Physics 133
Final Exam
1:30 - 3:18 PM, Tuesday, June 6

Spring 2000 2:30 Section

Name (1 pt):_____

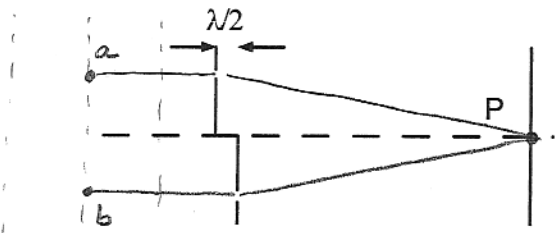
Recitation Instructor (1 pt):_____

This test consists of a total of 9 pages, 7 of problems, an optional question about course format, and an equation sheet.

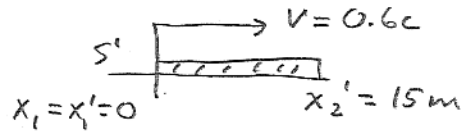
Section I - short problems/questions

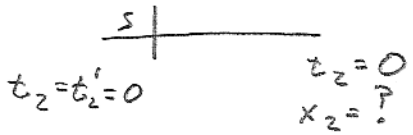
I.1 (10 pts) A double slit experiment is modified as shown in the figure so that one of the slits is $\lambda/2$ farther to the right than the other. At "P", the central location on the screen, is there a maximum or a minimum?
Why? A maximum

The distance (+ phase) from "a" to "P" and "b" to "P" are the same ⇒ in phase + maximum at "P"



I.2 (10 pts): A stick of length $l = 15$ m in the S' frame is moving at $v = 0.6c$ relative to observers in the S frame. How long do observers in the S frame measure the stick to be?





method: make measurement simultaneously in S at $t_1 = t_2 = 0$

$x_2' = \gamma(x_2 - v t_2)$

$15m = 1.25(l_s - 0.6c \cdot 0)$

$\boxed{l_s = \frac{15m}{1.25} = 12m}$

$\gamma = \frac{1}{\sqrt{1-.36}} = 1.25$

I.3 (10 pts): As measured in parsecs, how far away is a star whose parallax is 0.1 arc sec?

$$D(pc) = \frac{1}{\alpha('')} = \frac{1}{0.1''} = 10\,pc$$

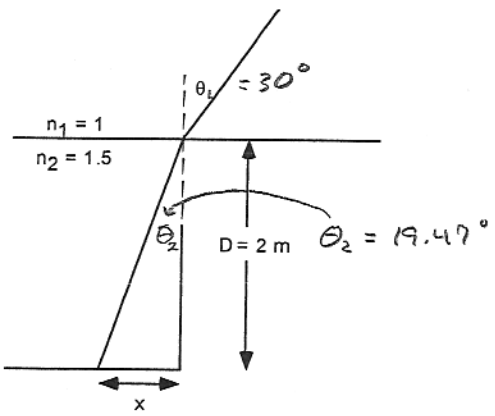
Name (1 pt): _____

I.4 (10 pts) A ray of light is incident on a pool of depth 2 m at an angle of $\theta = 30^0$ from the normal. The liquid in the pool has an index of refraction of $n_2 = 1.5$. As shown in the figure the ray enters the pool at its edge and hits the bottom a distance x from the edge of the pool. What is x?

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

$1 \cdot 0.5 = 1.5 \sin\theta_2$

$\sin\theta_2 = 1/3 \Rightarrow \theta_2 = 19.47$



$\tan\theta_2 = \frac{x}{2m}$

$0.3536 = \frac{x}{2m}$

$x = 0.707\,m$

In the following two multiple choice questions, circle the best answer.

I.5 (10 pts): Most of the deuterium in the universe was created

(a) during the first few minutes after the big bang.
(b) in the era around the time of the launching of the microwave background radiation.
(c) in the interiors of stars like the sun.
(d) in supernova collapses

I.6 (10 pts): Which of the following does NOT significantly effect or predict the future of the universe?

(a) The mass density of the universe
(b) the ratio of iron to magnesium in the universe
(c) The size of the Hubble constant
(d) the abundance of dark matter in the universe

