Physics 114 – Practice Test Solutions for Midterm 3
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Conceptual Question 1:

(a) Does light traveling from one medium to another always bend toward the normal?
(b) As light travels across the interface between two media, does its frequency change?
(c) Its wavelength?
(d) Its velocity?

Explain your answers.

(a) Not necessarily. If the index of refraction of the second medium is smaller than the first medium, then the ray bends away from the normal.
(b) No, the frequency is proportional to the energy of the wave. Since there is no energy loss during the passage from one medium to another, frequency remains constant.
(c) Yes, the wavelength is the ratio of the speed of light to its frequency. Since the frequency is constant and the speed changes, wavelength also changes.
(d) Yes. Light propagates in a medium by being constantly absorbed and emitted by the atoms that make up the medium. This slows the wave down and reduces its speed compared to vacuum.

Conceptual Question 2:

A thin converging lens is used to form a real image of a nearby object. If the object is moved closer to the lens, a new real image is observed. Does the new image differ from the old one (*a*) in position relative to the lens, (*b*) in size? If it does, describe how.

As the object distance decreases, the image distance must increase. Therefore the new image is formed further away from the lens. Since the magnification is the ratio of the image distance to object distance, the magnification will increase and the new image will be larger than the old one.

Problem 1:

In SI units, the electric field in an electromagnetic wave is described by the following equation. $E_y = (100\,V/m)\sin(1.00\times10^7\,x - \omega t)$

(a) Find the amplitude of the corresponding magnetic field oscillations.
(b) Find the wavelength λ.
(c) Find the frequency f.
(d) What is the intensity of the wave?

(a) $$B_{\max} = \frac{E_{\max}}{c} = \frac{100\,V/m}{3\times10^8\,m/s} = 3.33\times10^{-7}\,T$$

(b) $$\lambda = \frac{2\pi}{k} = \frac{2\pi}{10^7\,m^{-1}} = 6.28\times10^{-7}\,m$$

(c) $$f = \frac{c}{\lambda} = \frac{3\times10^8\,m/s}{6.28\times10^{-7}\,m} = 4.78\times10^{14}\,Hz$$

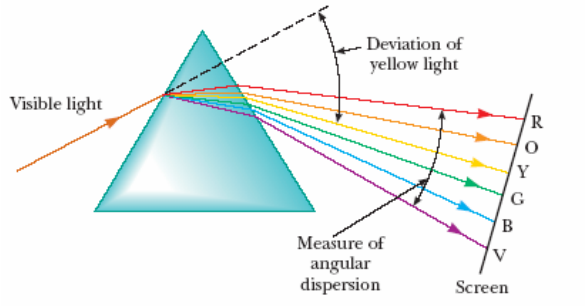
(d) $$I = \frac{E_{\max}B_{\max}}{2\mu_0} = \frac{(100\,V/m)(3.33\times10^{-7}\,T)}{2(4\pi\times10^{-7}\,Tm/A)} = 13.25\,W/m^2$$

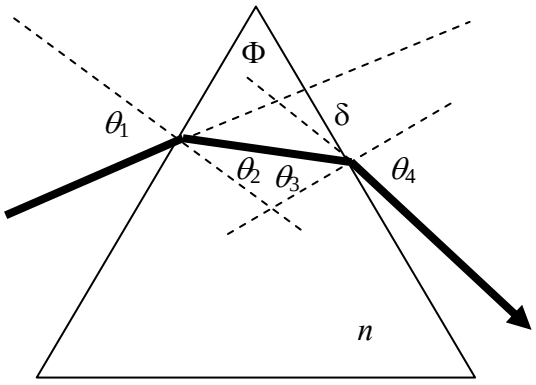
Problem 2:

The index of refraction for violet light in silica flint glass is 1.66 and that for red light is 1.62.

(a) What is the angular dispersion of visible light passing through a prism of apex angle 60.0° if the angle of incidence is 50°?

(b) Prove that violet light will undergo total internal refraction at the second surface if the angle of incidence is 39°.





$\sin\theta_1 = n\sin\theta_2$ then, $\theta_2 = \arcsin\left(\dfrac{\sin\theta_1}{n}\right)$

$\theta_3 = \Phi - \theta_2$ and, $\sin\theta_4 = n\sin\theta_3$.

Therefore, $\theta_4 = \arcsin(n\sin\theta_3)$

For violet light, $n = 1.66$. Then,

$\theta_2 = \arcsin\left(\dfrac{\sin 50°}{1.66}\right) = 27.5°$,

$\theta_3 = 60° - 27.5° = 32.5°$ and,

$\theta_4 = \arcsin(1.66\sin 32.5°) = 63.1°$

For red light, $n = 1.62$.

