Tests from previous years.
PHYS 204

[redacted]

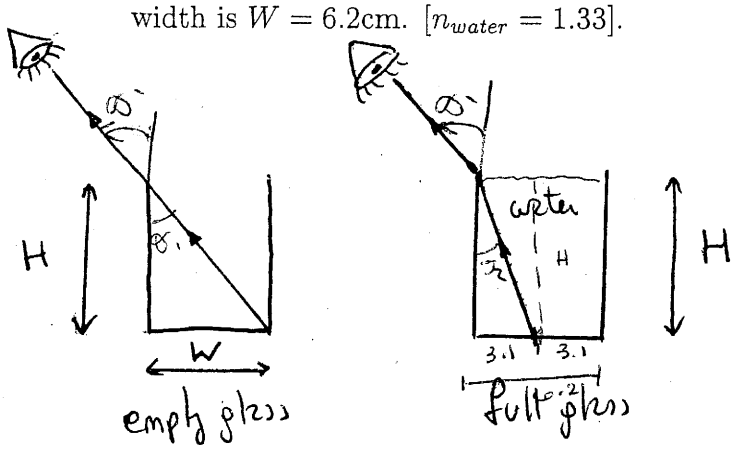
TEST # 3. PHYS 204. SPRING 2003. 05/08/03

NAME: [redacted]

[redacted]

1. **Refraction of Light** (20 points).

The observer in the figure is positioned so that the far edge of the bottom of the empty glass is just visible. When the glass is filled to the top with water, the center of the bottom of the glass is just visible to the observer. Find the height, H, of the glass, given that its width is $W = 6.2\text{cm}$. $[n_{water} = 1.33]$.



$$\sin\theta_1 = \frac{W}{\sqrt{H^2+W^2}}$$

$$\sin\theta_1 = n_w \sin\theta_2$$

$$\sin\theta_2 = \frac{W}{2\sqrt{H^2+(\frac{W}{2})^2}}$$

$$n = \frac{c}{v} \Rightarrow v_{water} = \frac{c}{n_{water}} = \frac{3.00\times10^8\,m/s}{1.33} = 2.26\times10^8\,m/s$$

No

$$d' = d\frac{n_2}{n_1}$$

$$3.1\times10^{-2} = 6.2\times10^{-2}\,m\,\frac{n_2}{1.33}$$

$$n_2 = \frac{3.1\times10^{-2}\times1.33}{6.2\times10^{-2}} = 6.65\times10^{-1}$$

No

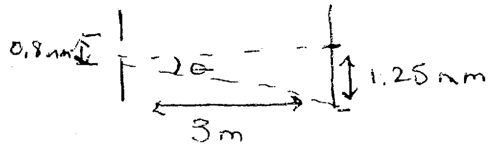
No

-18

$$\frac{W}{\sqrt{H^2+W^2}} = 1.33\,\frac{W}{2\sqrt{H^2+(\frac{W}{2})^2}}$$

2a. Diffraction from a single slit. (8 points)

Monochromatic light from a distance source is incident on a slit 0.8 mm wide. On a screen 3 m away, the distance from the central maximum of the diffraction pattern to the first minimum is measured to be 1.25 mm. Calculate the wavelength of the light.



$W = 0.8\ mm = 8 \times 10^{-4} m$

$L = 3 m$

$y = 1.25 mm = 1.25 \times 10^{-3}$

$\theta = \tan^{-1}\left(\frac{1.25 \times 10^{-3} m}{3 m}\right)$

$\theta = .024°$

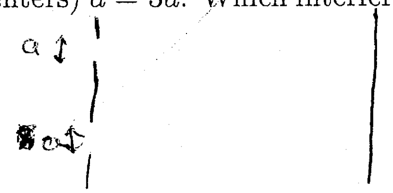
$\sin\theta = \frac{\lambda}{W}$

$\lambda = \sin\theta W = \sin(.024) \cdot 8 \times 10^{-4} m$

$\lambda = 3.35 \times 10^{-7}$ ✓

2b. Diffraction and interference. (14 points)

An interference pattern is produced by monochromatic light incident on two identical parallel slits of width a and separation (between centers) $d = 3a$. Which interference maxima m_i will be missing in the pattern?



The first order interference maxima will be seen.

No

−12

2c. (6 points) If the two-slit experiment were done with white light, what would be seen?

A rainbow would be seen

+ white in the center

−2

3. Relativity.

A spacecraft of length 100m (as measured by a person on the spacecraft) travels away from earth with speed 0.7c relative to the earth. $v = 0.7c$ $L_0 = 100m$

3a. (12 points) Calculate the length of the spacecraft as observed by a person in the earth. $L = ?$

$v = 0.7c$

$\frac{v}{c} = 0.7$ $\left(\frac{v}{c}\right)^2 = .49$

$$L = L_0\sqrt{1-\frac{v^2}{c^2}}$$

$$= 100m\sqrt{1-.49}$$

$$\boxed{L = 71.4m}$$

3b. (12 points) If a person in the spacecraft measures a time interval of 8s, calculate the measurement of the time interval for the observer in earth.

$t_0 = 8s$

$$\Delta t = \frac{\Delta t_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{8s}{\sqrt{1-.49}} = \boxed{11s}$$

4. **Relativity.**

4a. (7 points) Describe some of the everyday consequences that would follow if the if the speed of light were 10 m/s instead of its actual value.

When you turn on a light switch it would take a longer time ~~[illegible]~~ for the light to come. and the pictures on the TV would come through in slow motion. ≈

−2

4b. (7 points) Some distant galaxies are moving away from us at speeds greater than $0.5c$. What is the speed of the light received on Earth from these galaxies? Explain.

The speed of light received on earth from these galaxies is 3.0×10^8 m/s. ~~This is because the~~ relative speeds are differe~~nt the A person on the~~ galaxy is ~~determin~~ @ rest + determinin~~g the speed while~~ w respect to the event. A person on eart~~h is in motion~~ with respect to the event + views them ~~occurring @ various~~ places.

−3 NO

4c. (7 points) How would velocities add if the speed of light were infinitely large?

If the speed of light was infinitely large velocity additions would be needless — NO

−7

4d. (7 points) Two events occur at the same space point in a particular frame of reference and are simultaneous in that frame. Is it possible that they may not be simultaneous in another frame? Explain.

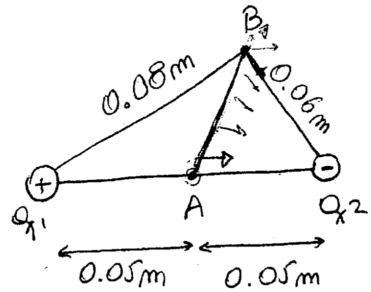
Yes. ~~[illegible]~~ For example, if a train is @ rest + is struck by ~~[illegible]~~ 2 lightning bolts that occured @ the same space point they would arrive @ the train simultaneously. But if the train is moving it ~~[illegible]~~ will not appear simultaneous.

$\Delta t = \gamma \Delta t_0$ ✓

TEST # 2. PHYS 204. SPRING 2001. 03/13/01

NAME:

1. Two point charges $q_1 = 6.8\mu C$ and $q_2 = -5.1\mu C$ are 0.10 m apart. Point A is midway between them and point B is 0.08 m from q_1 and 0.06 m from q_2 (see Fig.). Take the potential to be zero at infinity.



(a) (10 points) Find the potential at point A

$V_1 = \frac{kq_1}{0.05m} = 1222640\ V = 1.2\ 10^6 V$

$V = 305660 V = 3.05\ 10^5 V$

$V_2 = -\frac{kq_2}{0.05m} = -916980\ V = -9.1\ 10^5 V$

(b) (10 points) Find the potential at point B

$V_1 = \frac{kq_1}{0.08} = 764150$

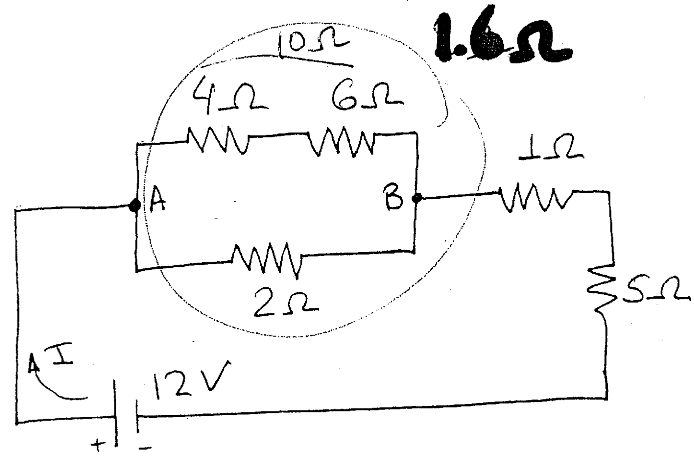
$V_2 = -\frac{kq_2}{0.06m} = -764150\ V$

$V = 0$.

(c) (5 points) Find the work done by the electric field on a charge of 2.50 [redacted]hat travels from A to B.

$W_{AB} = qV_A - qV_B = qV_A = 0.76$

2. In the circuit shown below,



(a) (10 points) Find the equivalent resistance of the circuit.

