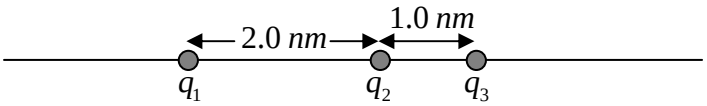
Physics 251 **Name: Answer Key**
Spring 2008 / Dr. Zimmerman
Quiz 1: Chapter 16

Show all your work

Consider three charges situated in a straight line as shown. Calculate the magnitude and direction of the net force acting on charge q_1 due to the other two charges. The values of the charges are given as: $q_1 = e$, $q_2 = e$, and $q_3 = -2e$. The elementary charge is $e = 1.6\times10^{-19}\ C$ and Coulomb's Law tells us,

$F = \frac{kq_1q_2}{d^2}$ with $k = 9.0\times10^{9}\ N\cdot m^2/C^2$



$$\vec{F}_{21} = \frac{-(9.0\times10^{9})(1.6\times10^{-19})^2}{(2.0\times10^{-9})^2} = -5.76\times10^{-11}\ N$$

$$\vec{F}_{21} = \frac{(9.0\times10^{9})(1.6\times10^{-19})(3.2\times10^{-19})}{(3.0\times10^{-9})^2} = 5.12\times10^{-11}\ N$$

$$\vec{F}_{net} = \vec{F}_{21} + \vec{F}_{31} = \boxed{-6.4\times10^{-12}\ N}$$

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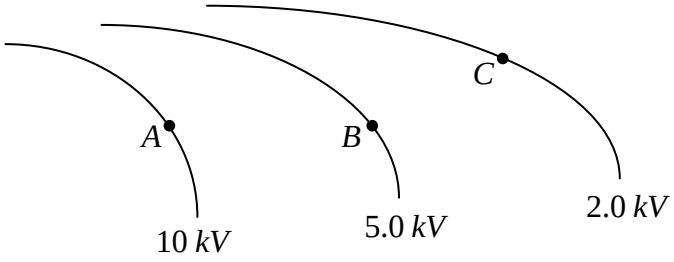
Quiz 2: Chapter 17

Show all your work

(a) Initially at rest, a proton moves from point *A* to point *C* under the influence of the electric force only. The curves are equipotentials. How fast is it moving when it arrives a point *C*?
(b) How much work must be done by an external agent to stop the proton at point *C* and return it to point *B* at rest? The mass of the proton is $1.67\times10^{-27}\ kg$. A few useful equations:
$W_{nc} = \Delta K + \Delta U\ ;\ U = qV\ ;\ K = mv^2/2$



(a) $\Delta K = -\Delta U$
$\frac{1}{2}mv^2 = -q\Delta V$
$v = \sqrt{\frac{-2q\Delta V}{m}} = \sqrt{\frac{-2(1.6\times10^{-19}\ C)(-8,000\ V)}{1.67\times10^{-27}\ kg}}$
$v = \boxed{1.24\times10^{6}\ m/s}$

(b) $W_{nc} = (0-\frac{1}{2}(1.67\times10^{-27}\ kg)(1.238\times10^{6}\ m/s)^2) + (1.6\times10^{-19}\ C)(+3,000\ V)$
$W_{nc} = \boxed{-8.0\times10^{-16}\ J}$

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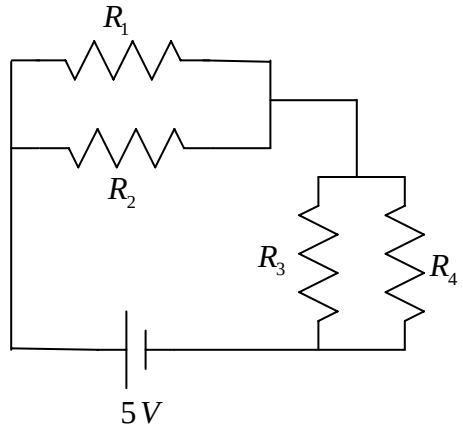
Quiz 3: Chapter 18

Show all your work

In the circuit shown, the resistors have the same value: $R_1 = R_2 = R_3 = R_4 = 2\,\Omega$. (a) Determine the equivalent resistance of the circuit. (b) What current flows through the battery? (c) What current flows in each resistor?



