Midterm Exam No. 03 (2014 Summer)

PHYS 203B: College Physics

Date: 2014 Jul 18

Solutions

(Name) (Signature)

1. (**10 points.**) The maximum strength (amplitude) of the magnetic field in an electromagnetic wave is $3.3 \times 10^{-6}\,\mathrm{T}$. What is the maximum strength of the wave's electric field?

2. (**10 points.**) A distant galaxy emits light that has a wavelength of 500.7 nm. On Earth, the wavelength of this light is measured to be 503.7 nm.

   (a) Is the galaxy approaching or receding from the Earth?

   (b) Determine the speed of the galaxy relative to the earth.

3. (**10 points.**) Figure 1 shows three polarizers in series. The angles θ_A, θ_B, and θ_C, represent the angles the respective transmission axis of the polarizers A, B, and C, makes with the vertical. Consider a beam of unpolarized light of intensity I_0 incident on the polarizer A. (Express your answers in terms of I_0.)

   (a) What is the intensity of the transmitted beam after it passes the polarizer A and before it passes polarizer B?

   (b) What is the intensity of the transmitted beam after it passes the polarizer B and before it passes polarizer C?

   (c) What is the intensity of the transmitted beam after it passes the polarizer C?

   (d) In the absence of polarizer B, what is the intensity of the transmitted beam after it passes the polarizer C?

4. (**10 points.**) A 2.0 cm object is placed upright at a distance 18.0 cm away from a concave mirror. The mirror's radius of curvature is 20.0 cm.

   (a) Calculate the image distance.

   (b) What is the magnification?

   (c) Is the image real or virtual?

   (d) Is the image inverted or upright?

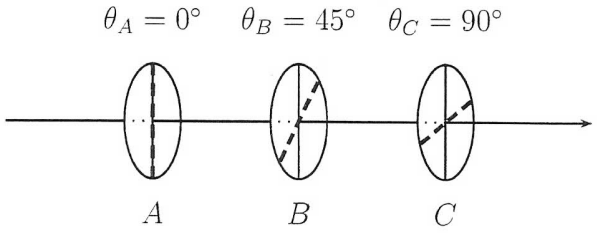


Figure 1: Problem 3

5. **(10 points.)** A ray of light has an angle of incidence of 34.0° on a block of quartz in air and an angle of refraction of 21.0°.

   (a) What is the index of refraction for this block of quartz?

   (b) What is the speed of light in the block of quartz?

6. **(10 points.)** The index of refraction of benzene is 1.80. The critical angle for total internal reflection, at a benzene-air interface, is about:

   (a) 56

   (b) 47

   (c) 34

   (d) 22

   (e) 18

7. **(10 points.)** A stone held just beneath the surface of a swimming pool is released and sinks to the bottom at a constant speed of 0.387 m/s. What is the apparent speed of the stone, as viewed from directly above by an observer who is in air? Refractive index of water in the pool is 1.33.

8. **(10 points.)** Two identical containers, one filled with water ($n = 1.33$) and the other with benzene ($n = 1.50$) are viewed from directly above. Which container (if either) appears to have a greater depth of fluid?

9. **(10 points.)** A 2.0 cm object is placed upright at a distance 12.0 cm away from the center of a concave lens (diverging lens). The magnitude of lens' focal length is 5.0 cm.

   (a) Calculate the image distance.

   (b) What is the magnification?

   (c) Is the image real or virtual?

   (d) Is the image inverted or upright?

   (e) What is height of the image?

(f) Confirm your above results by drawing a ray diagram for the above case. Points will be awarded for precision.

10. (**10 points.**) Qualitatively describe the optical phenomenon involved in the formation of a rainbow. Is the rainbow a real or a virtual image?

MTE-03, Prob 1

$$\epsilon_0 E^2 = \frac{1}{\mu_0} B^2$$

$$\Rightarrow \quad E^2 = c^2 B^2$$

$$\Rightarrow \quad E = cB = 3\times 10^8 \times 3.3\times 10^{-6}$$

$$= 990 \ \frac{N}{C}$$

MTE-03, Prob 2

$$f' = f\left(1 \pm \frac{V_{rel}}{c}\right)$$

$$\frac{1}{\lambda'} = \frac{1}{\lambda}\left(1 \pm \frac{V_{rel}}{c}\right)$$

$$\frac{1}{\lambda'} - \frac{1}{\lambda} = \frac{1}{\lambda}\,\frac{V_{rel}}{c}$$

$$\frac{V_{rel}}{c} = \frac{\lambda - \lambda'}{\lambda'} = \frac{500.7 - 503.7}{503.7}$$

$$V_{rel} = 1.79 \times 10^6 \ \frac{m}{s}$$

(a) wavelength increases.
⇒ frequency decreases.
⇒ galaxy is receding.

