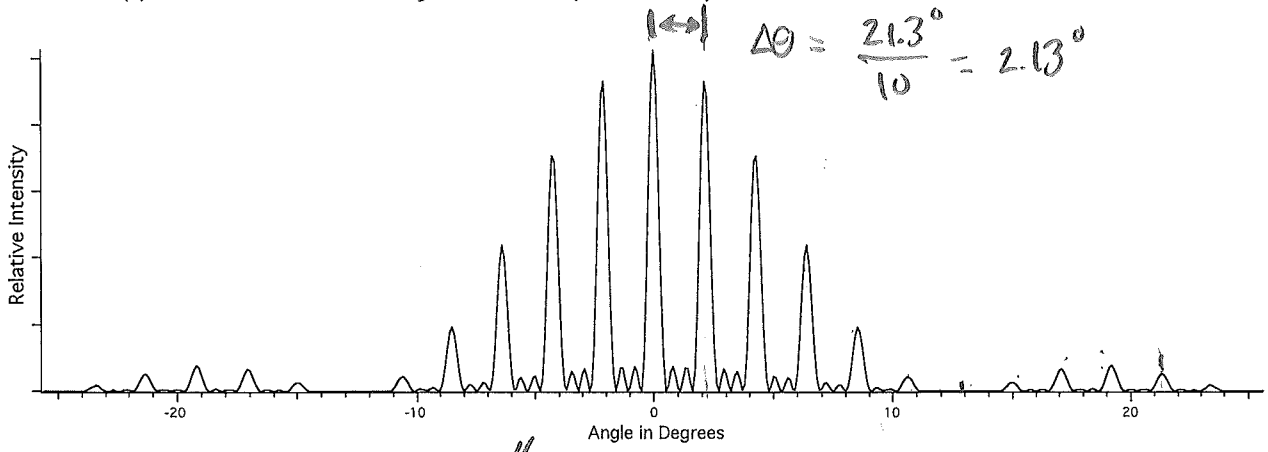
Physics 262 Fall 2010 Exam 3 Solutions

Useful equations

$\phi = \frac{\Delta path}{\lambda} \cdot 2\pi$ $\quad d\sin\theta = m\lambda$ $\quad a\sin\theta = m'\lambda$ $\quad \sin\theta = 1.22\lambda/D$

The figure shows an intensity pattern on a distant wall from one or more identical slits, including both diffraction and interference effects. λ=500 nm. The angle is the angle away from the central maximum, as seen from the slit(s). A coherent source of plane waves (like a laser) was used to illuminate the slits.




$\Delta\theta = \frac{21.3^\circ}{10} = 2.13^\circ$

1] How many slits were used? (Choose 1-9) 4

2&3] What is the slit width, in nanometers? $a\sin\theta = \lambda \quad \theta = 13^\circ \quad a = 2223$ nm

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

$d\sin\theta = \lambda \quad d = 13453$ nm

---

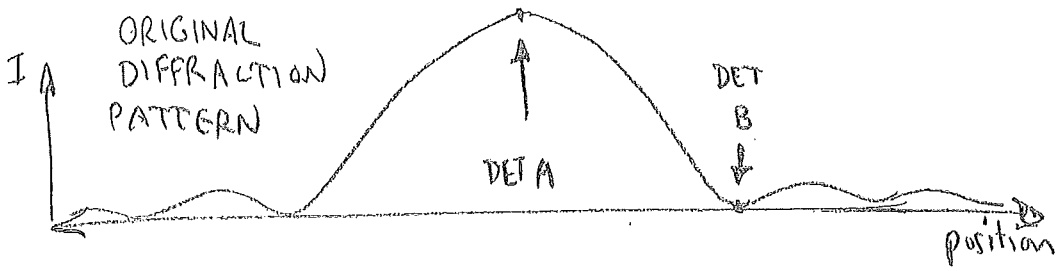
6&7] Two detectors are placed to measure a single slit diffraction pattern; one at the first zero (**B**), and one at the central maximum (**A**). A quarter of the slit is then blocked: from ¼ of the way to ½ of the way across the slit.


What is the ratio of the intensity of **the original (unblocked) central maximum** to the intensity now read by the detector that was originally at the side zero (**B**)?

$E_{cm,0}/E = 2\pi/\sqrt{2} \quad I_{cm}/I = (E_{cm}/E)^2 = 4\pi^2/2 = 19.7$

8] To the nearest 10%, how much of the slit should you block if you want the maximum intensity in detector B?

A] 0%
B] 10%
C] 20%
D] 30%
E] 40%
F] 50% leaves max.
G] 60%
H] 70% phasor sum ($\propto 2r$)
I] 80%
J] 90%



You wish to design a camera for a spy plane that will allow you to read license plates from 30 km up. To achieve this, you need 1 cm resolution, i.e. a point source must give an Airy disk with an apparent radius of 1 cm (out to the first zero of the Airy pattern).