Circuit equations:

$$\Delta V = IR$$
$$R_{series} = \sum R_i$$
$$R_{parallel} = \left(\sum \frac{1}{R} \right)^{-1}$$

(a) $R_{12} = R_{34} = \left[\frac{1}{R_3} + \frac{1}{R_4} \right]^{-1} = \left[\frac{1}{2\,\Omega} + \frac{1}{2\,\Omega} \right]^{-1} = 1\,\Omega$

$R_{eq} = 1\,\Omega + 1\,\Omega = \boxed{2\,\Omega}$

(b) $I = \Delta V / R_{eq} = 5\,V / 2\,\Omega = \boxed{2.5\,A}$

(c) $I = 2.5\,A / 2 = \boxed{1.25\,A}$, *since all resistors are the same, the current is equally divided.*

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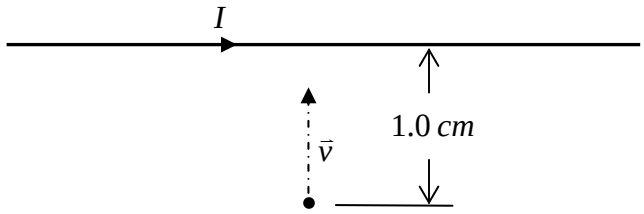
Quiz 4: Chapter 19

Show all your work

An "infinite" straight wire carries a current of $25\ A$ to the right and a proton moves in a direction perpendicular toward the wire at a speed of $3.0\times10^{5}\ m/s$. (a) Determine the magnitude and direction of the wire's magnetic field at the location of the proton. (b) Now find the magnetic force acting on the proton. (c) If the proton has a mass of $1.67\times10^{-27}\ kg$, what is its acceleration at the point shown? The following quantities/formulas may come in handy-dandy:
$e=1.602\times10^{-19}\ C$, $\mu_0=1.256\times10^{-6}\ T\cdot A/m$, $B=\mu_0 I/2\pi r$, $F=qvB\sin\theta$, $F=I\ell B\sin\theta$.



(a) $\vec{B}=(1.256\times10^{-6}\ T\cdot A/m)(25\ A)/[2\pi(0.01\ m)]=\boxed{5\times10^{-4}\ T}$ *into the page.*

(b) $\vec{F}=(1.602\times10^{-19}\ C)(3.0\times10^{5}\ m/s)(5.0\times10^{-4}\ T)=\boxed{2.4\times10^{-17}\ N}$ *to the left.*

(c) $\vec{a}=\vec{F}/m=2.4\times10^{-17}\ N/1.67\times10^{-27}\ kg=\boxed{1.4\times10^{10}\ m/s^2}$ *to the left.*

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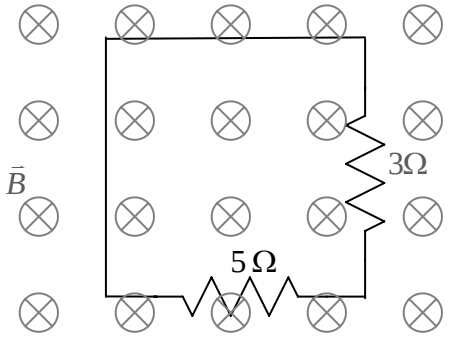
Quiz 5: Chapter 20

Show all your work

(2) A circuit having $5\,\Omega$ and $3\,\Omega$ resistors in series also has a uniform B-field ($2.0\,T$) that points into the page. The loop is a square of side $20\,cm$. (a) If the magnetic field drops to zero in a time of $0.01\,s$, find the average induced EMF in the circuit. (b) Find the magnitude and direction of the current that flows in the circuit due to this EMF. Explain your answer for the direction carefully.



(a) $\varepsilon = -\dfrac{\Delta\Phi_B}{\Delta t} = -\dfrac{0 - 0.08\,T}{0.01\,s} = \boxed{+8.0\,V}$

(b) $I = \varepsilon / R = 8.0\,V / 8.0\,\Omega = \boxed{1.0\,A}$; the current flows CW since the loop area and field point into the page (by the R.H.R.).

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Quiz 6: Chapter 22

Show all your work

NASA scientists on earth are communicating with astronauts who have landed on Mars $2\times10^{11}\ m$ away. (a) What is the absolute minimum time that earth scientists must wait for a response from the astronauts? (b) If the radio signal is sent from earth with an average power of $150\ kW$, what is the average intensity of the signal by the time it arrives at Mars? Assume the transmitter on earth is a point source.