$R = 7.6\,\Omega$

(b) (4 points) Find the total current I from the battery

$I = \frac{V}{R} = \frac{12V}{7.6\,\Omega} = 1.58A$

(c) (3 points) Find the equivalent resistance between points A and B, and the voltage V_{AB} between the points A and B.

$R_{AB} = 1.6\,\Omega$

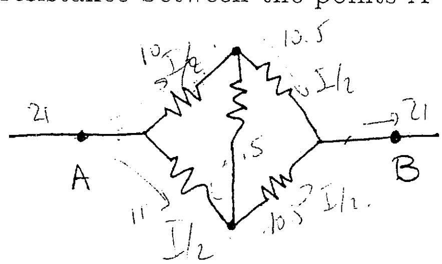
$V_{AB} = I \cdot R_{AB} = 1.6\,\Omega \cdot 1.5A = 2.4V$

(d) (5 points) Find the power dissipated by the 5Ω resistor.

$P = I^2 R = (1.58A)^2 \cdot 5\,\Omega = 12.5\ W$

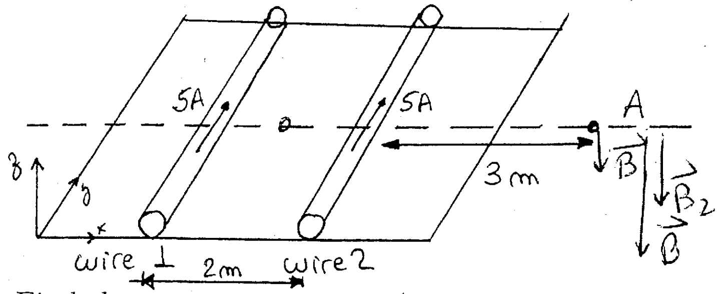
$P = \frac{V^2}{R^2} R = \frac{V^2}{R}$

(e) (3 points) Can you replace the combination of resistors (all of 1Ω) shown below by a single equivalent resistance between the points A and B. Explain.



No.

3. Consider two long straight wires separated by a distance of 2 m as in the figure. The wires carry currents of $5A$ in the same direction as shown in the figure.



(a) (15 points) Find the net magnetic field (magnitude and direction) at point A. Show the direction of the magnetic field of both wires and the total magnetic field in the diagram.

$B = \frac{\mu_0 I}{2\pi r}$

$B_1 = \frac{2 \times 10^{-7} \times 5A}{5m} = 2 \times 10^{-7} T$

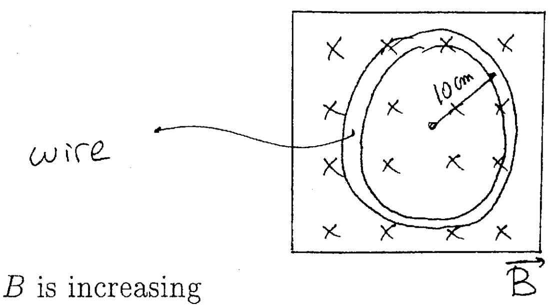
$B_2 = \frac{2 \times 10^{-7}\ 5A}{3m} = 3.3\ 10^{-7} T$

$B = 5.3\ 10^{-7} T.$

(b) (10 points) Relative to the wire 1, locate a point on the dashed line in the figure where the total magnetic field is zero. (Hint: the point is located between the two wires).

Center. 1 meter from wire 1.

4. A circular loop of wire is in a region of spatially uniform magnetic field as shown in the figure. The magnetic field is directed into the plane of the figure. Determine the direction (clockwise or counterclockwise) of the induced current in the loop, when (explain your reasoning):



(a) (5 points) B is increasing

CCW

(b) (5 points) B is decreasing

CW

(c) (5 points) B is constant with value B_0

$\Phi = 0 \Rightarrow$ no current.

(d) (10 points) In the case of increasing magnetic field, calculate the magnitude of the induced emf if the loop has a radius of 10 cm, and the magnetic field goes from an initial value of 0T to a final value of 3T in a time interval of 0.1s.

$$\mathcal{E} = \frac{A \Delta B}{\Delta t} = \frac{\pi \cdot (10^{-1} m)^2 \, 3T}{0.1 s} = 0.94 V$$

TEST # 1. PHYS 204. SPRING 2001. 02/28/01

NAME:

1. A siren S1 emits a wave of frequency 680 Hz with a amplitude of 6cm. Assume that the speed of sound is 340 m/s

(a) (6 points) Find the sound's wavelength and the period if the siren is at rest.

$v = \lambda f \Rightarrow \lambda = \frac{v}{f} = \frac{340 m/s}{680 1/s} = 0.5 m$

$T = \frac{1}{f} = \frac{1}{680 \frac{1}{s}} = 1.4 \; 10^{-3} s$

(b) (6 points) Write down the mathematical expression describing this wave assuming that it propagates towards $+x$.

$y(x,t) = A \sin\left(2\pi f t - \frac{2\pi}{\lambda} x\right)$

$y(x,t) = (6cm) \sin\left(\pi \frac{1360}{s} t - \frac{4\pi}{m} x\right)$

(c) (8 points) If a listener L moves at 170 m/s towards S1, with S1 remaining at rest, find the frequency observed by L.

source

$f_s = 680 Hz$

L ← $v_o = 170 m/s$

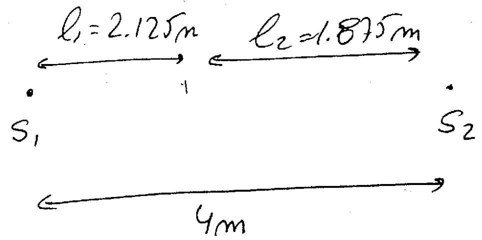
$f_o = f_s \left(1 + v_o/v\right) = 680 Hz \left(1 + \frac{170}{340}\right) = $ ~~[illegible]~~ Hz

1020Hz

(d) (10 points) Consider a second siren S2, identical with S1 (they are in phase and emit a wave with the same frequency), located 4 m to the right of an facing S1. If P is a point (on the line joining S1 and S2) 2.125 m to the right of S1, determine whether the interference at P is constructive or destructive.

$$|l_1 - l_2| = 0.25\,m = \frac{\lambda}{2} \Rightarrow \text{destructive}$$

$\lambda = 0.5\,m$

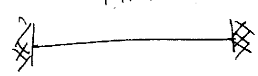


2. A string, fixed at both ends, has a length of 4 m and a mass per unit length of 0.01 kg/m. The tension in the string is 0.25 N.

(a) (8 points) Obtain the speed of a transverse wave traveling along the string.

$$v = \sqrt{\frac{F}{m/L}} = \sqrt{\frac{0.25\ N}{0.01\ kg/m}} = 5\ m/s$$

$4m = L$



$\frac{m}{L} = 0.01 \frac{kg}{m}$

$F = 0.25$

(b) (8 points) The frequency, period and wavelength of the 3rd harmonic emitted by the string.

$$f_n = \frac{nv}{2L} \qquad n=3 \qquad f_3 = \frac{3 \times 5 m/s}{2\ 4m} = 1.875\ Hz$$

$$\lambda_3 = \frac{v}{f_3} = \frac{5 m/s}{1.875 Hz} = 2.66\ m$$

(c) (7 points) Obtain the wave's intensity level if the wave's intensity is 10^{-11} W/m^2.

$$I = 10^{-11} \frac{W}{m^2} \qquad I_0 = 10^{-12}\ W/m^2$$

$$\beta = 10\,dB \log\left(\frac{I}{I_0}\right) = 10\,dB \log\left(\frac{10^{-11}}{10^{-12}}\right) = 10\,dB \log 10 = 10\,dB$$

(d) The tension on the string is kept the same as before, but the length of the string is increased by a factor of 2:

(d1) (6 points) Does the speed of the transverse wave change?

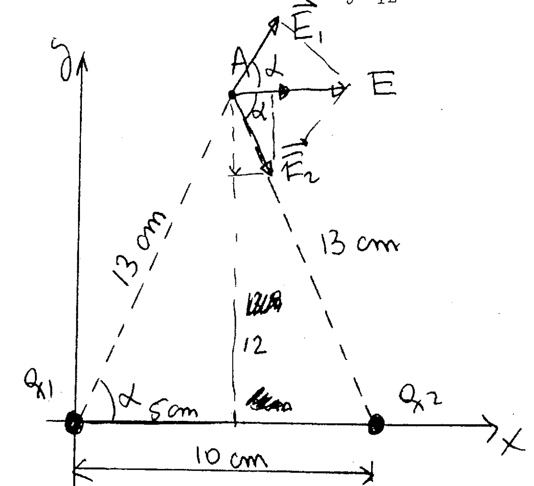
NO.

(d2) (6 points) Calculate the new fundamental frequency of the string.

$$f_1 = \frac{v}{2(2L)} = \frac{5 m/s}{2 \times 8 m} = \frac{5}{16}\ Hz = 0.3125\ Hz.$$

3. Point charges q_1 and q_2 of $+12\mu C$ and $-12\mu C$, respectively, are placed 0.10 m apart (see figure). Compute the electric field cause by q_1, the electric field caused by q_2 and the total electric field (with magnitude and direction) at:

(a) (20 points) Point A.



