PHY294 Exam #3   Nov30.,2006

Name:_____ Student #:_____

Show work for <u>all</u> problems. Include units in answer.

Some physical constants:

$e = 1.6 \times 10^{-19}$ C
$c = 3 \times 10^8$ m/s
$m_p = 1.67 \times 10^{-27}$ kg $= 938$ MeV/c^2

1. What are the two fundamental postulates of the theory of relativity?

    a) the laws of physics are the same in all inertial frames of reference
    b) the speed of light in vacuum is the same in all frames of reference

2. An out-of-control alien spacecraft I diving into a star at a speed of 1×10^8 m/s. At what speed, relative to the spacecraft, is the starlight approaching?

3×10^8 m/s; see b above

3. A rocket traveling at a speed of 0.5c sets out for the nearest star, Alpha Centauri, which is 4.25 light years from the Earth. It returns to the Earth immediately after reaching Alpha Centauri (there was no parking available).

What distance will the rocket travel and how long will the journey last according to (a) stay-at-home earthlings and (b) the rocket crew? Which answers are the correct ones?

Let's do the Earth first. According to an observer on the Earth, the rocket travels 8.50 light years and takes 17 years. (Neglect any time for slowing down or speeding up.)

Let's calculate γ.

$$\gamma = \frac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - .25}} = 1.15$$

$d_{rocket} = d_{earth}/\gamma = 8.5$ light years/$1.15 = 7.39$ light years
$t_{rocket} = \gamma t_{earth} = 17/1.15$ years $= 14.8$ years

The observer on the Earth has no accelerations, so his answers are the correct ones.

4. What is the angle of incidence in air of a light ray whose angle of refraction in glass (n=1.5) is half of the angle of incidence?

Let's think this through. We have the equation
$n_1 \sin \theta_1 = n_2 \sin \theta_2$

Or specifically in this case

$\sin \theta = 1.5 \sin \theta/2$

This won't work for small angles (substitute θ for $\sin \theta$) and it won't work for $\theta/2 > 41.8°$ ($\theta > 83.6°$) since the right hand-side of the equation would be greater than 1. But the angle is near 83.6°, in fact around 83°. Not remembering my trigonometric identities, I just iterated towards the correct answer.

5. Find the focal length of the glass (n=1.5) lens below
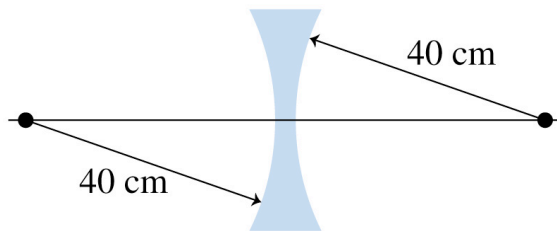
40 cm

40 cm

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$
$$R_1 = -40cm$$
$$R_2 = +40cm$$
$$\frac{1}{f} = (0.5)\left(\frac{1}{-0.4m} - \frac{1}{0.4m}\right)$$
$$\frac{1}{f} = 0.5(-5m^{-1})$$
$$f = -0.40m$$

6. What phenomena of light can be explained by its particle nature? What phenomena of light can be explained by its wave nature? Explain why. (Name at least two for each.)

Particle nature: reflection and refraction
Wave nature: diffraction and interference

7. A concave mirror has a focal length of 40 cm. Determine the object position for which the resulting image is upright and four times the size of the object.

