Solutions

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Student Number

UNIVERSITY OF CALIFORNIA AT BERKELEY
DEPARTMENT OF PHYSICS
PHYSICS 7C
FALL SEMESTER 2008
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First Midterm Examination October 2, 2008

This examination is closed book. You may refer to a single $8\frac{1}{2}\times 11$ sheet of paper (both sides) that you have prepared.

Work all problems.

1	__________	/20
2	__________	/20
3	__________	/20
4	__________	/20
5	__________	/20
Total	__________	/100

1. A plane light wave of frequency ω and wave number k (k = 2π/λ), propagating in the positive z direction.

   a. If the electric field is in the $\hat{X}$ direction with amplitude $\mathbf{E_0}$ what is the direction of the magnetic field?

   b. If the amplitude of the electric field is 30 volts/m what is the amplitude of the magnetic field?

   c. What is the average value of the energy flux striking a disk of radius 2 m?

   d. If the wave is reflected, what is the average force on the disk?

a. B is in the $\hat{y}$ direction.

b. $\mathbf{B} = \frac{\mathbf{E}}{c}, \quad B = \frac{30}{3\times 10^8} = 10^{-7}\,Tesla\,.$

c. $\langle \mathbf{S} \rangle = \left\langle \frac{\mathbf{E}\times\mathbf{B}}{\mu_0} \right\rangle = \frac{1}{2}\sqrt{\frac{\varepsilon_0}{\mu_0}}\mathbf{E}^2 = \frac{1}{2}\frac{1}{377}30^2 = 1.19 W/m^2$

   Average power flux striking the disk = $4\pi \times \langle \mathbf{S} \rangle = 15$ Watts

d. The average pressure is $2\frac{\langle \mathbf{S} \rangle}{c}$. The total force is Pressure X area $= \frac{2\times 15}{3\times 10^8} = 10^{-7} N$

2. The index of refraction of water is ~ 1.3 for radiation in the visible range. For microwaves it is 9!

a. For microwaves passing from the water into air, find the critical angle of reflection.

b. What does this mean for radio transmission from a submarine? Explain.
Note: The salt water is a fairly good conductor and will also play a major role. You may ignore this effect.

c. What is Brewster's angle for the microwaves exiting the water into the air?

d. If a submarine tries to communicate by sending microwave radiation through the surface, over what angular range should the radiation be sent? (That is, with respect to the normal to the surface.)

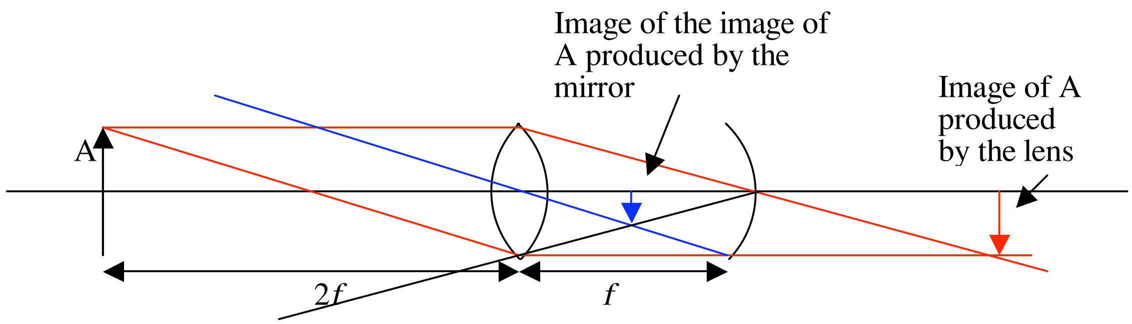
a. $\sin\theta_c = \dfrac{n_2}{n_1} = \dfrac{1}{9},\ \theta_c = 6.38^o$

b. The only waves that can exit the water are those in a narrow cone perpendicular to the surface. This radiation is spread over the full hemisphere above the water.

c. $\tan\theta_B = \dfrac{n_2}{n_1} = \dfrac{1}{9} = 6.34^o$

d. With the narrow cone described in b. most of the power is totally reflected from the surface and then absorbed either by the water or by the ocean bottom.

