Physics 262 Fall 2010 Exam 3

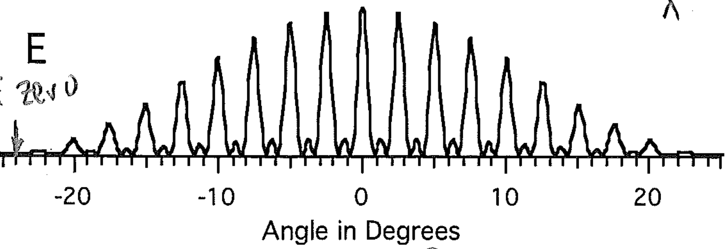
The figure shows an intensity pattern on a distant wall from one or more identical slits, including both diffraction and interference effects. λ=600 nm.

$\phi = 2\pi = \frac{\Delta path}{\lambda} \cdot 2\pi$ so $d \sin\theta = \lambda$

$\theta = 2.5°$

$\rightarrow d = 1.37 \times 10^4$ nm

Diff zero



1] How many slits were used? (Choose 1-9) 3

2&3] What is the slit width, in nanometers? Diff min @ 24° $a \sin\theta = \lambda$ $a = 1475$ nm

4&5] What is the separation between adjacent slits, in nanometers? (Enter 0,0 if there is only 1 slit.)

1.37×10^4 nm

6&7] Two detectors are placed to measure a single slit diffraction pattern; one at the first zero, and one at the central maximum. The middle of the slit is then blocked (from ¼ of the way to ¾ of the way across the slit.) What is the new ratio of the intensity at the central maximum to the intensity *where the first zero of the pattern was.* See below.

8&9] In a microscope, the tube length is typically ~ 100 times the focal length of the objective lens, and so Fraunhofer diffraction can be used for light coming from the sample. For a microscope objective with a radius of 5 mm, in a microscope with a tube length of 20 cm, what is the radius of the Airy pattern from a point microscopic source (like, e.g. a "quantum dot")? Answer in microns. λ = 500 nm

10&11] If the focal length of the objective lens is 2 mm, how large (in radius) does this point source appear to be? Answer in nanometers.

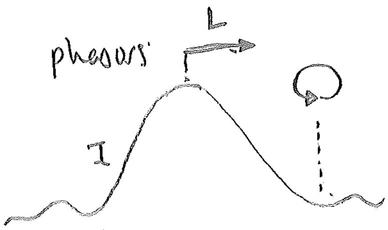
Alice and Bob are having a swimming contest. Alice is going to swim straight across the river (1000 m) and back; Bob is going to swim 1000 m up the river and back. They both swim the crawl at 1 stroke per second, and in still water they swim 2 m/s. The speed of the river is 1 m/s.

12&13] How long (in seconds) does it take Bob to swim the race?

14&15] How long (in seconds) does it take Alice to swim the race?

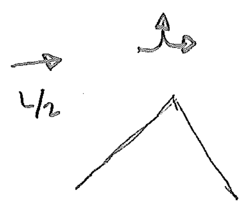
16] Who takes fewer strokes (i.e. wins the race?) **a) Alice** b) Bob c) they tie

6&7



After blocking

phasors.

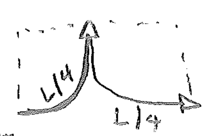


E field ratio $= \frac{L/2}{L/\pi} = \pi/2$

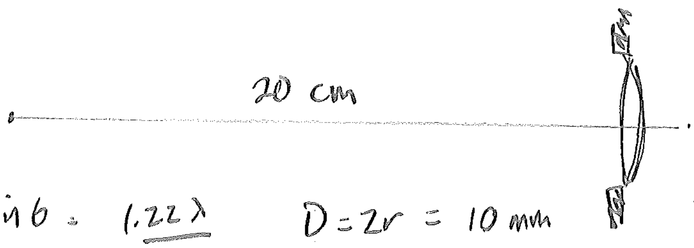
I ratio $= \pi^2/4 = 2.467$.

$\frac{2\pi r}{4} = \frac{L}{4}$

$r = L/2\pi$



8&9]



$\sin\theta = \frac{1.22\lambda}{D}$ $D = 2r = 10$ mm
$\lambda = 500$ nm

$= 6.1\times10^{-5}$ first zero of airy disk

At a distance of 20 cm, this makes a spot

$R_{spot} = 20 \cdot 6.1\times10^{-5}$ (cm) $= 1.22\times10^{-3}$ cm $= 12.2\ \mu m$.