(In other words, on the film, the Airy pattern from a point source on the ground will have a very small radius… but given the magnification of the lens, this Airy pattern should correspond to a 1 cm radius spot on the ground.)

9] If the lens has a focal length of 3 m, what is the radius *on the film* of the image of a 1 cm radius spot on the ground, *ignoring diffraction effects.*

$\frac{S_i}{S_o} = \frac{S'}{S} = \frac{3}{3\times10^4}$ $S \approx f$

$S_i = 1\text{cm} \times 10^{-4}$

$= 10^{-6}\,m = 1\mu m$

A] 1 nm
B] 10 nm
C] 100 nm
(D] 1 μm
E] 10 μm
F] 100 μm
G] 1 mm
H] 10 mm
I] 100 mm

10&11] What is the diameter of the camera lens, **in cm**, that gives an Airy disk of this size on the film? $\lambda = 500\,nm$

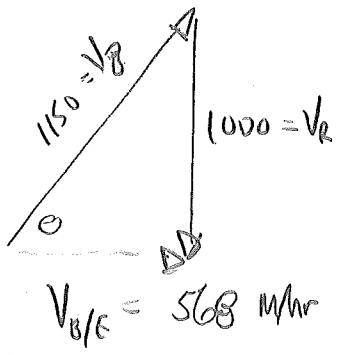
Angle subtended by disk $= 1\mu m/3m = 0.33\times10^{-6} = \sin\theta = \frac{1.22\lambda}{D}$ $D = 183$ cm.

**Galilean Relativity.**

12] Bob wishes to swim straight across a river that is 1000 m wide. He swims at 1150 m/hr in still water; the river flows with a uniform speed of 1000 m/hr. What angle should he aim upstream (to the nearest 10°)

A] 10°
B] 20°
C] 30°
D] 40°
E] 50°
(F] 60°
G] 70°
H] 80°

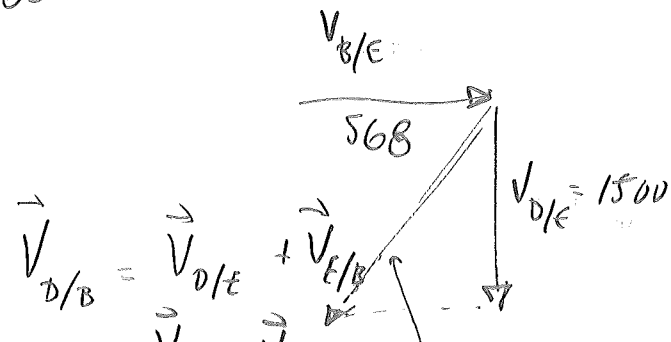
13&14] A duck is swimming downstream at 1500 m/hr (relative to the earth.) What is the *speed of the duck,* relative to Bob? (in m/s) 1604 m/hr $\rightarrow 2\times10^3$




$V_{B/E} = 568$ m/hr

$\sin\theta = \frac{1000}{1150}$

$\theta = 60^\circ$




$\vec{V}_{D/B} = \vec{V}_{D/E} + \vec{V}_{E/B}$

$= \vec{V}_{D/E} - \vec{V}_{B/E}$

$|\vec{V}_{D/B}| = \sqrt{1500^2 + 568^2}$

$= 1604$ m/hr.

**Einstein's Relativity**

A spacetime diagram is shown. The t' axis is the worldline for a spaceship, the t axis is for the earth. The axes are calibrated in light-years, each hashmark is one light year.

$V_s = \frac{3}{5}c$

15] What is the speed of the spaceship, divided by c? (To the nearest $1/10^{th}$)

A] 0
B] 0.1
C] 0.2
D] 0.3
E] 0.4
F] 0.5
G] 0.6
H] 0.7
I] 0.8
J] 0.9

16] What time, according to the spaceman, does event A occur (to the nearest year after the ship passes the earth?) 4 years.

17] According to the spaceman, which event occurs first, A or B?

18] Of course, we can only learn about an event by receiving a signal (like a flash of light) telling us the event has occurred. We **infer** when events actually occurred by taking into account light travel time.
If flashes of light accompany the events A and B, which flash of light will the spaceman **see** first?

19] According to the earth observer, at the time of event A, does the spaceman's clock show **more** or **less** elapsed time (since t=0) than his own clock? A] more B] less C] same elapsed time

20] According to the spaceman, at the time of event A, does the earth clock show **more** or **less** elapsed time (since t=0) than his own clock? A] more B] less C] same elapsed time