Name (1 pt): _____

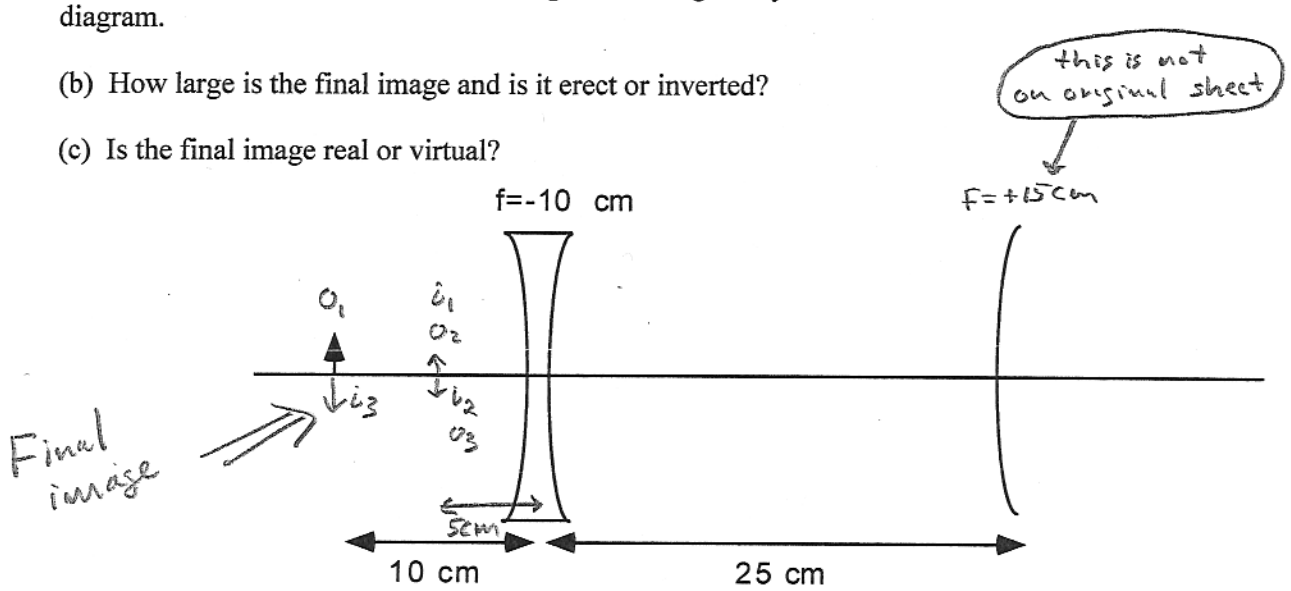
Part II.

II.1 (30 pts) The optical system below consists of a lens on the left and a mirror on the right. The object is erect and has a height of 2 cm. After the light has passed the lens for the second time and exited the system

(a) What is the location of the final image? Unambiguously draw and label this location on the diagram.

(b) How large is the final image and is it erect or inverted?

(c) Is the final image real or virtual?



#1 lens 1st time:

$$\frac{1}{10cm} + \frac{1}{i} = \frac{1}{-10cm} \Rightarrow i = -5cm \Rightarrow m_1 = -\frac{i}{p} = 1/2$$

#2 mirror:

$$\frac{1}{30cm} + \frac{1}{i} = \frac{1}{+15cm}; \quad \frac{1}{i} = \frac{1}{15cm} - \frac{1}{30cm} = \frac{1}{30cm} \Rightarrow i = +30cm \Rightarrow m_2 = \frac{-30}{30} = -1$$

#3 lens again:

$$\frac{1}{-5cm} + \frac{1}{i} = \frac{1}{-10cm}; \quad \frac{1}{i} = \frac{1}{5cm} - \frac{1}{10cm} \Rightarrow i = 10cm \Rightarrow m_3 = -\left(\frac{10}{-5}\right) = +2$$

b) $m = m_1 m_2 m_3$

$= (1/2)(-1)(+2) = -1$

Final size $= (2cm)(-1) = -2cm$

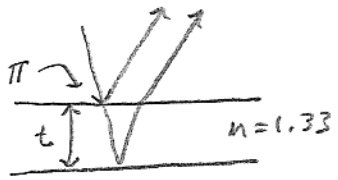
[inverted]

c) real

A3

Name (1 pt): _____

II.2 (25 pts): The reflection of perpendicularly incident white light by a soap film in air has an interference maximum at 600 nm and a minimum at 450 nm, and there are no minimum or maxima between 450 nm and 600 nm. If n = 1.33 for the film, what is the film thickness?



for $\lambda = 600nm$ maximum

for $\lambda = 450nm$ minima

$\lambda_n = \frac{600}{1.33} = 450nm$

$\lambda_n = \frac{450}{1.33} = 338nm$

For maximum

$t = (n + 1/2)\frac{\lambda_n}{2}$, $n = 0, 1, 2 \ldots$ $1/4, 3/4$

For minimum

$t = n\frac{\lambda_n}{2}$, $n = 0, 1, 2 \ldots$ $0\ 1/2\ 1$

while the "n" must be adjacent, they do not need to be the same

equate

$(n+1/2)\frac{450nm}{2} = (n+1)\frac{338nm}{2}$

$n \cdot 450nm + 225nm = n \cdot 338nm + 338nm$

$n \cdot 112nm = 113nm \Rightarrow n = 1$

From max: $t = 3/2\ \frac{450nm}{2} = 337.5nm$ ✓

From min: $t = n+1\ \frac{338nm}{2} = 338nm$ ✓

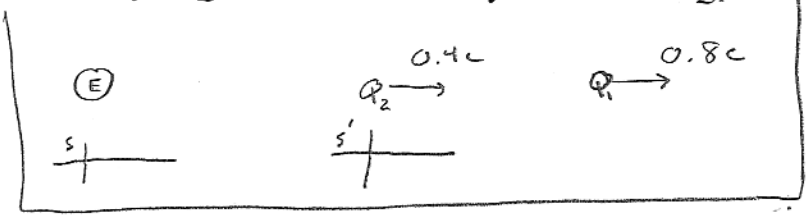
Name (1 pt): _____

II.3 (25 pts): It is concluded from measurements of the light emitted by quasar Q_1 that it is moving away from us at a speed of 0.800*c*. Quasar Q_2, which lies in the same direction in space but is closer to us, is moving away from us at a speed 0.400c.