10 & 11] With $f_{obj} = 2$ mm, Mag $\approx \frac{20\text{ cm}}{2\text{ mm}} = 100$

So apparent dot size $= \frac{12.2\ \mu m}{100} = 122$ nm.

12 & 13] Bob $V_u = 1$ m/s $t_u = \frac{d}{V_u} = \frac{1000}{1} = 1000$ s.

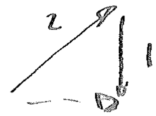
$V_D = 3$ m/s. $t_d = \frac{d}{V_d} = \frac{1000}{3} = 333$ s.

total time = 1333 sec.

14 & 15) Alice

$V = \sqrt{2^2 - 1^2}$ $t = \frac{2d}{V} = \frac{2000}{\sqrt{3}} = 1155$ sec.

$= \sqrt{3}$



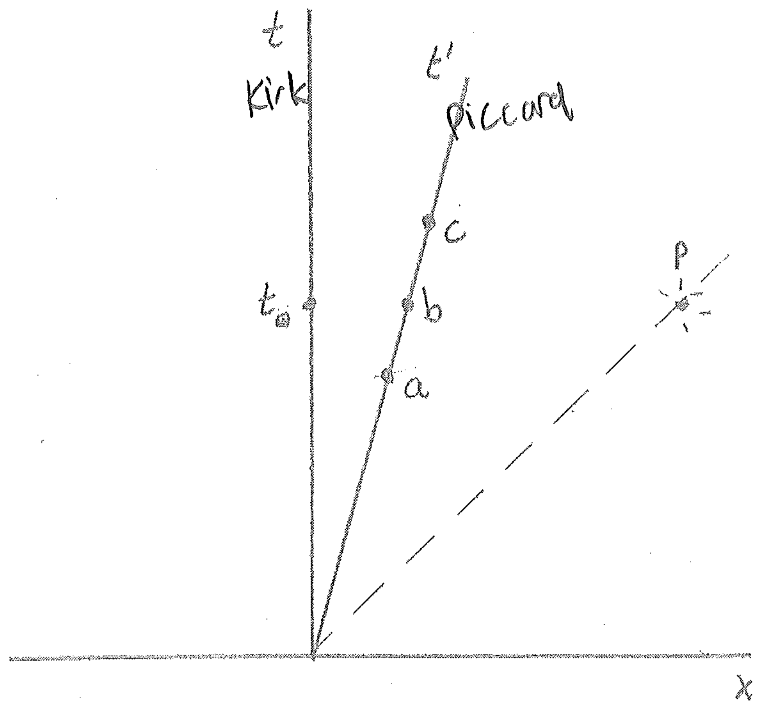
A spacetime diagram is shown. The t' axis is the worldline for a spaceship. When the spaceship leaves the earth, a photon torpedo (traveling at the speed of light, of course) is launched from the earth and hits a Klingon ship at event p. According to Captain Kirk (who has retired and stayed on earth doing Priceline commercials), the Klingon ship was hit at time t_0.

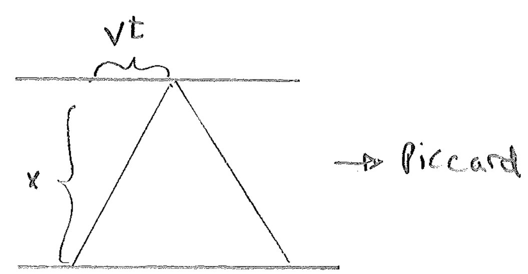
17] According to Gallilean relativity, at what point on the t' axis would Captain Piccard judge the Klingon ship to have been hit? (b)

18] According to Einstein's relativity, at what point on the t' axis would Captain Piccard judge the Klingon ship to have been hit? (a)

19] The previous questions have dealt with how to read a spacetime diagram. But we also must be concerned with how to calibrate a spacetime diagram. Taking into account the calibration, does Piccard's clock show (a) more elapsed time (b) less elapsed time or (c) the same elapsed time as Kirk's when the Klingon ship is hit?

20&21] More about calibration: if Piccard is moving at 1/3 the speed of light, and $t_0 = 900$ s, use a light clock to figure out what Piccard's clock reads (according to Kirk) when Kirk's clock reads 900 s.





when $t_{kirk} = \frac{\sqrt{x^2 + v^2 t_{kirk}^2}}{c}$ $\quad t_{pic} = \frac{x}{c}$

$$\frac{t_P}{t_K} = \sqrt{1 - v^2/c^2} = \sqrt{1 - 1/9} = 0.943$$

$t_P = 848$ s.

note: this is point b on line t'.