Name: SOLUTIONS Student #: _____

THOMPSON RIVERS UNIVERSITY

PHYS 1150
Mechanics & Waves

Instructor: Richard Taylor

MIDTERM EXAM

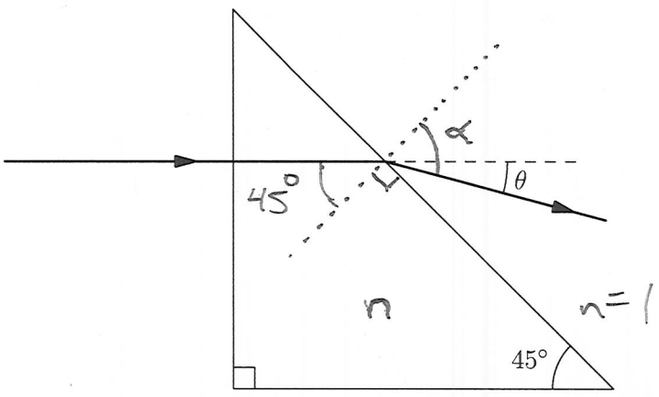
27 Oct 2014 12:30–13:20

Instructions:

1. Read the whole exam before beginning.
2. Make sure you have all 5 pages.
3. Organization and neatness count.
4. Justify your answers.
5. Clearly show your work.
6. You may use the backs of pages for calculations.
7. You may use an approved calculator.

PROBLEM	GRADE	OUT OF
1		6
2		14
3		12
4		11
TOTAL:		43

/6 **Problem 1:** A 45°–45°–90° prism is suspended in air, as shown below. A laser beam is incident perpendicular to one of the faces. The transmitted beam that exits the hypotenuse of the prism makes an angle of $\theta = 15.0°$ with the direction of the incident beam. Find the index of refraction of the prism.



refraction at hypotenuse:

$$n \sin 45^\circ = (1) \sin \alpha \quad \text{(Snell's Law)}$$

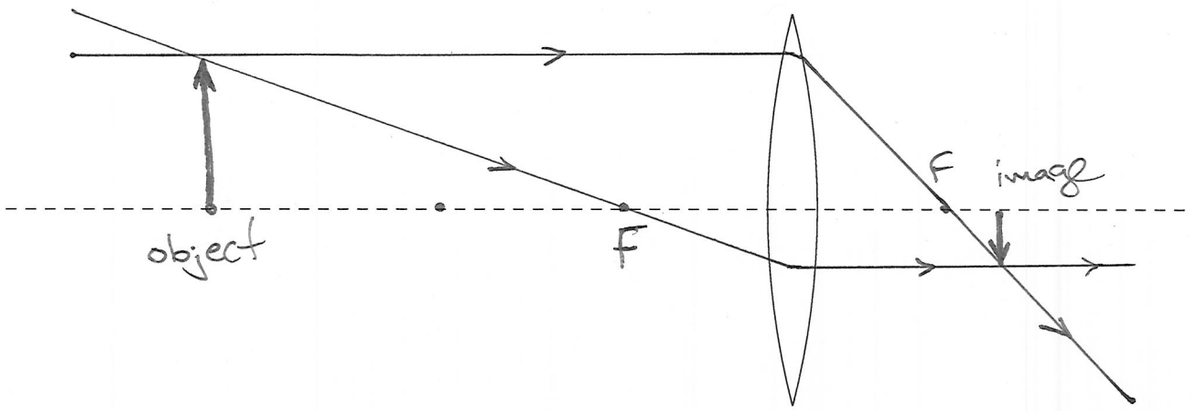
$$\alpha = 45^\circ + \theta$$

$$= 45 + 15 = 60^\circ \Rightarrow n \sin 45^\circ = \sin 60^\circ$$

$$\rightarrow n = \frac{\sin 60^\circ}{\sin 45^\circ} = \frac{\sqrt{3}/2}{\sqrt{2}/2} = \sqrt{\frac{3}{2}} \approx \boxed{1.22}$$

/14 **Problem 2:** An object's distance from a "thin" converging lens is 3.00 times the focal length.

/4 (a) Use a principal ray diagram to graphically locate the object and its image in the figure below.



/4 (b) Calculate the distance of the object's image from the lens. Express your answer as a multiple of the focal length.

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$p = 3f \rightarrow \frac{1}{3f} + \frac{1}{q} = \frac{1}{f}$$

$$\rightarrow \frac{1}{q} = \frac{2}{3} \cdot \frac{1}{f} \rightarrow \boxed{q = \frac{3}{2}f}$$

/2 (c) Calculate the magnification of the image.

$$M = -\frac{q}{p} = -\frac{\frac{3}{2}f}{3f} = \boxed{-\frac{1}{2}}$$

/1 (d) Is the image upright? or inverted?

inverted.

/1 (e) Is the image real? or virtual?

real.

/2 (f) If the object is moved farther from the lens, does the magnification increase, decrease, or remain the same? Explain.

decrease.