(a) At what velocity would an observer on Q_1 measure us to be receding?

(b) What velocity for Q_2 would be measured by an observer on Q_1.

a) 0.8c



b) the velocity of Q_1 as observed S: $x = 0.8c\,t$ (u)

relate to S': $x = \gamma(x' + vt') = \gamma(x' + 0.4c\,t')$

$t = \gamma\left(t' + \frac{vx'}{c^2}\right) = \gamma\left(t' + \frac{0.4c\,x'}{c^2}\right)$

substitute:

$$\gamma(x' + vt') = u\gamma\left(t' + \frac{vx'}{c^2}\right)$$

$$= ut' + \frac{uvx'}{c^2}$$

$$t'(v-u) = x'\left(\frac{uv}{c^2} - 1\right)$$

$$u' = \frac{x'}{t'} = \frac{u-v}{1-\frac{uv}{c^2}} = \frac{0.8c - 0.4c}{1 - \frac{(0.8c)(0.4c)}{c^2}}$$

$$= \frac{0.4c}{1-.32} = \frac{0.4c}{.68} = .588c$$

but this is Q_1 as observed by Q_2 (S')

Q_2 as observed by Q_1 is also receding at 0.588c, but as viewed by Q_1, to the left

85

(24-E)

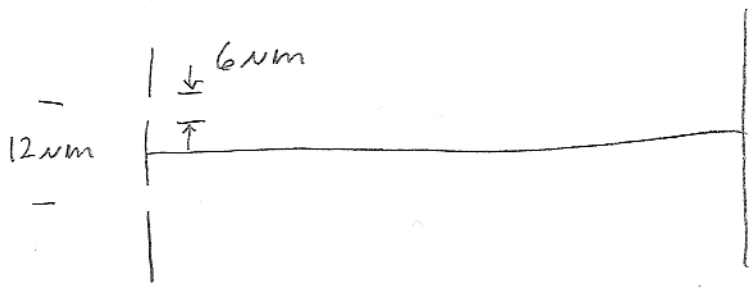
Name (1 pt): _____

II.4 (30 pts): A double slit with slit separation 12 μm and slit width 6 μm is illuminated with light of wavelength $\lambda = 600$ nm.

(a) What is the angular location of the first side maximum in the interference pattern?

(b) What is the angular location of the third side maximum in the interference pattern?

(c) What is the ratio of the light intensities for these two maxima?



For interference pattern: $d \sin\theta = m\lambda$ - max

a) $m=1 \Rightarrow \sin\theta = \frac{\lambda}{d} = \frac{.6\,\mu m}{12\,\mu m} = 0.05 \Rightarrow \theta = 2.866°$

b) $m=3 \Rightarrow \sin\theta = \frac{3\lambda}{d} = \frac{1.8\,\mu m}{12\,\mu m} = 0.15 \Rightarrow \theta = 8.629°$

c) This is determined by the diffraction pattern

$$I = I_m \left(\frac{\sin\alpha}{\alpha}\right)^2 \qquad \alpha = \frac{\pi a}{\lambda}\sin\theta \qquad \frac{\pi a}{\lambda} = \frac{\pi\, 6\,\mu m}{.6\,\mu m} = 10\pi$$

$$I_1 = \cancel{I_m}\left(\frac{\sin[(10\pi)(.05)]}{(10\pi)(.05)}\right)^2 \qquad \sin \pi/2 = +1$$

$$I_2 = \cancel{I_m}\left(\frac{\sin[(10\pi)(.15)]}{(10\pi)(.15)}\right)^2 \qquad \sin\frac{3\pi}{2} = -1$$

$\pi/2$ and $3\pi/2$

$$\frac{I_1}{I_2} = \left(\frac{3\pi/2}{\pi/2}\right)^2 = 9$$

#6

Name (1 pt): _____

II.5 (22 pts): What is the speed of a particle

(a) Whose kinetic energy is equal to three times its rest energy?

(b) Whose total energy is equal to three times its rest energy?
relate to these questions?

a) $K = mc^2(\gamma - 1)$, $K = 3mc^2$

$3 = 1(\gamma - 1)$

$4 = \gamma = \frac{1}{(1 - v^2/c^2)^{1/2}} \Rightarrow$ $16\left(1 - \frac{v^2}{c^2}\right) = 1$

$\frac{15}{16} = \frac{v^2}{c^2}$ $\boxed{v = \sqrt{\frac{15}{16}}\, c}$

b) $E = \gamma mc^2$ $E = 3mc^2$

$3 = \gamma = \frac{1}{(1 - v^2/c^2)^{1/2}} \Rightarrow$ $9\left(1 - \frac{v^2}{c^2}\right) = 1$

$\frac{8}{9} = \frac{v^2}{c^2}$ $\boxed{v = \sqrt{\frac{8}{9}}\, c}$