$E = \frac{k q}{r^2}$ $\quad k = 8.99 \times 10^9 \frac{N.m^2}{C^2}$

$E_1 = 8.99 \times 10^9 \frac{N m^2}{C^2} \cdot \frac{12\ 10^{-6} C}{(0.13\ m)^2} = 6.4\ 10^6 \frac{N}{C}$

$E_2 = 6.4\ 10^6 \frac{N}{C}$

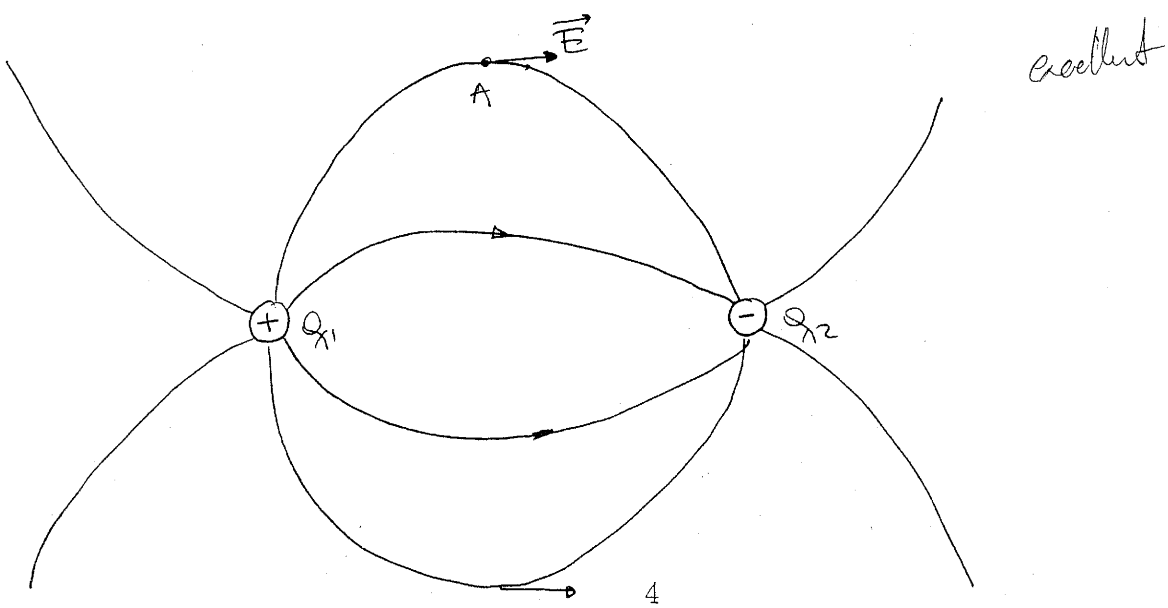
$\cos\alpha = \frac{5}{13} = 0.38.$ $\quad \sin\alpha = \frac{12}{13} = 0.92$ $\quad 5^2 + y^2 = 13^2 \Rightarrow y^2 = 13^2 - 5^2$, $y = 12$

	E_x	E_y
$\vec{E}_1$	$E_1 \cdot \cos\alpha = 2.4\ 10^6$	$E_1 \cdot \sin\alpha = 5.9\ 10^6$
$\vec{E}_2$	$E_2 \cos\alpha = 2.4\ 10^6$	$-E_2 \sin\alpha = -5.9 \times 10^6$
$\vec{E}$	$4.8\ 10^6 \frac{N}{C}$	0

magnitude $4.8\ 10^6 \frac{N}{C}$ in the positive x direction.

(b) (15 points) Draw approximately the electric field lines for this charge configuration.

excellent



FINAL. PHYS 204MM. SPRING 2001. 05/17/01

NAME:

- You are given 7 problems in this final.
- Only the 6 problems with the best scores will count toward the final grade. Each problem counts 16.67 points.
- The grades will be posted in my office (Levich Institute, Steinman Hall, T1M-12) Friday May 18 in the afternoon.
- Good luck!

Some useful constants:

k = permittivity of free space =

μ_0 =

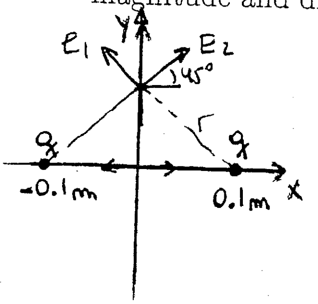
R = dz.

$c = 3. 10^8$ m/s

E_n

1a. Electric Field.

In a (x, y) coordinate system a positive point charge $q = 2 \times 10^{-8}$C is placed at the point $x = 0.1$ m, $y = 0$, and an identical point charge is placed at $x = -0.1$m, $y = 0$. Find the magnitude and direction of the electric field at the origin and at $x = 0$, $y = 0.1$m.



$E = \frac{kq}{r^2}$ $\quad k = 8.99 \times 10^9 \frac{N.m^2}{C^2}$

at origin $\quad E = 0$

at $x=0, y=0.1$ $\quad E_\perp = 8.99 \times 10^9 \frac{N.m^2}{C^2} \times \frac{2 \times 10^{-8} C}{2 \times 0.1^2 m^2}$

$r = \sqrt{2}\, 0.1$

at $(y = 0.1m)$ $\quad E = 2 E_1 \cos 45° = 12713.78 \frac{N}{C}$

1b. Electric Potential.

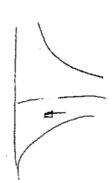
The potential at a certain distance from a point charge is 452 V, with the potential taken to be zero at infinity, and the electric field is 226 N/C. Calculate the distance to the point charge, and the magnitude of the charge. Is the electric field directed toward or away from the point charge?

$V(r) = \frac{kq}{r} = 452V$

$E(r) = \frac{kq}{r^2} = 226 \frac{N}{C}$

$\frac{452}{226 \frac{N}{C}} = \frac{kq/r}{kq/r^2} \Rightarrow r = \frac{452}{226 \frac{N}{C}} = 2m$

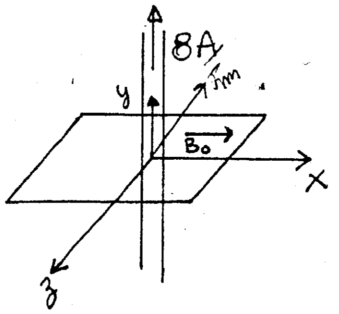
$\Rightarrow q = \frac{452V}{k} \times 2m = 1\ 10^{-7} C.$



2a. Magnetic force on a wire, and magnetic field.

A long straight, vertical wire carries a current of 8 A upward in a region with a horizontal and constant external magnetic field $B_0 = 6$ T in the $x-$direction as seen in the figure.

(i) What are the magnitude and direction of the magnetic force on a 1 cm section of the wire that is in this uniform magnetic field.



$F = I L B_0 \sin\theta$

$F = 8A \times 0.01\ m\ 6T \sin 90°$

$F = 0.48$ N in $-z$ direction.

(ii) What is the ~~total~~ magnetic field produce by the current (magnitude and direction) at the point $x = 2$ cm, $z = 0$, $y = 0$.

$B_w = \frac{\mu_0 I}{2\pi r} = 8 \times 10^{-5}\ T\ (-\hat{z})$ $\mu_0 = 4\pi \times 10^{-7}\ \frac{T \cdot m}{A}$ permeability of free space.

$B_0 = 6T\ \hat{x}$

$\vec{B} = (6T, 0, -8 \times 10^{-5} T)$

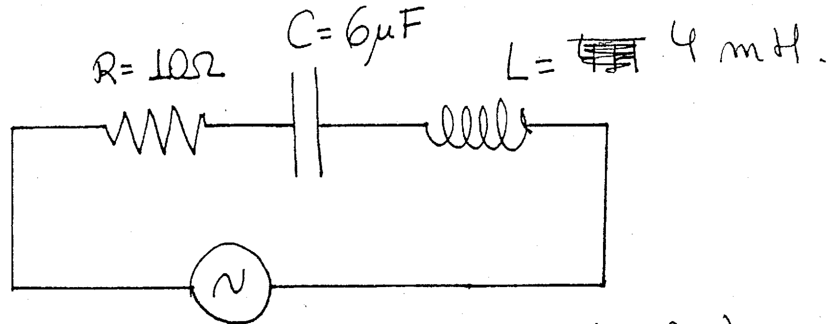
2b. Can a charged particle move through a magnetic field without experiencing a magnetic force? Explain

$F = q_0 v \cdot B \cdot \sin\theta$

if $\theta = 0 \Rightarrow F = 0$.

3. AC Circuits.

In the circuit shown bellow,



$V(t) = 100V \sin(2\pi f t)$

3a. Find the impedance

$X_C = \frac{1}{2\pi f C} = 265\Omega$ $\qquad f = 100 Hz$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ $\qquad X_L = 2\pi f L = 2.512 \Omega$

$Z = 262 \Omega$

3b. The rms current

$I_{rms} = \frac{V_{rms}}{Z} = 0.266 A$ $\qquad V_{rms} = \frac{100V}{\sqrt{2}} = 70.71 V$

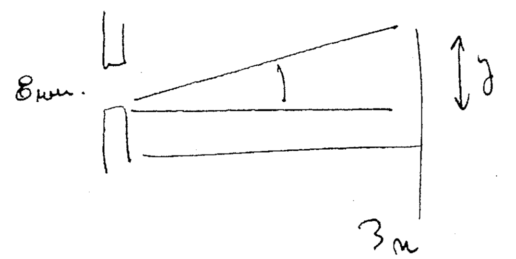
3c. The resonance frequency

$f_0 = \frac{1}{2\pi \sqrt{LC}}$

$f_0 = 1027 Hz.$

4a. Diffraction from a single slit.