(a) $\Delta t_{min} = 2d/c = 4\times10^{11}\ m/3\times10^{8}\ m/s = \boxed{1{,}333\ s}$

(b) $\bar{I} = \bar{P}/4\pi r^2 = 1.5\times10^{5}\ W/4\pi(2\times10^{11}\ m)^2 = \boxed{3\times10^{-19}\ W/m^2}$

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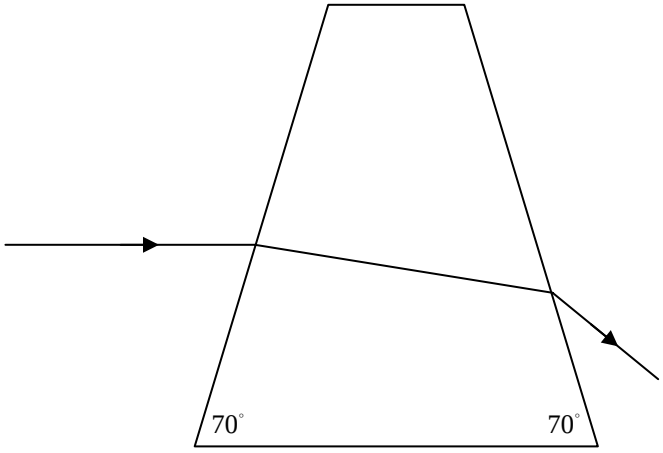
Quiz 7: Chapter 23

Show all your work

Light traveling horizontally in air is incident on an isoceles trapezoid of index 1.4 as shown. At what angle does the ray exit?



The incident angle is $\theta_i = 20^\circ$.

For the 1st refraction we have,

$1\sin 20^\circ = 1.4\sin\theta_{r1}$

$\theta_{r1} = 14.14^\circ$

This ray hits the other side of the trapezoid at an incident angle of $\theta_{i2} = 25.86^\circ$

Thus, for the 2nd refraction we have,

$1.4\sin 25.86^\circ = 1\sin\theta_{r2}$

$\theta_{r2} = \boxed{37.63^\circ}$

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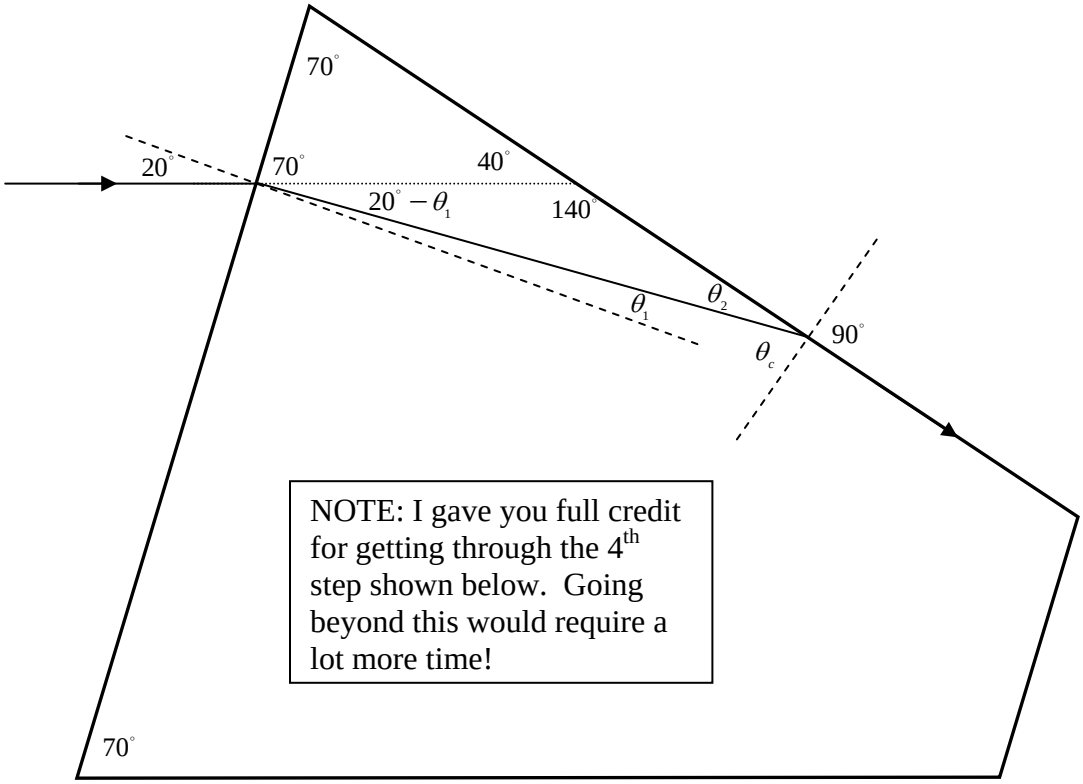
Quiz 7b: Chapter 23

Show all your work

Light traveling horizontally in air is incident on an isoceles trapezoid as shown. What should the index of refraction be so that the light does not exit the prism?



