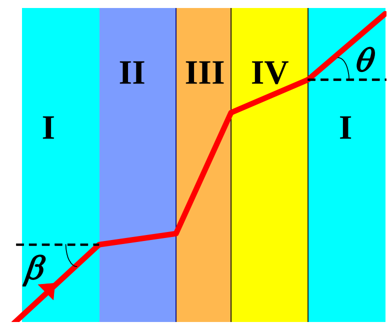
PHYSICS 223
Exam-2

NAME______________________

1. In the figure shown, light travels from material **I**, through three layers of other materials with surfaces parallel to one another, and then back into another layer of material **I**. The refractions (but not the associated reflections) at the interfaces are shown.



1.A Rank the materials according to the index of refraction, greatest first.

a) II, IV, I, III **b) II, I, IV, III**

c) IV, III, I, II **d) IV, I, III, II**

e) NA

1.B Circle the expression(s) that is (are) right

a) In the figure above, assuming that the incident angle β remains the same, if the layers II and IV were interchanged, then the refracted angle θ would increase.

b) In the figure above, assuming that the incident angle β remains the same, if the layers II and IV were interchanged, then the refracted angle θ would decrease.

c) In the figure above, assuming that the incident angle β remains the same, if the thickness of layer III is reduced to zero, then the refracted angle θ would increase.

d) In the figure above, assuming that the incident angle β remains the same, if the thickness of layer III is reduced to zero, then the refracted angle θ would decrease.

e) All the expressions above are incorrect.

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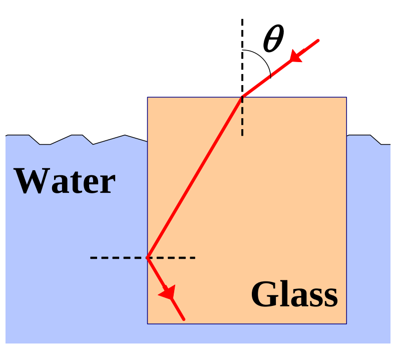
2. A ray of light falls on a rectangular glass block (n_g=1.5) that is almost completely submerged in water (n_w=1.33) as shown in the figure



2.A Find the maximum angle θ_{max} at which total internal reflection at the water-glass interface still occurs.

a) 48^o **b) 53^o**

c) 41.5^o **d) 44^o**

e) NA

2.B Would total internal reflection occur at the vertical interface for the value of θ_{max} found in part 2A above if the water were removed? Circle your answer.

ANSWER: **YES** **NO**

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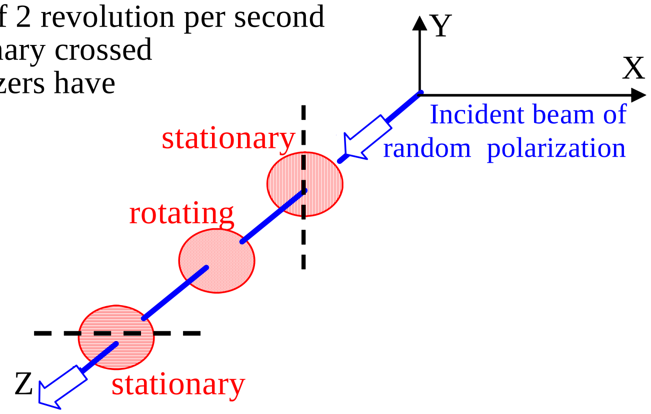
3. A polarizer is rotated at a rate of 2 revolution per second between a similar pair of stationary crossed polarizers (the stationary polarizers have their transmission axis oriented perpendicular to each other.)



3A. The intensity of the emergent beam (after passing the 3 polarizers) will change at a frequency equal to (in cycles/sec)

a) 2 **b)** 8 **c)** 3 **d)** 4 **e)** NA

3B. At the instant when the transmission axis of the rotating polarizer makes 60 degrees with the first polarizer, the fraction of light's initial intensity transmitted by the system is

a) $\frac{1}{8}$ **b)** $\frac{3}{32}$ **c)** $\frac{1}{16}$ **d)** $\frac{3}{16}$ **e)** NA

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4. **4A** The laws of refraction and reflection are the same for sound as for light. The speed of sound in air is 340 m/s and in water it is 1510 m/s. If a sound wave approaches a plane water surface at an angle of incidence of 12°, what is the angle of refraction?

a) 49.3° **b)** 2.7° **c)** 67.4° **d)** 12° **e)** NA

4B A layer of ethyl alcohol (n = 1.361) is on top of water (n = 1.333). At what angle relative to the normal to the interface of the two liquids is light totally reflected?

a) 78° **b)** 88° **c)** 68° **d)** 58° **e)** The critical angle is undefined.