MTE-03, Prob 3

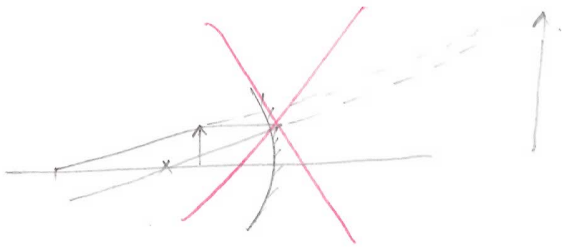
(a) $I_A = \frac{I_0}{2}$

(b) $I_B = I_A \cos^2(\theta_B - \theta_A)$
$= I_A \cos^2 45 = I_A \frac{1}{2} = \frac{1}{4} I_0$

(c) $I_C = I_B \cos^2(\theta_C - \theta_B)$
$= I_B \cos^2 45 = I_B \frac{1}{2} = \frac{1}{8} I_0$

(d) $I_C = I_A \cos^2(\theta_C - \theta_A)$
$= I_A \cos^2 90 = 0.$

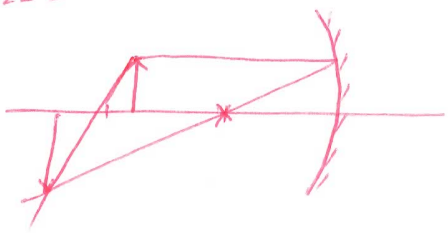
MTE-03, Prob 4



(a) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

$\frac{1}{18.0} + \frac{1}{d_i} = \frac{1}{10}$

$\frac{1}{d_i} = \frac{1}{10} - \frac{1}{18} \Rightarrow$ $d_i = +22.5$ cm



(b) $m = -\frac{d_i}{d_o} = -\frac{+22.5\text{ cm}}{(18\text{ cm})} = +1.25$

(c) real

(d) inverted

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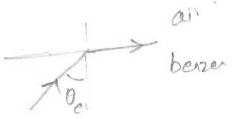
MTE-03, Prob 5

(a) $1 \sin 34 = n \sin 21 \Rightarrow n = 1.56$

(b) $n = \frac{c}{v}$ $\quad v = \frac{c}{n} = \frac{3\times10^8}{1.56} = 1.92\times10^8 \ \frac{m}{s}$

MTE-03, Prob 6



$n_b \sin\theta_c = 1 \times \sin 90°$

$\theta_c = \sin^{-1}\left(\frac{1}{1.8}\right) = 33.75° \rightarrow 34°$

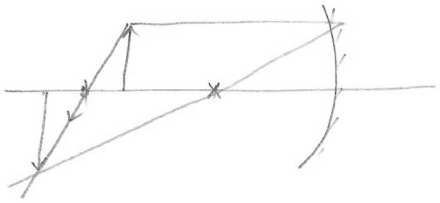
MTE-03, Prob 4

(a) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

$\frac{1}{18.0} + \frac{1}{d_i} = \frac{1}{10}$

$\frac{1}{d_i} = \frac{1}{10} - \frac{1}{18}$

$= \frac{18 - 10}{10 \times 18} = \frac{8}{180} \Rightarrow d_i = 22.5\,cm$

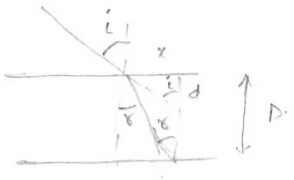


(b) $m = -\frac{d_i}{d_o} = -\frac{22.5\,cm}{18\,cm} = -1.25$

(c) real

(d) inverted

MTE-03, Prob. 7



for small angle.

$$\sin i \approx \tan i = \frac{x}{d}$$

$$\sin r \approx \tan r = \frac{x}{D}$$

$$1 \times \sin i = n_w \sin r$$

$$d \sin i = D \sin r$$

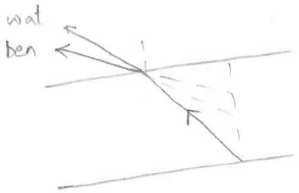
$$\frac{d}{t} = \frac{D}{t} \frac{1}{n_w}$$

$$V_{apparent} = V_{real} \frac{1}{n_w}$$

$$= 0.387 \frac{1}{1.33}$$

$$= 0.291 \frac{m}{s}$$

MTE-03, Prob 8

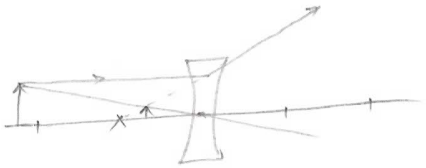


Using earlier problem,

$$d = D \frac{1}{n}$$

So, the container with water will appear deeper, because $n_w < n_b$.

MTE-03, Prob 9



(a) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

$\frac{1}{12} + \frac{1}{d_i} = -\frac{1}{5}$

$\frac{1}{d_i} = -\frac{1}{5} - \frac{1}{12} \Rightarrow d_i = -3.53\,cm.$

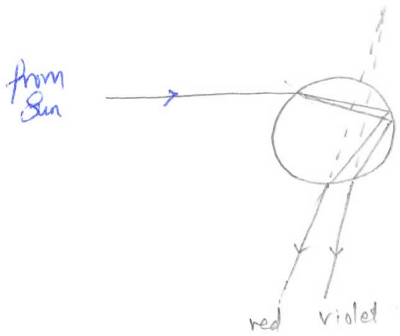
(b) $m = -\frac{d_i}{d_o} = -\frac{(-3.53cm)}{12\,cm} = +0.29$

(c) virtual

(d) upright

(e) $h_i = m h_o = 0.29 \times 2\,cm = 0.58\,cm$

MTE-03, Prob 10



Rainbow is a virtual image.