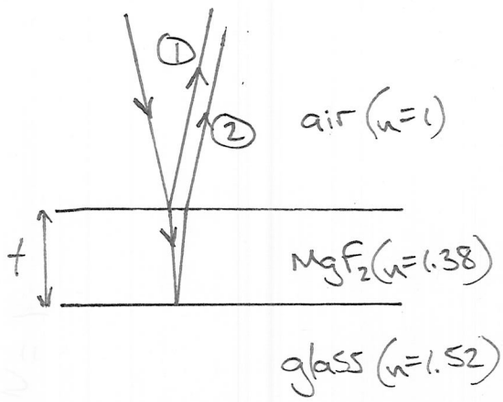
- moving object toward ∞ concentrates image near focal point

/12 **Problem 3:** A thin film of MgF_2 (with index of refraction $n = 1.38$) having thickness 1.00×10^{-5} cm ($= 100$ nm) is used to coat a camera lens (which itself is made of glass with $n = 1.52$).

(a) What are the three longest wavelengths that are *intensifed* in the reflected light? Are any of these wavelengths in the visible spectrum?

/5

- both waves ① and ② undergo 180° phase shift on reflection
→ path length difference is the only cause of relative phase difference
→ for constructive interference:



$$\delta = 2t = m\lambda_n = m\frac{\lambda}{n} \quad (m = 1, 2, 3, \ldots) \rightarrow \lambda = \frac{2nt}{m}$$

$$\lambda = \frac{2(1.38)(100\,\text{nm})}{m} \rightarrow$$

$m=1$: $\lambda = 276$ nm
$m=2$: $\lambda = 138$ nm
$m=3$: $\lambda = 92$ nm

} none in visible spectrum ~400–700 nm

(b) What are the three longest wavelengths that are *darkest* in the reflected light? Are any of these wavelengths in the visible spectrum?

/5

for destructive interference:

$$\delta = 2t = \frac{\lambda_n}{2} + m\lambda_n = \left(m + \tfrac{1}{2}\right)\lambda_n = \left(m + \tfrac{1}{2}\right)\frac{\lambda}{n}$$

$$\rightarrow \lambda = \frac{2nt}{m + 1/2} = \frac{2(1.38)(100\,\text{nm})}{m + \frac{1}{2}} \quad (m = 0, 1, 2, \ldots)$$

$m=0$: $\lambda = 552$ nm ← visible (green)
$m=1$: $\lambda = 184$ nm
$m=2$: $\lambda = 110$ nm

(c) Based on your answers to part (a) and (b), what is the most likely apparent color of the lens? (Note: red light has wavelength about 700 nm; violet light has wavelength about 400 nm.)

/2

- destructive interference is complete for green light, less so toward ends of visible spectrum; lens probably appears red/purple.

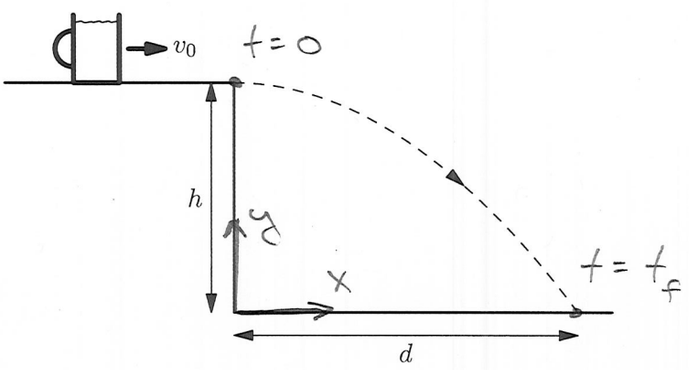
/14 **Problem 4:** In a local bar, a customer slides an empty beer mug down the counter. The mug slides off the counter and strikes the floor a distance d from the base of the counter. The height of the counter is h. Air resistance is negligible.

(a) Find an expression (in terms of h, d and g) for the mug's time of flight from the counter edge to the floor.

/4

$$y(t) = y_0 + v_{y0}t + \frac{1}{2}a_y t^2$$

$$= h + 0 - \frac{1}{2}gt^2$$



$$y=0 \Rightarrow \frac{1}{2}gt_f^2 = h$$

$$\Rightarrow \boxed{t_f = \sqrt{\frac{2h}{g}}}$$

(b) Find an expression (in terms of h, d and g) for the initial speed v_0 with which the mug left the counter.

/4

$$x(t) = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$$

$$= 0 + v_0 t + 0$$

$$x(t_f) = d = v_0 t_f \rightarrow v_0 = \frac{d}{t_f} = \frac{d}{\sqrt{2h/g}} = \boxed{d\sqrt{\frac{g}{2h}}}$$

(c) Find an expression (in terms of h and d) for the direction (angle below horizontal) of the mug's velocity just before it hits the floor.

/4

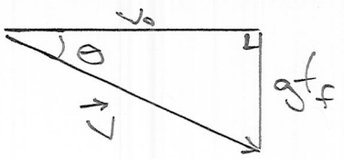
$$v_x(t) = v_0$$

$$v_y(t) = v_{y0} + a_y t = 0 - gt$$

$$\Rightarrow \vec{v}(t_f) = (v_0, -gt_f)$$

$$= \left(d\sqrt{\frac{g}{2h}}, -\sqrt{2gh}\right)$$

$$\tan\theta = \frac{\sqrt{2gh}}{d\sqrt{g/2h}} = \frac{2h}{d}$$



$$\rightarrow \boxed{\theta = \tan^{-1}\frac{2h}{d}}$$

(d) If the initial speed of the beer mug were *faster*, would the time of flight be greater, less, or the same? Explain.

/2

the same. t_f is indep. of v_0 (depends only on g, h).