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5. **5A** A ray passes from air (n_a=1) into water (n_w=1.33), striking the surface of the water with an angle of incidence of 45°. Which of the following four quantities change as the light crosses the air-water interface: (1) wavelength, (2) frequency (3) phase velocity (4) direction of propagation,

a) 1 and 2, only **b)** 2, 3, and 4, only **c)** 1, 3, and 4 , only **d)** 3 and 4, only **e)** 1, 2, 3, and 4

5B Calculate the fraction of light energy reflected from an air-water interface at normal incidence.

a) 4% **b)** 1% **c)** 0.3% **d)** 2% **e)** NA

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6. **6A** A glass surface (n_g=1.5) has a layer of water on it (n_w=1.33). Light in the glass is incident on the glass-water interface. Find the critical angle for total internal reflection.

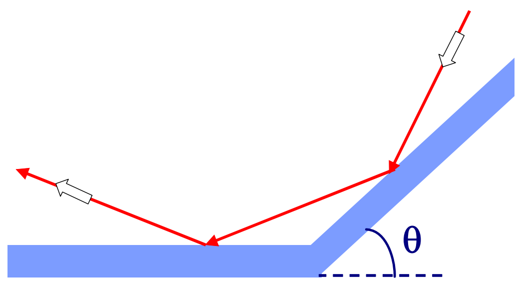
a) 51° **b)** 59° **c)** 42° **d)** 48° **e)** NA

6B The figure below shows two plane mirrors that make an angle q with each other. The angle between the incident and reflected ray is

a) θ **b)** 2θ

c) 3θ **d)** θ /2

e) (2/3) θ



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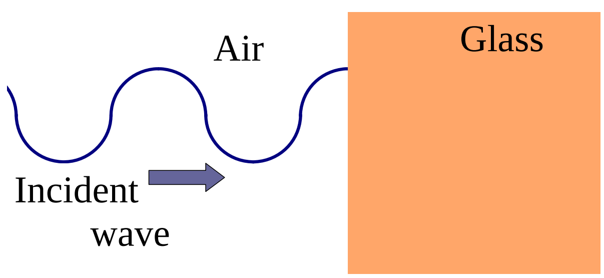
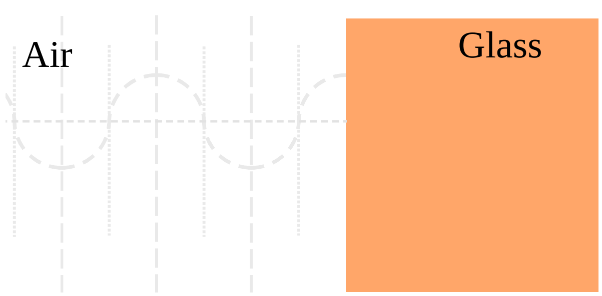
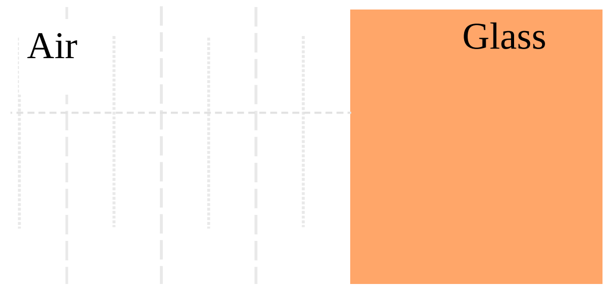
7. The figure shows the profile of an incident wave at t=0.



7.A Sketch the profile of the transmitted and reflected wave at t=0



7.A Sketch the profile of the transmitted and reflected wave at $t=T/4$ (where T is the period of the wave).



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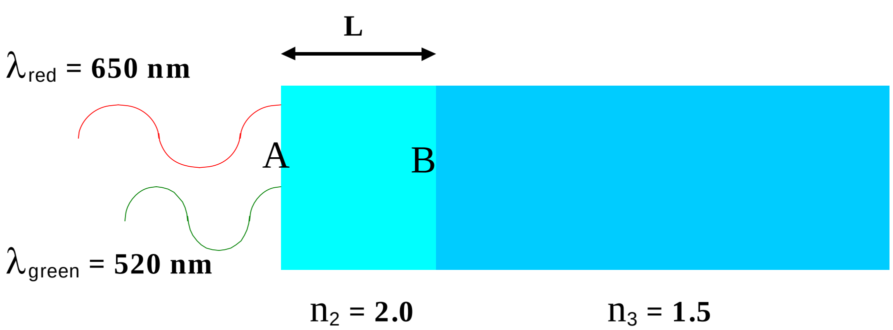
8. The figure below shows red and green light incident from air. The thickness "L" of the thin film is unknown.