3.



A thin lens and a concave mirror each with a focal length f are placed as shown. An object is placed at "A", a distance $2f$ from the lens.

a. Draw a ray diagram.

b. Find the image with respect to the mirror.

c. Is it real or virtual? Explain

d. Find the magnification.

a. See above.

b. One way by the geometry of the ray diagram. The image is $\frac{f}{2}$ from the mirror.

Or by calculation the image produced by the lens may be found from: $\frac{1}{d_I} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{f} - \frac{1}{2f} = \frac{1}{f} \quad \therefore \; d_I = 2f$

This it is the object for the mirror and it is at an object distance of - f.
So the mirror produces an image at a distance given by:

$\frac{1}{d_I} = \frac{1}{f} - \left(\frac{1}{-f}\right) = \frac{2}{f} \quad \therefore \; d_I = \frac{f}{2}$ It is positive so it is in front of the mirror.

c. The image is real as light rays from the object converge directly at the image.

d. As with b. above it may be read directly from the geometry of the ray diagram as -1/2.

Or it may be calculated from the magnification of the first image is $m_1 = -\frac{d_0}{d_I} = -\frac{2f}{2f} = -1$

And the magnification of the second image is $m_2 = -\frac{d_I}{d_0} = -\left(\frac{\frac{f}{2}}{-f}\right) = \frac{1}{2}$.

So the total magnification is: $m = m_1 m_2 = -1 \times \frac{1}{2} = -\frac{1}{2}$.

4. Two Physics grad students were talking and as usual they were trying to out do each other. Joe said that yesterday he had run across the Golden Gate Bridge. Well Jim wanted to brag about his new binoculars. He said "I was on the roof of LeConte Hall and saw you with my brand new 7X50 binoculars. I know it was you because I could see the old Cal shirt you always wear when you go jogging."

The 50 in 7 X 50 means the binoculars have a 50 mm objective lens. The Golden Gate Bridge is about 18km from LeConte hall. The "*Cal*" on the shirt is about 10 cm high. You may assume 500 nm for the wavelength of the light. Neglect the distortion from temperature variations in the atmosphere.

a. In a few words, what is the physics that might limit the ability to have a clear enough image to recognize a person or the script?

b. Could Jim have seen an adult person with his binoculars?

c. Could he have read the Cal on the shirt?

a. The circular aperture of the objective lens diffracts the incoming light through an angle $\Delta\theta = \dfrac{1.22\lambda}{D}$ where: D is the diameter of the aperture. This produces a smearing of the image thus rendering details smaller than this impossible to see.

b. For these binoculars $\Delta\theta = \dfrac{1.22 \times 500 \times 10^{-9}}{50 \times 10^{-3}} = 1.22 \times 10^{-5}$ rad

Thus, the size of the smearing at the bridge is $\Delta\ell = \Delta\theta \times 18km = 1.22 \times 10^{-5} \times 18 \times 10^{3} = 0.22m$

A person is of size of the order of 1 to 2 m. Thus, they should be detectable.

c. The "*Cal*" is smaller than the 22 cm above so would not be resolved.

5. A pinhole 0.5 mm diameter is used as a source for a double-slit interference experiment. A sodium lamp (λ = 590 nm) is used. If the distance from the source to the double-slit is 0.5 m, what is the maximum slit spacing such that interference fringes are just observable?

The diffraction spreads the light by an angle $\Delta\theta = \frac{1.22\lambda}{D}$ as in problem 4. In this case, it must be spread by over a large enough area to send coherent light to each slit.

$$\Delta\theta = \frac{1.22 \times 590 \times 10^{-9}}{.5 \times 10^{-3}} = 1.44 \times 10^{-3} rad$$

The spread at the double-slit screen is = $1.44 \times 10^{-3} \times 0.5m = 7.2 \times 10^{-4} m$, or 0.7mm

The slits will need to be closer together that 1.4 mm