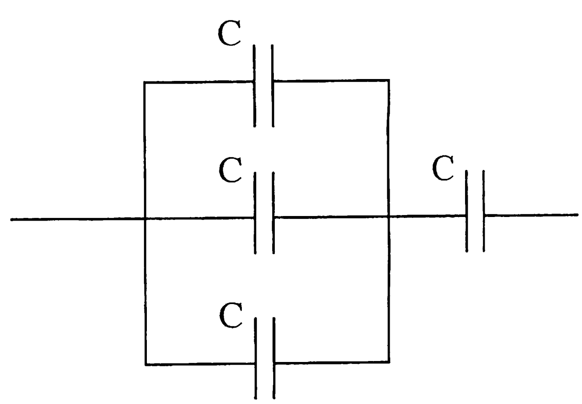
(b) 3.4×10^{-9} N along the $-x$ direction
2.5×10^{-9} N along the $-y$ direction

(c) 1.4×10^{-9} N along the $-x$ direction
6.3×10^{-10} N along the $-y$ direction

(d) 2.2×10^{-9} N along the $-x$ direction
1.0×10^{-9} N along the $-y$ direction

(e) 2.2×10^{-9} N along the $+x$ direction
1.0×10^{-9} N along the $+y$ direction

20. Four capacitors are connected as shown below. What is the equivalent capacitance?



(a) $C/4$

(b) $2C$

(c) $3C$

(d) $3C/4$

(e) $4C$

21. An electron is traveling along the $+y$ direction, and experiences a magnetic force that is along $-z$. What is the direction of the magnetic field?

(a) along the $-z$ direction

(b) along the $+x$ direction

(c) along the $-x$ direction

(d) along the $-y$ direction

(e) along the $+z$ direction

22. The Earth's magnetic field has a magnitude of approximately 5.0×10^{-5} T, and in West Lafayette this field is directed towards the North geographic pole. If a proton is traveling in an Easterly direction with a speed of 600 m/s, what is the magnitude and direction of the magnetic force on the proton?

(a) 4.8×10^{-21} N directed upwards, away from the Earth's surface

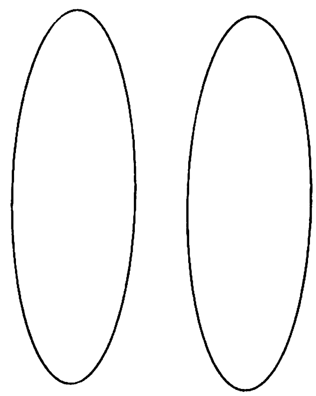
(b) 4.8×10^{-21} N directed downwards, into the Earth's surface

(c) 4.8×10^{-21} N directed towards the west

(d) 3.0×10^{-3} N directed upwards, into the Earth's surface

(e) 3.0×10^{-3} N directed downwards, into the Earth's surface

23. A current I flows in the loop on the left, and this current is counterclockwise as viewed from the right. If I is increasing, what is the direction of the induced current on the loop on the right (as viewed from the right?



(a) clockwise

(b) counterclockwise

(c) there is no induced current in this case

24. An inductor with $L = 45$ mH contains a magnetic energy of 0.023 J. What is the current through the inductor?

(a) 0.46 A

(b) 1.0 A

(c) 0.50 A

(d) 45 mA

(e) 0.71 A

The End

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