Monochromatic light from a distance source is incident on a slit 0.8 mm wide. On a screen 3 m away, the distance from the central maximum of the diffraction pattern to the first minimum is measured to be 1.25 mm. Calculate the wavelength of the light.



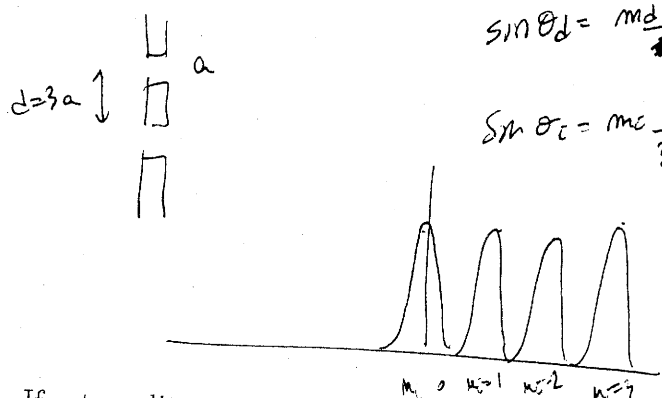
$\sin\theta = \frac{\lambda}{W}$

$\sin\theta \approx \frac{1.25\,mm}{3\,10^{3}\,mm} = \frac{\lambda}{0.8\,mm} = 4.16\;10^{-4}$

$\lambda = 3 \times 10^{-7}\,m.$

4b. Diffraction and interference.

An interference pattern is produced by two identical parallel slits of width a and separation (between centers) $d = 3a$. Which interference maxima m_i will be missing in the pattern.



$\sin\theta_d = \frac{m_d\,\lambda}{a}$

$\sin\theta_i = \frac{m_i\,\lambda}{3a}$

$\frac{m_d}{a} = \frac{m_i}{3a}$

$m_i = 3\,m_d$

$m_i = 3, 6, \ldots$

~~4c. If a two-slit experiment were done with white light, what would be seen?~~

5. Relativity.

A spacecraft of rest-length 100m (as measured by a person on the spacecraft) travels away from earth with speed $0.7c$ relative to the earth.

5a. Calculate the length of the spacecraft as observed by a person in the earth.

$$\Delta t_0 = \Delta t \Big/ \sqrt{1 - (v/c)^2} = 11.20 \text{ sec.}$$

5b. If a person in the spacecraft measures a time interval of 8s, calculate the measurement of the time interval for the observer in earth.

$$L = L_0 \sqrt{1 - \left(\frac{v}{c}\right)^2} = 71.41 \text{ m}$$

5c. The spacecraft fires a rocket towards the earth. The earth-based observer measures that the rocket is approaching with a speed of $0.2c$. Calculate the speed of the rocket relative to the spacecraft. At which velocity do the observer in Earth see the rocket move away from the spacecraft?

6a. The Bohr model.

(i) A hydrogen atom that is initially in the ground level absorbs a photon, which excites it to the $n = 3$ level. Determine the wavelength and frequency of the photon.

~~ΔE~~ =

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{3^2}\right)$$

$R = 1.097 \times 10^7 m^{-1}$

Rydberg constant

$\lambda = 1.03\ 10^{-7}\ m \leftarrow \frac{1}{\lambda} = R\ 0.88$

Bohr energy level for hydrog.

$E_n = (-13.6 eV)\frac{Z^2}{n^2}$

$f = \frac{c}{\lambda} = 2.89\ 10^{15}\ Hz.$

(ii) How much energy in electron volts does it take to ionize an electron in the hydrogen atom from the ground level?

$c = 3 \times 10^8\ m/s$

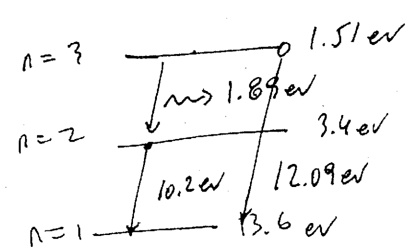
$E = -13.6 eV.$

(iii) A 12.09 eV photon is absorbed by the hydrogen atom. When the electron returns to the ground level ($n = 1$), what possible energies can the emitted photons have?

12.09 eV

1.89 eV

10.2 eV.



6b. Atomic structure. Quantum mechanics.

According to the atomic model in quantum mechanics, write down the 18 possible sets of the 4 quantum numbers (n, l, m_l, m_s) of the hydrogen atom with $n = 3$.

n =	l	m_l	m_s
3	0	0	$1/2$
3	0	0	$-1/2$
3	1	-1	$\pm 1/2$
3	1	0	$\pm 1/2$
3	1	1	$\pm 1/2$
3	2	-2	$\pm 1/2$
3	2	-1	$\pm$
3	2	0	$\pm$
3	2	1	$\pm$
	2	2	$\pm$

7a. Nuclear Physics.

The only two stable nuclides with more proton than neutrons are ${}^{1}_{1}H$ and ${}^{3}_{2}He$. Why is $Z > N$ so uncommon?

7b. Radioactive decay.

The number of radioactive nuclei present at the start of an experiment is 5×10^{10}. The number of nuclei 20 days later is 2×10^{9}. What is the half-live (in days) of the nuclei?

$$2 \times 10^9 = 5 \times 10^{10} e^{-\lambda 20 \text{ days}}$$

$$\frac{2}{5} 10^{-1} = e^{-\lambda 20}$$

$$\lambda = 0.16 \frac{1}{\text{days}}$$

$$T_{1/2} = \frac{\ln 2}{\lambda} = 4.33 \text{ days}$$

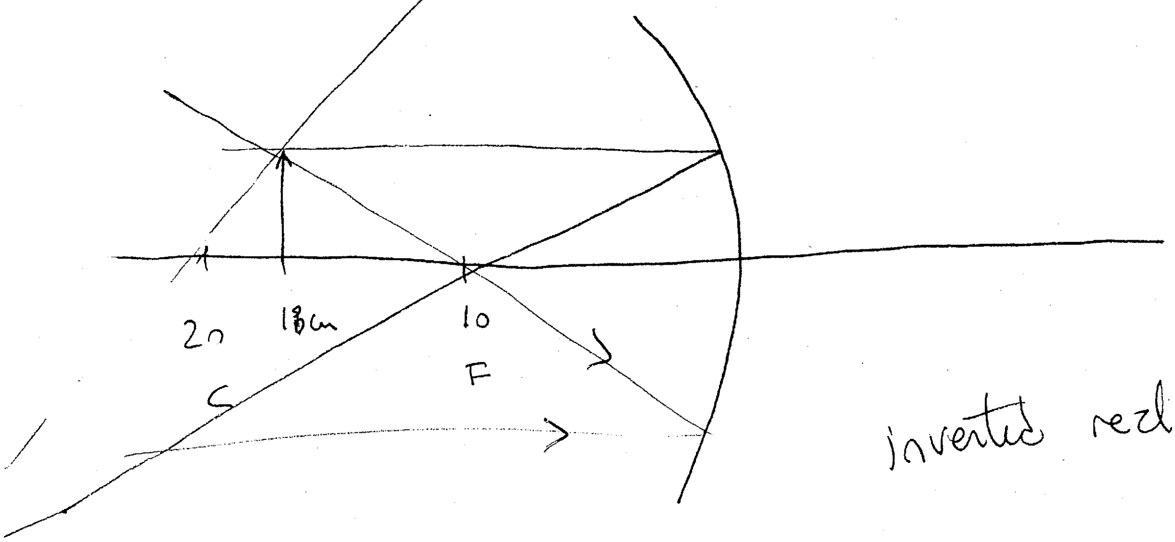
TEST # 3. PHYS 204. SPRING 2004. 04/30/04

April 30, 2004

NAME:

1. **Reflection of Light. Mirrors** (25 points).