- Snell's law (left side): $1\sin 20^\circ = n\sin\theta_1 \quad \rightarrow \quad n = \sin 20^\circ / \sin\theta_1$ [1]
- Snell's law (right side): $n\sin\theta_c = 1 \quad \rightarrow \quad n = 1/\sin\theta_c$ [2]
- Equate [1] & [2] (since $n = n$): $\sin 20^\circ / \sin\theta_1 = 1/\sin\theta_c \quad \rightarrow \quad \sin\theta_1 = \sin 20^\circ \sin\theta_c$ [3]
- Relate θ_c to θ_1: $\theta_c = 90^\circ - \theta_2$ & $\theta_2 = 20^\circ - \theta_1$. Therefore, $\theta_c = 70^\circ - \theta_1$ and [3] becomes: $\sin\theta_1 = \sin 20^\circ \sin\left(70^\circ - \theta_1\right)$
- Use the identity: $\sin\left(70^\circ - \theta_1\right) = \sin 70^\circ \cos\theta_1 - \cos 70^\circ \sin\theta_1$ to get,
- $\sin\theta_1 = \sin 20^\circ \left[\sin 70^\circ \cos\theta_1 - \cos 70^\circ \sin\theta_1\right]$
- Now divide both sides by $\sin\theta_1$
- $1 = 0.3214\cot\theta_1 - 0.1170 \quad \rightarrow \quad \theta_1 = 16.05^\circ$
- Then use [1] to get the index of refraction: $n = \dfrac{\sin 20^\circ}{\sin\theta_1} = \boxed{1.24}$

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Quiz 8: Chapter 24

Show all your work

When you look at the tiny snail shell of *Potamopyrgus antipodarum* through a converging lens, the $2.0\,mm$–long shell appears to be $7.0\,mm$ long. If the shell and its image have the same orientation and the shell is placed $2.5\,cm$ from the lens, determine (a) the location of the image and (b) the focal length of the lens. (c) Sketch a ray diagram to roughly confirm you calculation. (d) What kind of image it this? Explain.

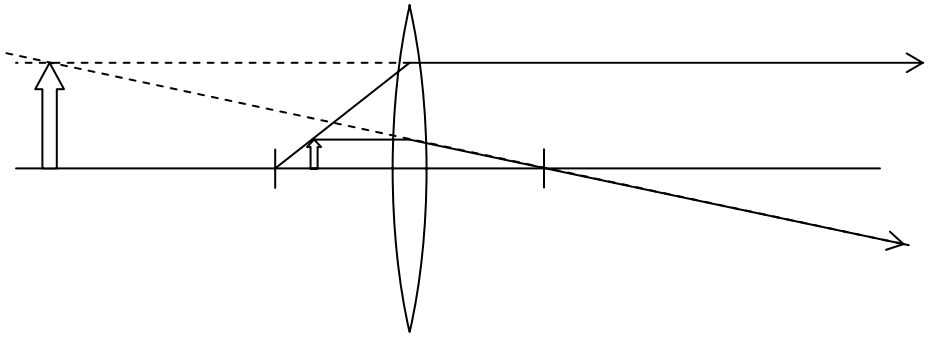
(a) $M = \dfrac{-q}{p} = +3.5 \quad \rightarrow \quad q = -3.5p$

$q = -3.5(2.5\,cm) = -8.75\,cm$

The image appears $8.75\,cm$ *behind the lens, on the same side as the object.*

(b) $\dfrac{1}{2.5} - \dfrac{1}{8.75} = \dfrac{1}{f} \quad \rightarrow \quad \dfrac{1}{f} = 0.2857 \quad f = 3.5\,cm$

(c)



(d) The image is *virtual* because light rays only appear to come from it.

Physics 251 **Name: ANSWER KEY**
Spring 2008 / Dr. Zimmerman
Quiz 9: Chapter 25

Show all your work

Astronomers have discovered a new star, some $570\ ly$ away, in the constellation Orion. However, they suspect that this star may be a binary – two stars closely spaced, orbiting around their center of mass. When viewed in the x-ray part of the spectrum ($\lambda = 20\ nm$) with a $2.5\ m$ – diameter telescope, the astronomers barely resolve that there are indeed two stars. How far apart are they? One light-year (ly) is $9.461\times10^{15}\ m$.

$$\theta_{min} = \frac{1.22\lambda}{D} = 9.76\times10^{-9}\ rad$$

$$s = R\theta = (570\ ly)(9.461\times10^{15}\ m)(9.76\times10^{-9}\ rad) = \boxed{5.26\times10^{10}\ m}$$