2

3

C F O I

Front   Back
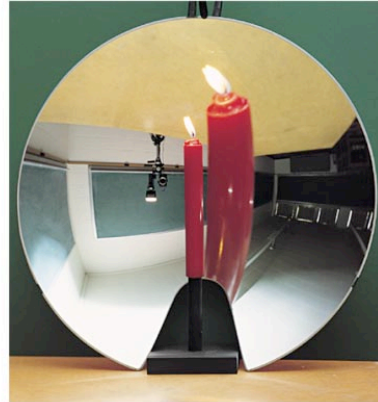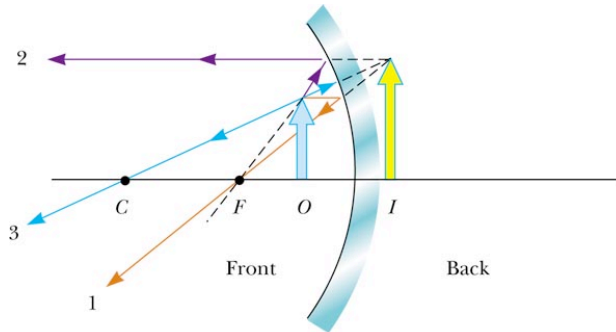
© 2003 Thomson - Brooks Cole   (b)

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$M = -\frac{q}{p} = +4$$

$$q = -4p$$

$$\frac{1}{p} - \frac{1}{4p} = \frac{1}{.4m}$$

$$\frac{4}{4p} - \frac{1}{4p} = \frac{1}{.4m}$$

$$\frac{3}{4p} = 2.5$$

$$p = 0.3$$

$$q = -1.2m$$

image is virtual as implied by negative value of image position
object position is 0.3 m

8. A double slit is illuminated simultaneously with orange light of wavelength 600 nm and light of an unknown wavelength. The m=4 bright fringe of the unknown wavelength overlaps the m=3 bright orange fringe. What is the unknown wavelength?

$d \sin\theta = m\lambda$

$d \sin\theta = 3(600nm) = 1800nm$

$d \sin\theta = 4\lambda = 1800nm$

$\lambda = 450nm$

9. The radius of curvature of the curved side of a plano-convex lens (first surface is a plane) with an index of refraction of n=1.64 is 23 cm. What is the focal length of the lens?

a) **36 cm**
b) -36 cm
c) 15 cm
d) -15 cm
e) infinity

$1/f = (n-1) [1/R_1 - 1/R_2]$
$R_2=infinity$
$R_1=0.23 m$
$f=36 cm$

10. A hydrogen atom and a neutron fuse to form deuterium. If the energy released in the fusion process is 3.6×10^{-13} J, what is the mass of the deuterium? Take the mass of the hydrogen atom as the mass of a proton. Be careful of significant figures.

$m_p=1.6727 \times 10^{-27}$ kg
$m_n=1.6749 \times 10^{-27}$ kg
$m_p + m_n = 3.3476 \times 10^{-27}$ kg

$E=mc^2$; $m=E/c^2=2.6 \times 10^{-13}$ J$/(3 \times 10^8$ m/s$)^2=4 \times 10^{-30}$ J
$m_{deuterium}=3.3476 \times 10^{-27}$ kg $- 0.004 \times 10^{-27}$ kg $= 3.3436 \times 10^{-27}$ kg

11. A proton in a high energy accelerator is given a kinetic energy of 7 TeV (7 trillion electron-volts). What is the value of gamma? What is its speed? (Note: keep all of the digits during the calculation.)

$$\gamma = \frac{1}{\sqrt{1-\beta^2}}$$

$$1-\beta^2 = \frac{1}{\gamma^2} = 1.796 X10^{-8}$$

$$\beta^2 = 0.999999982c$$

$$\beta = 0.999999991c$$

12. A narrow beam of white light is incident on a sheet of quartz. The beam disperses in the quartz, with red light (λ=700 nm) traveling at an angle of 26.3° with respect to the normal and violet light (λ=400 nm) traveling at 25.7°. The index of refraction of quartz for red light is 1.45. What is the index of refraction of quartz for violet light?

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_1 \sin\theta_1 = 1.45 \sin(26.3^o) = 0.642$$

$$n_1 \sin\theta_1 = n_2 \sin(25.7^o) = 0.434 n_2$$

$$n_2 = 1.48$$