An object 0.400 cm tall is placed 18.0 cm to the left of a concave spherical mirror having a radius of curvature of 20.0 cm (a) Draw a ray diagram showing the formation of the image. (b) Determine (using the mirror equation) the position, size, orientation, and nature (real or virtual) of the image. (c) Repeat (a) and (b) for the case in which the mirror is convex.



inverted real

$d_o = 18$ cm

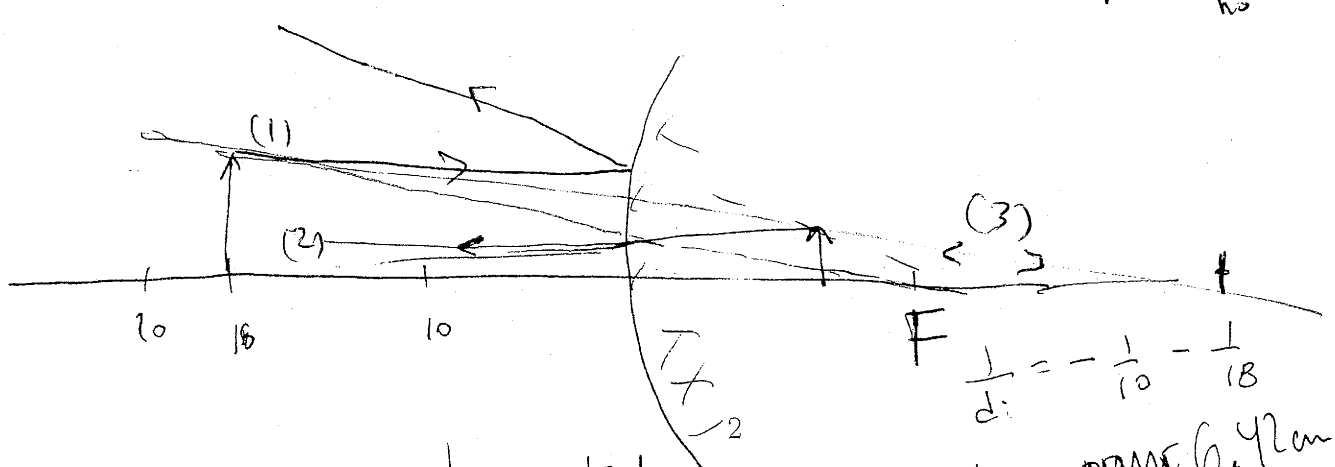
$$\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f}$$

$$\frac{1}{d_i} = \frac{1}{10} - \frac{1}{18}$$

$d_i = 22.5$ cm

$h_i = 0.5$ cm

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$



upright virtual

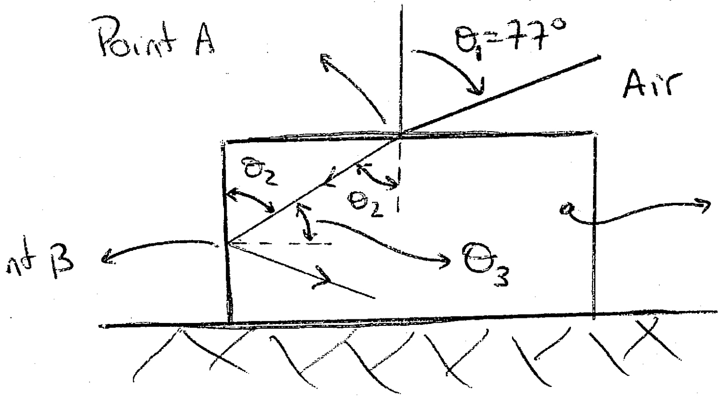
$$\frac{1}{d_i} = -\frac{1}{10} - \frac{1}{18}$$

$d_i = -6.42$ cm.

$h_i = 0.144$ cm

2.a. Refraction of Light. (20 points).

A piece of glass with an index of refraction n rests on a desk as shown in the figure. An incident ray of light enters the horizontal top surface of the glass at an angle $theta = 77^o$ to the vertical. (a) It is impossible to have total internal reflection at point A. Explain why. (b) Find the minimum value of n for which the internal reflection on the **vertical surface** of the glass (Point B) is total. (Hint: the following formulae may help you to solve this problem; $\sin^2\theta_2 + \cos^2\theta_2 = 1$, and $\sin\theta_3 = \cos\theta_2$).



theta = $\theta = 77^\circ$

glass with index of refraction $n > 1$

(a) because $n > 1$

(b) $\sin\theta_1 = n \sin\theta_2$ $\qquad \theta_2 = 44.5^\circ$

$\sin\theta_3 = \frac{1}{n} = \cos\theta_2 \qquad \theta_3 = 45.49$

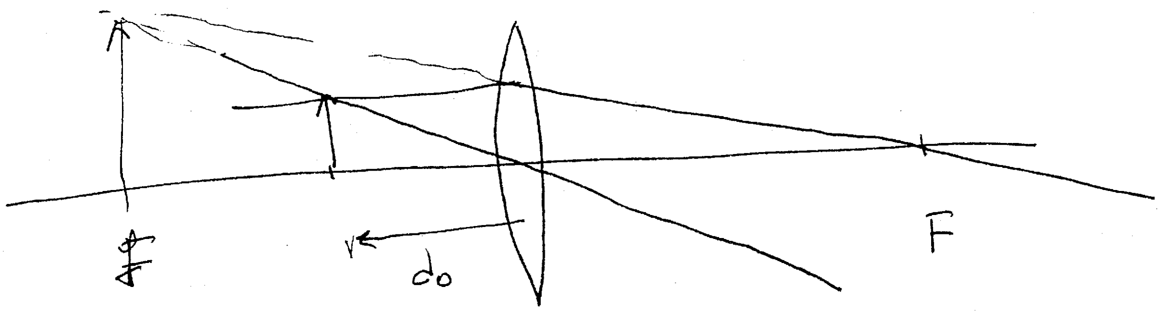
use $\cos^2\theta_2 + \sin^2\theta_2 = 1$

$\left(\frac{1}{n}\right)^2 + \left(\frac{\sin\theta_1}{n}\right)^2 = 1 \Rightarrow \frac{1}{n^2}\left(1 + \sin 77^2\right) = 1$

$n = \sqrt{1 + \sin^2 77} = 1.39$

2.b Lenses (15 points).

An object is a distance $f/2$ from a convex (converging) lens. (a) Use a ray diagram to find the approximate location of the image. (b) is the image upright or inverted? (c) Is the image real or virtual? Explain.



$$\frac{1}{d_i} = \frac{1}{f} - \frac{2}{f} = -\frac{1}{f}$$

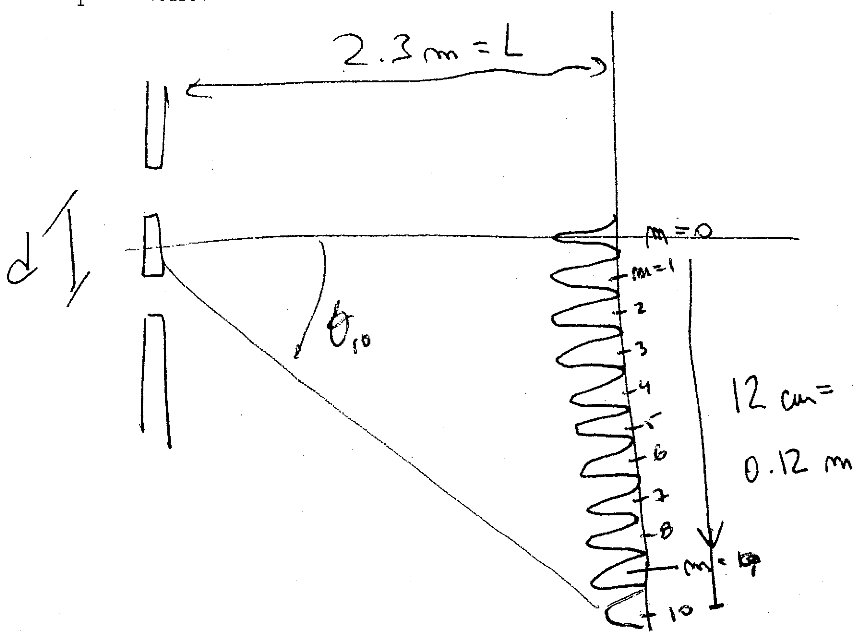
$$d_i = -f$$

$$d_o = \frac{f}{2}$$

Virtual upright

3.a Interference. (20 points).

Two slits with separation of 8.5×10^{-5}m create an interference pattern on a screen 2.3 m away. If the tenth bright fringe above the central fringe is a linear distance of 12 cm from it, what is the wavelength of light used in the experiment?



$d = 8.5 \times 10^{-5}$ m

$\sin\theta_{10} = 10 \frac{\lambda}{d}$

$\sin\theta_{10} = \frac{0.12 \text{ m}}{\sqrt{2.3^2 + 0.12^2}}$

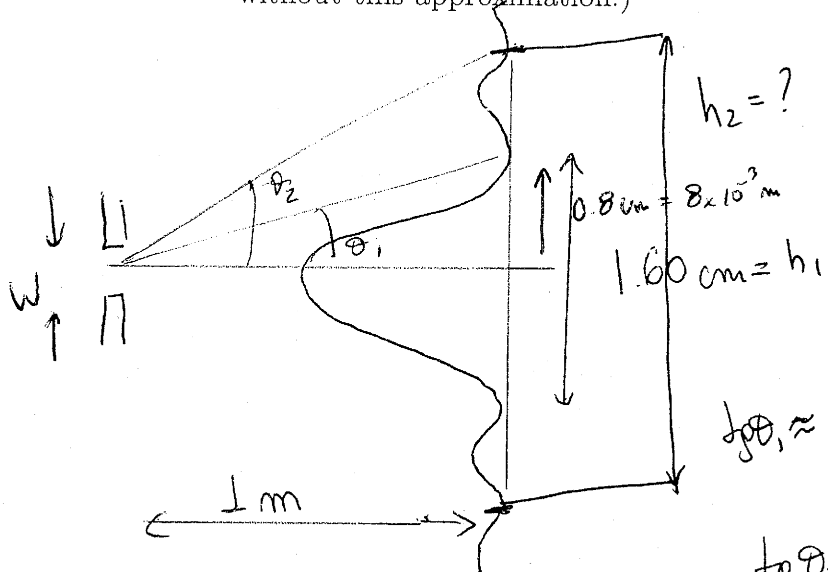
$\lambda = \sin\theta_{10} \times \frac{8.5 \times 10^{-5} \text{ m}}{10}$

$\boxed{\lambda = 443 \text{ nm}}$

$\theta_{10} = 2.98°$

3.b Diffraction. (20 points).

