Name_____

Physics 111 Quiz #5, October 21, 2024

Please show all work, thoughts and/or reasoning to receive partial credit. The quiz is worth 10 points total, and all parts may not be of equal weight.

I affirm that I have carried out my academic endeavors with full academic honesty.

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1. A $100mW$ beam of red laser light with wavelength $\lambda_{red} = 632nm$ is incident on a slab of gemstone that has been submerged in water ($n_w = 1.33$). The beam of red laser light is incident at an angle of 40^0 in the water and the beam of red laser light is seen to make an angle of 31.6^0 in the gemstone. Both angles are measured with respect to the normal to the gemstone's surface. From the chart below, what could be the identity of the gemstone?

Gemstone material	n_m
Opal	1.40
Emerald	1.55
Topaz	1.60
Sapphire	1.77
Cubic Zirconia	2.15
Diamond	2.40

$n_w \sin\theta_w = n_m \sin\theta_m$

$n_m = n_w \times \left(\frac{\sin\theta_w}{\sin\theta_m}\right) = 1.33 \times \left(\frac{\sin 40}{\sin 31.6}\right)$

$n_m = 1.63$ and the gemstone is most likely topaz.

2. Suppose that the gemstone from part 1 was removed from the water and placed in the air. The red laser light is again incident on the gemstone at an angle of 40^0 in the air. The red laser light travels through the gemstone and exits on the opposite side from where it entered. What is the critical angle at the gemstone/air interface? Use the index of refraction value from the table above, for the gemstone you found in part 1.

$n_1 \sin\theta_1 = n_2 \sin\theta_2 \rightarrow n_{topaz} \sin\theta_c = n_{air} \sin 90 \rightarrow \sin\theta_c = \frac{n_{air}}{n_{topaz}}$

$\theta_C = \sin^{-1}\left(\frac{n_{air}}{n_{topaz}}\right) = \sin^{-1}\left(\frac{1.00}{1.60}\right) = 38.7^0$

3. Suppose that this gemstone from part 1 was used as a lens in an experiment. The lens is placed $30cm$ from an object. The image of the object is found on the same side of the lens as the object, at a distance of $75cm$ from the lens. What is the focal length and type of lens used in the experiment?

$$\frac{1}{f_{topaz}} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{30cm} - \frac{1}{75cm} \rightarrow f_{topaz} = 50cm$$

Since the focal length of the topaz lens is positive, the topaz lens must therefore be converging.

4. The image of the object was measured and found to be $5.5cm$ tall. How tall was the object and what is the orientation of the object with respect to its image?

$$\frac{h_i}{h_o} = \frac{d_i}{d_o} \rightarrow h_o = \left(\frac{d_o}{d_i}\right) h_i = \left(\frac{30cm}{75cm}\right) \times 5.5cm = 2.2cm$$

Since this is a virtual image, the image is oriented in the same direction as the object.

5. Suppose that a second gemstone lens (with focal length $12cm$) was made placed $10cm$ to the right of the first lens. If the object is again placed to the $30cm$ left of the first lens, where is the final image of the object located. Measure this distance with respect to the second lens.

The image of the object from the first lens (which will be the object for the second lens) is located $75cm$ to the left of the first lens, from part 3. Since the lenses are separated by a distance of $10cm$, the object distance to the second lens is $d_{o2} = d_{i1} + D = 75cm + 10cm = 85cm$.

$$\frac{1}{f_{topaz,2}} = \frac{1}{d_{o2}} + \frac{1}{d_{i2}} \rightarrow \frac{1}{d_{i2}} = \frac{1}{f_{topaz,2}} - \frac{1}{d_{o2}} = \frac{1}{12cm} - \frac{1}{85cm} \rightarrow d_{i2} = 14cm$$