8A Which of the following expression is correct

a) The frequency of the red beam is higher when travels inside the film when compared to its frequency in the air

b) The frequency of the green beam is higher when travels inside the film when compared to its frequency in the air

c) The time it takes for the green beam to travel from A to →B and return to →A (inside the film) is numerically equal to $4L/c$

d) The green beam incident on the interface "B" will experience 180 degrees phase shift upon reflection.

e) NA

8B Which of the following expression is correct

a) The green beam incident on the interface "B" will experience 180 degrees phase shift upon reflection, but the red beam will experience no phase shift.

b) In the case of the red light: If the film were very small ($L < 0.1\ \lambda_{red}$) the beams reflected from the interfaces "A" and "B" will interfere destructively .

c) In the case of the green light: If the film were very small ($L < 0.1\ \lambda_{green}$) the beams reflected from the interfaces "A" and "B" will interfere constructively.

d) In the case of the green light: If the film were very small ($L < 0.1\ \lambda_{green}$) the beams reflected from the interfaces "A" and "B" will always interfere constructively regardless of the value of n_3.

e) NA

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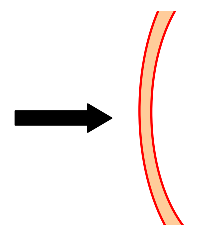
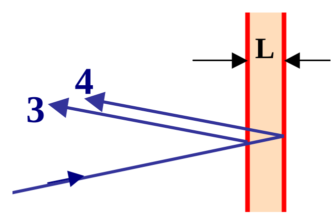
9 **9.A** White light, with a uniform intensity across the visible wavelength range of 400 nm to 690 nm. Is perpendicularly incident on a water film of index of refraction n= 1.33 and thickness L=320 nm, that is suspended in air. At what wavelength does the light reflected by the film look brightest to an observer?



a) 475 **b)** 547 **c)** 657 **d)** 567 nm **e)** NA

9B. The figure shows the reflection of light from a thin film of thickness L and index of refraction *n* surrounded by air (the rays are drawn tilted for clarity). What is the phase difference between the rays **3** and **4**?



a) $\frac{2\pi}{\lambda_0} nL$ **b)** $\pi + \frac{2\pi}{\lambda_0} nL$ **c)** πL **d)** π **e)** NA

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10. **10A** In order to calculate the force an ideal gas exerts on the wall of a container, we assume that each molecule transfers momentum of magnitude $2\ m_o\ v_x$ when it collides with a wall perpendicular to the *x*-axis. To calculate the force that each molecule exerts on the wall we can also assume that the time interval between collisions in a cube of side length *d* is

a) $\frac{d}{2v_x}$ **b)** $\frac{d}{v_x}$ **c)** $\frac{\sqrt{2}\ d}{v_x}$ **d)** $\frac{2d}{v_x}$ **e)** $\frac{2\sqrt{2}\ d}{v_x}$

10B An **ideal gas** is composed by 3.7×10^{27} **monoatomic** particles which fill a vessel of volume V= 3m x 10m x 5m, exerting a pressure of P = 1 atmosphere at T= 300 K. What of the following expressions is correct?

a) In the same vessel and at the same temperature of 300K, 3.7×10^{27} **diatomic** particles will exert a pressure of P = 2 atmospheres.

b) In the same vessel and at the same temperature of 300K, 3.7 x 10^{27} **diatomic** particles will exert a pressure of P = 1 atmosphere.

c) In the same vessel and at the same temperature of 300K, 3.7 x 10^{27} **diatomic** particles will exert a pressure of P = 0.5 atmospheres.

d) In the same vessel and at the same temperature of 300K, 3.7 x 10^{27} **diatomic** particles will exert a pressure greater than 1 atmosphere, but there is not enough information to calculate the exact pressure.

e) In the same vessel and at the same temperature of 300K, 3.7 x 10^{27} **diatomic** particles will exert a pressure lower than 1 atmosphere, but there is not enough information to calculate the exact pressure.

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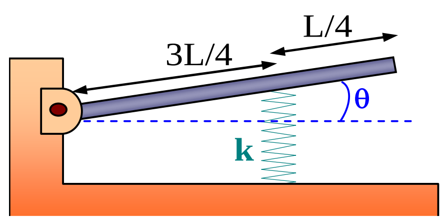
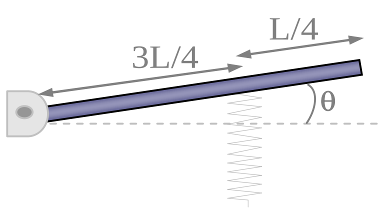
11 The figure shows a horizontal planks of length **L=50** cm, and mass **M= 1 Kg**, pivoted at one end. The planks' is also supported by a spring at 3/4 of its length, as shown in the figure; the spring constant has a value of k=10 N/cm. The spring is neither compressed nor stretched when the plank is horizontal. Assume that the plank undergoes small amplitude oscillations?