Then, $\theta_2 = \arcsin\left(\dfrac{\sin 50°}{1.62}\right) = 28.2°$, $\theta_3 = 60° - 28.2° = 31.8°$ and,

$\theta_4 = \arcsin(1.66\sin 31.8°) = 58.6°$

$\boxed{\Delta\delta = 63.1° - 58.6° = 4.5°}$

Problem 3:

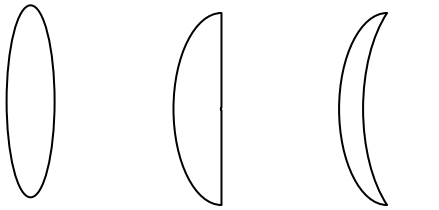
Design a lens that produces a virtual image which is double the size of an object 10 cm away. The lens should be made of crown glass (n = 1.515). Make a sketch of the lens. Your design should indicate the radii of curvature of the two faces of the lens (there is no unique answer to this question).

Virtual image: $q < 0$, $M = -\dfrac{q}{p} = -\dfrac{q}{10cm} = 2$. Then, $q = -20cm$

$\dfrac{1}{p} + \dfrac{1}{q} = \dfrac{1}{10cm} + \dfrac{1}{-20cm} = \dfrac{1}{20cm} = \dfrac{1}{f}$. Then, $f = 20cm$.

Also, $\dfrac{1}{f} = (n-1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$.

$\boxed{\dfrac{1}{R_1} - \dfrac{1}{R_2} = \dfrac{1}{20(1.515-1)} = \dfrac{1}{10.3cm}}$.



R_1 = 20.6 cm, R_2 = -20.6 cm

R_1 = 10.3 cm, R_2 = ∞

R_1 = 5 cm, R_2 = 9.72 cm

Any combination of R_1 and R_2 that satisfy this equation will be acceptable. Above are some examples.

Multiple Choice Questions:

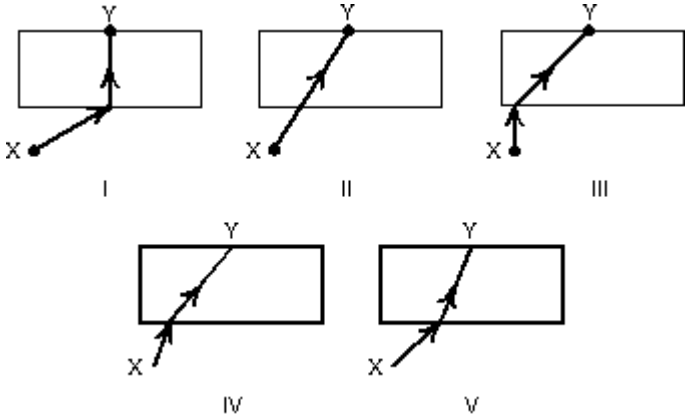
1. The time averaged energy in a sinusoidal electromagnetic wave is:
   a) overwhelmingly electrical
   b) slightly more electrical than magnetic
   c) equally divided between the electric and magnetic fields
   d) slightly more magnetic than electrical
   e) overwhelmingly magnetic

While the SI unit value of the magnetic field is a smaller number compared to the electric field, the energy density of each is equal.

2. When an electromagnetic wave meets a reflecting surface, the direction taken by the reflected wave is determined by:
   a) the material of the reflecting surface
   b) the angle of incidence
   c) the index of the medium
   d) the intensity of the wave
   e) the wavelength

The reflected angle is equal to the incidence angle regardless of the two media or the properties of the incident wave.

3. Which diagram below illustrates the path of a light ray as it travels from a given point X in air to another given point Y in glass?
   a) I
   b) II
   c) III
   d) IV
   e) V



Since the index of refraction of glass is higher than air, the light bends towards the normal as it enters the glass.

4. An object is 2 m in front of a plane mirror. Its image is:
   a) virtual, inverted, and 2 m behind the mirror
   b) virtual, inverted, and 2 m in front of the mirror
   c) virtual, erect, and 2 m in front of the mirror
   d) real, erect, and 2 m behind the mirror
   e) none of the above

A flat mirror produces images that are virtual, erect and an equal distance behind the mirror.

5. In a two lens microscope, the intermediate image is:
   a) virtual, erect and magnified
   b) real, erect and magnified
   c) real, inverted and magnified
   d) virtual, inverted and reduced
   e) virtual, inverted and magnified

The intermediate image is produced between the objective and the eyepiece. Being a real image, it is inverted. It also has lateral magnification.