A screen is placed 1.00 m behind a single slit. The central maximum in the resulting diffraction pattern on the screen is 1.60 cm wide. What is the distance between the two second-order minima? (Note that the calculations for this problem can be simplified assuming that $\sin\theta \approx \tan\theta$. If you use this approximation explain why it should be valid in this problem and explain clearly where are you using it. Otherwise, the problem can be also solved without this approximation.)



dark fringes.

$\sin\theta_m = \frac{m\lambda}{W}$

$tg\theta_1 \approx \sin\theta_1 = \frac{h_1}{2\ 1m} = \frac{\lambda}{W}$

$tg\theta_2 \approx \sin\theta_2 = \frac{h_2 \times}{2\times 1m} = \frac{2\lambda}{W}$

$\frac{h_2}{2\times 1m} = 2\frac{h_1}{2\ 1m}$

$h_2 = 2h_1 = 3.2\,cm$

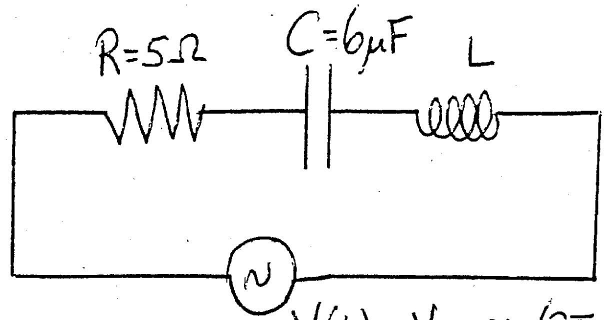
$\sin\theta_1 = \frac{h_1/2}{\sqrt{1m^2 + \left(\frac{h_1}{2}\right)^2}}$

$\sin\theta_2 = \frac{h_2/2}{\sqrt{1m^2 + \left(\frac{h_2}{2}\right)^2}}$

$\frac{h_2}{2\sqrt{(1m)^2 + \left(\frac{h_2}{2}\right)^2}} = 2\frac{\lambda}{W} = 2\frac{h_1/2}{\sqrt{(1m)^2+\left(\frac{h_1}{2}\right)^2}}$

TEST # 3. PHYS 204. APRIL 28, 2001

NAME:



$V(t) = V_0 \sin(2\pi f t)$

$V_0 = 10V$

1.1 In the circuit shown above,

(a) (5 POINTS) Find the impedance at resonance

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = 5\Omega$

(b) (5 POINTS) Find the value of L ~~at resonance~~ if the resonance frequency is $f_0 = 100$ Hz.

$f_0 = \frac{1}{2\pi} \frac{1}{\sqrt{LC}}$

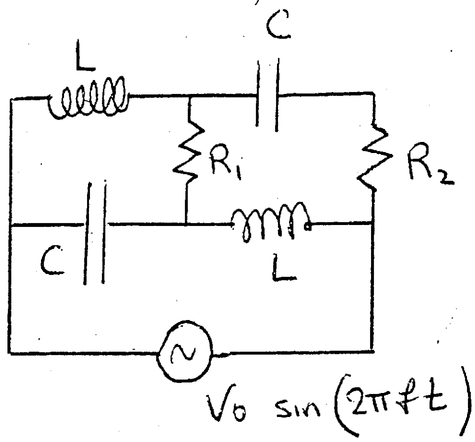
$L^{-1} = (2\pi f_0)^2 C \qquad L = \frac{1}{(2\pi f_0)^2 C} = 0.42\ H$

(c) (5 POINTS) Find the I_{rms} at resonance.

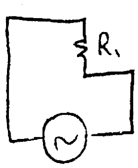
$I_{RMS} = \frac{V_0}{\sqrt{2} R} = \frac{10V}{\sqrt{2}\, 5\Omega} = \frac{~~3.53~~}{1.41} A$

1.2 (10 POINTS) In the circuit below, the generator delivers 10 times as much current at very low frequencies than it does at very high frequencies. Find the ratio $R_1/(R_1+R_2)$.

(Hint: Draw a diagram showing the equivalent circuits at low and high frequencies. Then calculate the current for each circuit.)

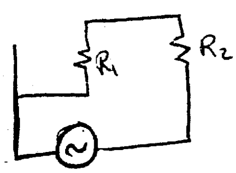


Low f



$I_1 = \frac{V_0}{R_1}$

High f



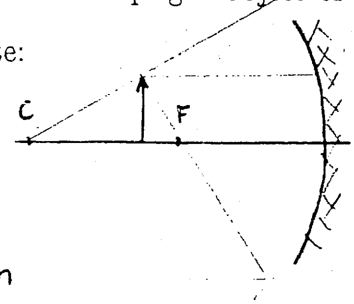
$I_1 = \frac{V_0}{R_1+R_2}$

$I_1 = 10\ I_2$

$\frac{V_0}{R_1} = 10\ \frac{V_0}{R_1+R_2}$

$\frac{R_1}{R_1+R_2} = \frac{1}{10}$

2.1. Consider a concave spherical mirror of focal distance 2m. An upright object of height 1.5 m is located at 2.5m to the left of the mirror. Calculate:



(a) (5 POINTS) The image distance

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ $d_o^{-1} = \frac{1}{2.5m}$ $f^{-1} = \frac{1}{2m}$

$\frac{1}{d_i} = \frac{1}{2m} - \frac{1}{2.5m} = \frac{1}{10\,m}$

(b) (3 POINTS) The magnification $d_i = 10m$

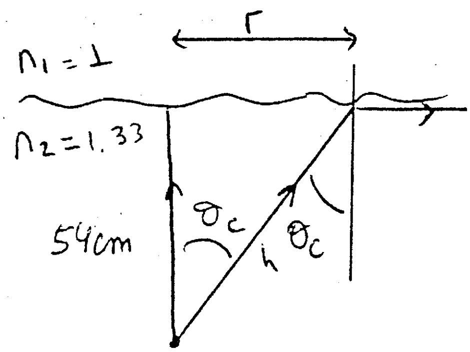
$m = -\frac{d_i}{d_o} = -4$

(c) (2 POINTS) Is the image upright or downright, virtual or real?

↓ real

(d) (5 POINTS) Draw a ray diagram.

2.2 (10 POINTS) A point source of light is 54 cm below the surface of a body water. Find the diameter of the largest circle at the surface through light can emerge from the water. (Hint: the index of refraction of water is 1.33, and think in terms of total internal reflection)



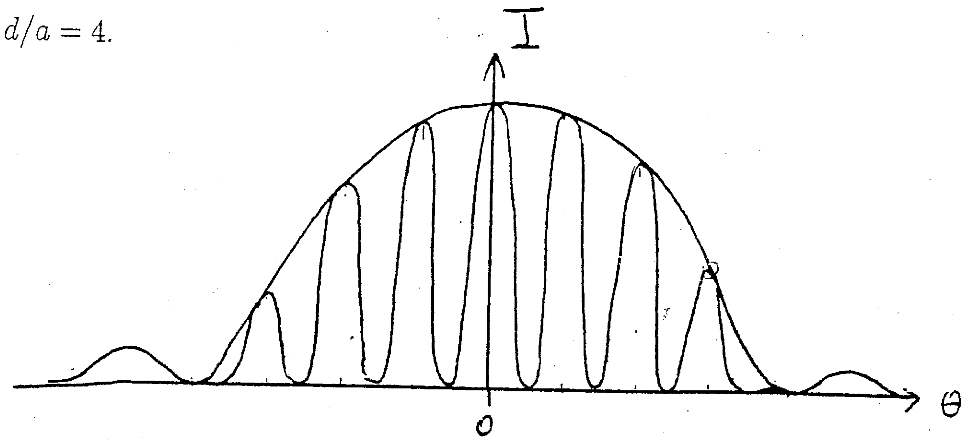
$\sin\theta_c = \frac{1}{1.33} = 0.75 \Rightarrow \theta_c = 48.$

$\sin\theta_c = \frac{r}{h}$

$tg\,\theta_c = \frac{r}{54\,cm}$

$r = 61.2cm$ $d = 122.4\,cm$

3. **Number of Interference Fringes in a Diffraction Maximum.** Consider the intensity pattern produced by two parallel slits with width a and separation d. The figure below shows the intensity pattern produced by the double slit with finite width. Notice that the central diffraction maximum contains exactly seven interference fringes, and in this case $d/a = 4$.



(a) (20 POINTS) What must the ratio d/a be if the central maximum contains exactly five fringes?

$\frac{d}{a} = 3$

first minimum of diffraction kills $m_i = 3$ bright interference fringe

$\sin\theta_D^1 = \frac{\lambda}{a}$

$\sin\theta_i^3 = 3 \cdot \frac{\lambda}{d}$

$\sin\theta_i^3 = \sin\theta_D^1$

$\frac{3\lambda}{d} = \frac{\lambda}{a}$

$\frac{d}{a} = 3$

In the case considered in part (a)

(b) (5 POINTS) How many fringes are contained within the first diffraction maximum on one side of the central maximum?

2

4.1 (8 POINTS) The positive muon is an unstable particle with an average lifetime of $2.2\mu s$ (measured in the rest frame of the muon). If the muon is made to travel at very high speed relative to a laboratory, its average lifetime is measured in the laboratory to be $19\mu s$. Calculate the speed of the muon expressed as a fraction of c.

$\Delta t_0 = 2.2\mu s$

$\Delta t = 19\mu s$

$$19\mu s = \frac{2.2\mu s}{\sqrt{1-(v/c)^2}} \rightarrow \sqrt{1-\frac{v^2}{c^2}} = 0.11$$

$\boxed{v = 0.993c}$

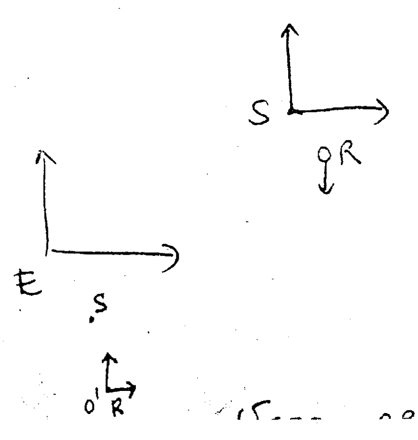
4.2 (8 POINTS) A spacecraft flies over the earth at a speed of $0.8c$. A scientist on the earth measures the length of the moving spacecraft to be 86.5m. The spacecraft later lands on earth, and the same scientist measures the length of the now stationary spacecraft. What value does the scientist get?

$L = 86.5\ m \qquad L_0 = ?$

$v = 0.8c$

$$L_0 = \frac{L}{\sqrt{1-(v/c)^2}} = \frac{86.5m}{\sqrt{1-0.8^2}} = 144\ m$$

4.3 (9 POINTS) A spaceship moving relative to the earth at a large speed fires a rocket toward the earth with a speed of $0.84c$ relative to the spaceship. An earth-based observer measures that the rocket is approaching with a speed of $0.29c$. What is the speed of the spaceship relative to the earth? Is the spaceship moving towards or away from earth?



$v_{RS} = 0.84c$

$v_{RE} = 0.29c$

$v_{SE} = ?$

$$v_{RE} = \frac{v_{RS} + v_{SE}}{1 + \frac{v_{RS} v_{SE}}{c^2}}$$

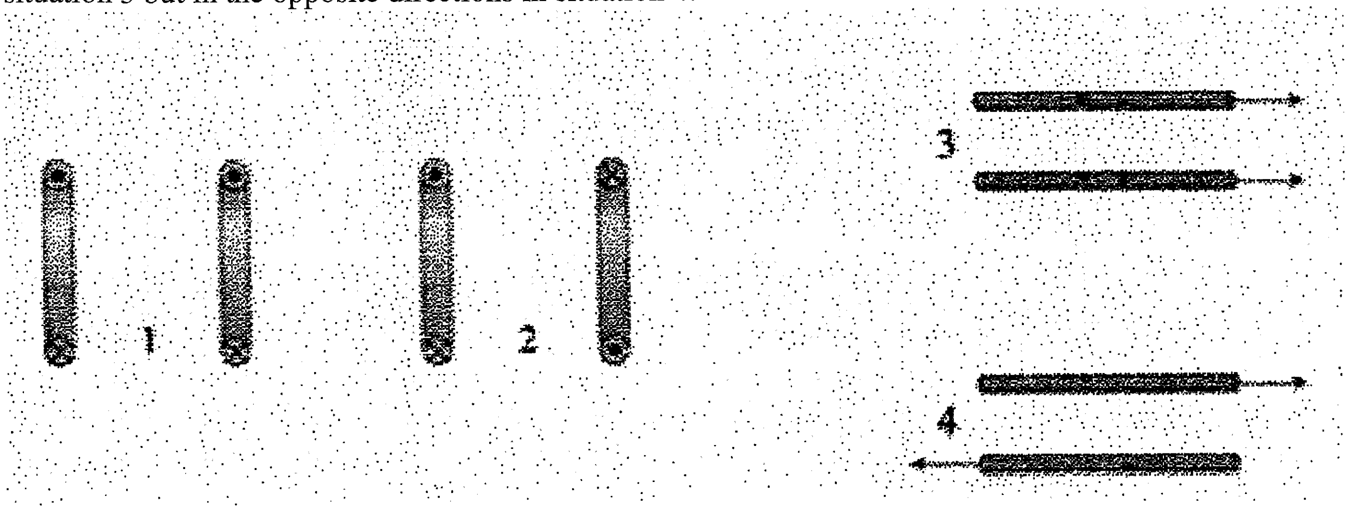
moving away.

$$v_{SE} = \frac{v_{SR} + v_{RE}}{\ldots} = -0.72c$$

Original.

EXAM

1. The figure shows four situations: 1 and 2 involve pairs of current-carrying loops while 3 and 4 involves pairs of current carrying long-straight wires. The currents travel in the same direction around the loops in situation 1 and the opposite direction in situation 2. The currents travel in the same direction in the straight wires in situation 3 but in the opposite directions in situation 4.



Regarding the forces acting between pairs loops (the forces between the loops in 1 or the forces between the loops in 2) and pairs of wires (the forces between the two wires in situation 3 or situation 4), which of the four situations display attractive forces?

(a) 1 and 4

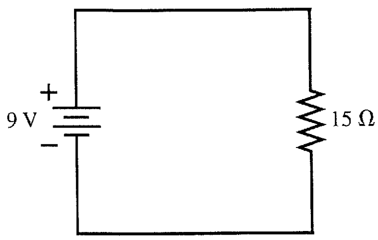
(b) 2 and 3

(c) 1 and 3

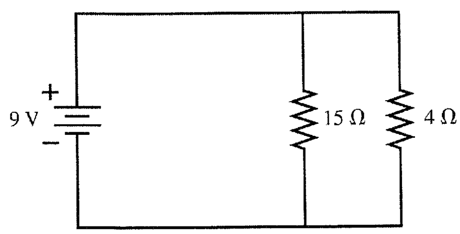
(d) 1 and 2

(e) 2 and 4

2. A 9 volt battery and a 15 Ω resistor are connected together producing a 0.6 amp current through both of them.



The circuit is altered by the addition of a 4 Ω resistor connected as shown:



What change in the current flowing through the battery results?

(a) Current through battery increases by 0.2 amp.

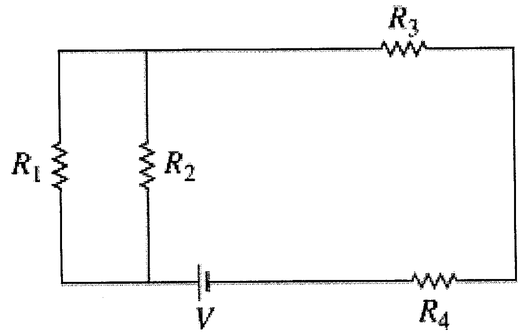
(b) Current through battery decreases by 0.44 amp.

(c) Current through battery decreases by 0.6 amp

(d) Current through battery increases by 2.25 amp

(e) Current through battery increases by 36.0 amp.

3. Consider the network of four resistors shown in the diagram, where R_1= 2.00 Ω, R_2= 5.00 Ω, R_3= 1.00 Ω and R_4 = 7.00 Ω. The resistors are connected to a battery with a constant voltage of magnitude V=6.0 Volts. What is the current going through the battery?



a) 0.46 A

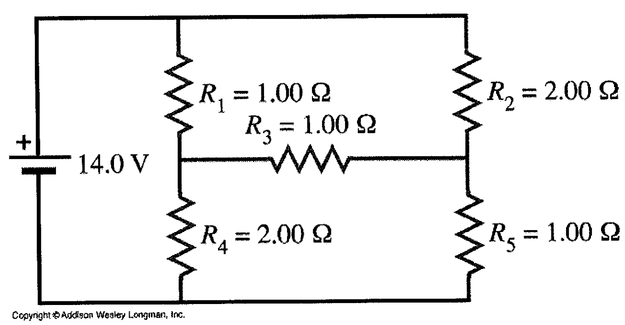
b) 0.77 A

c) 0.63 A

d) 0.40 A

e) 0.42 A

4. The electric current through the battery is 10 amps in the circuit below. The resistances are indicated in the figure. What is the equivalent resistance of the network?



(a) 2.25 ohms

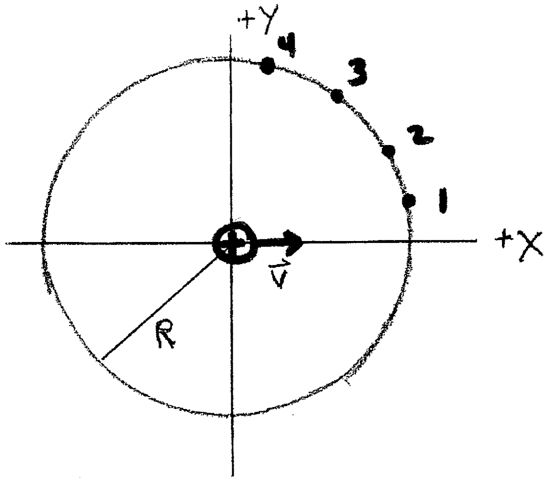
(b) 1.40 ohms

(c) 3.55 ohms

(d) 5.55 ohms

(e) 0.81 ohms

5. The figure shows a point positive charge moving in the +x direction. A circle of radius R has been drawn around the charge with four points selected and labeled 1 to 4.



Rank the magnitudes of the magnetic field created by the moving charge at these four points, from largest to smallest.

(a) $B_2 > B_3 > B_1 = B_4$

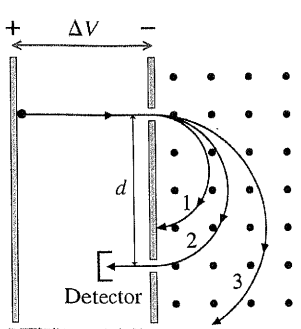
(b) $B_2 > B_3 > B_4 > B_1$

(c) $B_1 = B_2 = B_3 = B_4$

(d) $B_1 > B_2 > B_3 > B_4$

(e) $B_4 > B_3 > B_2 > B_1$

6. Rank the masses of the three particles, which have the same charge, that are accelerated across the potential difference before entering a uniform magnetic field pointing out of the page from largest to smallest.



(a) $m_1 > m_2 > m_3$

(b) $m_2 > m_3 > m_1$

(c) $m_1 > m_3 > m_2$

(d) $m_3 > m_2 > m_1$

(e) $m_2 > m_1 > m_3$

7. An electron, mass is 9.1 x 10^{-31} kg, moves through a magnetic field whose magnitude is 0.55 T. The angle between the direction of the electron's velocity and the magnetic field is 75 degrees. The magnitude of the velocity of the electron is 2.5 x 10^2 meters/second. What is the acceleration of the electron?

(a) 2.3 x 10^{13} m/sec^2

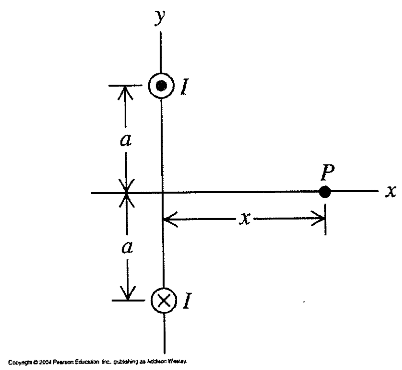
(b) 1.8 x 10^{-17} m/sec^2

(c) 2.2 x 10^{-17} m/sec^2

(d) 8.1 x 10^{16} m/sec^2

(e) 2.5 x 10^{-14} m/sec^2

8. The figure below shows two currents, I, perpendicular to the page, one current coming out and going into the plane of the paper. The currents are in the form of very long straight current-carrying wires. What current, perpendicular to the plane of the page, just as these two currents are, and passing through the point (-x, 0) in the plane of the paper would make the net B field at P zero?



(a) No current in a line parallel to the two shown in the figure and passing through the point (-x, 0) can cancel the field produced at point P by the two currents shown in the figure above.

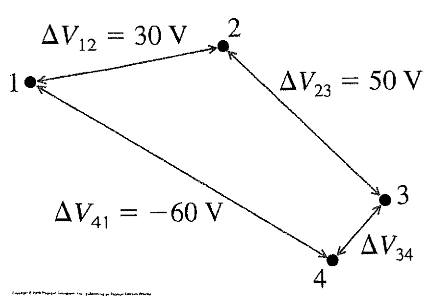
(b) 2I

(c) $\frac{a^2}{a^2+x^2}I$

(d) $\frac{2a^2}{a^2+x^2}I$

(e) $\frac{x^2}{a^2+x^2}I$

9. What is the voltage difference $\Delta V_{34} = V_3 - V_4$?



(a) 20 V

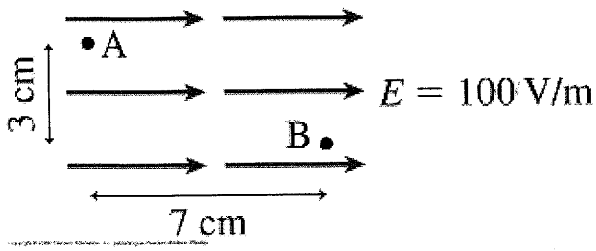
(b) -10 V

(c) 30 V

(d) -30 V

(e) -20 V

10. What is the magnitude of the potential difference between points A and B?



(a) 7 V

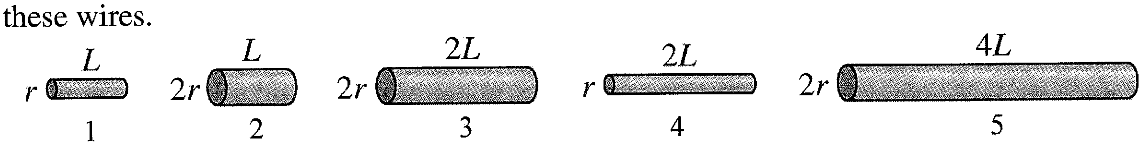
(b) 760 V

(c) 3 V

(d) 10 V

(e) 40 V

11. The wires in the figure below are all made of the same material. Rank n order, from largest to smallest, the resistivities ρ_a to ρ_e of these wires.



(a) $\rho_1 > \rho_2 > \rho_3 > \rho_4 > \rho_5$

(b) $\rho_5 > \rho_3 > \rho_2 > \rho_4 > \rho_1$

(c) $\rho_1 > \rho_4 > \rho_2 > \rho_3 > \rho_5$

(d) $\rho_1 = \rho_2 = \rho_3 = \rho_4 = \rho_5$

(e) $\rho_1 > \rho_4 > \rho_2 > \rho_3 > \rho_5$

Exam 4 Spring 2009 Formula Sheet

$$V_{elec} = \frac{1}{4\pi\varepsilon_o}\frac{Q}{R}$$

$$V_{elec} = \sum_i \frac{1}{4\pi\varepsilon_o}\frac{q_i}{r_i}$$

$$E_s = -\frac{dV}{ds}$$

$$E_{\text{wire}} = \frac{\Delta V_{\text{wire}}}{L}$$

$$\Delta V = V_f - V_i = -\int_{s_i}^{s_f} E_s\, ds$$

$$\Delta V_{bat} = \frac{W_{chem}}{q} = \varepsilon$$

$$\Delta V_{bat} = \Delta V_1 + \Delta V_2 + \cdots$$

$$C = \frac{Q}{\Delta V_C}$$

$$C = \varepsilon_0 \frac{A}{d}$$

$$C = \kappa C_0$$

$$\Delta V_C = Ed = \frac{E_0}{\kappa} d = \frac{(\Delta V_C)_0}{\kappa}$$

$$E_0 = \frac{\eta_0}{\varepsilon_0}$$

$$E_{induced} = \frac{\eta_{indeuced}}{\varepsilon_0}$$

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$$

$$C_{\text{eq}} = C_1 + C_2 + C_3 + \cdots$$

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

$$u = \frac{1}{2}\varepsilon_0 E^2$$

$$P_R = I\,\Delta V_R = I^2 R = \frac{(\Delta V_R)^2}{R}$$

$$P = I\mathcal{E}$$

$$\vec{J} = nq\vec{v}_d$$

$$\rho = \frac{E}{J} = \frac{1}{\sigma}$$

$$R = \frac{\rho L}{A}$$

$$I = \frac{\Delta V_{\text{wire}}}{R}$$

$$V = \mathcal{E} - Ir$$

$$R_{\text{eq}} = R_1 + R_2 + R_3 + \cdots$$

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

$$\sum I = 0$$

$$\Delta V_{\text{loop}} = \sum_i (\Delta V)_i = 0$$

$$\vec{F} = q\vec{v} \times \vec{B}$$

$$\vec{F} = q\vec{E}$$

$$r = \frac{mv}{qB}$$

$$f = \frac{qB}{2\pi m}$$

$$\vec{F} = I\vec{l} \times \vec{B}$$

$$v = E/B$$

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

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,\Delta\vec{s}\times\hat{r}}{r^2}$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \frac{\mu_0 N I R^2}{2(z^2 + R^2)^{3/2}}$$

$$B = \frac{\mu_0 N I}{2R}$$

$$B = \frac{\mu_0 I}{2\pi R^2} r$$

$$B = \frac{\mu_0}{4\pi}\frac{2\mu}{z^3}$$

$$\mu = IA$$

$$B = \frac{\mu_0 N I}{L} = \mu_0 n I$$

$$\oint \vec{B}\cdot d\vec{s} = \mu_0 I$$

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

$$\Delta V_H = \frac{IB}{tne}$$

$$\vec{A}\cdot\vec{B} = AB\cos\theta$$

$$\vec{A}\cdot\vec{B} = A_x B_x + A_y B_y + A_z B_z$$

$$\vec{C} = \vec{A}\times\vec{B} = AB\sin\theta\,\hat{n}$$

$$C = AB\sin\theta$$

$$W = F\,d\cos\theta$$

$$K = \tfrac{1}{2} m v^2$$

$$y = y_o + v_{oy}\Delta t + \tfrac{1}{2} a_y (\Delta t)^2$$

$$F = ma$$

$$a = v^2/r$$

$$W = mg$$

$$\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ N m}^2/\text{C}^2$$

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

$$\mu_o = 4\pi \times 10^{-7} \frac{\text{T m}}{\text{A}}$$

$e = 1.6 \times 10^{-19}$ C

$g = 9.8$ m/s^2

electron mass = 9.11×10^{-31} kg

proton mass = 1.67×10^{-27} kg