11.A Draw the corresponding free body diagram for the plank and indicate the magnitude of the torque (calculated around the pivot point) produced by each of the forces when θ = 0.01 radians.



Torque 1: ________________________________

Torque 2: ________________________________

Torque 3: ________________________________

11.B Consider the same mechanical system described in question #1 above.

a) 6.5 **b)** 9.0 **c)** 5.8 **d)** 0.75 **e)** NA

SOME HELPFUL FORMULAS

1Hertz = 1 Hz = 1 oscillation per second

nm = 10^{-9} m, μm = 10^{-6} m

ε_0= 8.85 x 10^{-12} F/m

c= 3×10^8 m/s

Angle in radians

θ (radian) = length/radius = Δl / R

Identity:

$$E_m COS(A) + E_m COS(B) =$$

$$= 2E_m COS\left(\frac{A-B}{2}\right)COS\left(\frac{A+B}{2}\right)$$

Waves traveling along a string: $v = (T/\mu)^{1/2}$

Doppler Effect:

$$f_{observer} = f_{source}\frac{V_{sound} \pm v_{observer}}{V_{sound} \pm v_{source}}$$

Beat frequency:

Let $\omega_2 = \omega_1 + \Delta\omega$

$$p = p_0 COS(\omega_2 t) + p_0 COS(\omega_1 t)$$

$$= 2p_0 COS\left(\frac{\Delta\omega}{2}t\right)COS\left(\frac{\omega_1+\omega_2}{2}\right)$$

Electromagnetic waves:

$$E_y = E_m COS(kx - wt)$$

$$B_z = B_m COS(kx - wt)$$

$$\frac{\partial E_y}{\partial x} = -\frac{\partial B_z}{\partial t} \qquad B_m = \frac{E_m}{c}$$

Poynting vector

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

Magnitude of the Poynting vector

$$|S| = \varepsilon_0 c E^2$$

Average:

$$\langle S \rangle = \tfrac{1}{2}\varepsilon_0 c E_m^{\ 2}$$

Waves

$y = A_m COS(kx - \omega t + \delta)$

A_m= amplitude,

$(\omega t + \phi)$ = phase of the motion,

δ is the phase constant, and

ω is the angular frequency.

Speed: $v = \lambda f$

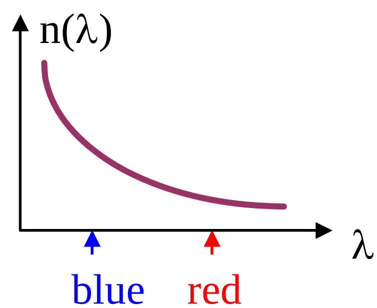
$$T = \frac{1}{f} \qquad \text{(Period)}$$

$$\omega = \frac{2\pi}{T} = 2\pi f \qquad \text{(angular frequency)}$$

$$k = \frac{2\pi}{\lambda}$$

Snell's law $n_1 SIN\,\theta_1 = n_2 SIN\,\theta_2$

Index of refraction: $n = \frac{c}{V}$



Brewster angle

Angle reflection + angle refraction = 90^o

Phase shift: $\Phi = k\,L$

THIN FILM INTERFERENCE

Condition for MAX reflection

(case a slab of thickness L and index of refraction n_2 surrounded by air)

$$2L = N\frac{\lambda_0}{2n_2} \qquad N = 1,3,5,\ldots$$

First Law of Thermodynmics

$\Delta U = Q - W$

Poynting vector

$$\langle S \rangle = \tfrac{1}{2}\varepsilon\, v E_m^2$$

Ideal Gas

$PV = nRT$, $R = 8.31 \times 10^{-23}$ J/mol K

$PV = NkT$, $k = 1.38 \times 10^{-23}$ J/K

Diffraction Grating

Angular location of the first minimum of intensity (around the zero-order maximum)

$n\, d\, SIN(\theta_{min}) = \lambda$

where n is the number of slits participating in the diffraction.

Absolute Temperature Scale or Kelvin Scale

$T = t_{Celsius} + 272.15$ K

RESOLVING POWER Diffraction Grating

$R = \lambda/\Delta\lambda = m\, n$, where

$\Delta\lambda$ is the required minimum difference between two wavelengths in order to distinguish them using the grating

n is the number slit in the grating.

m is the order of the maximum intensity (m = 1,2,3,…).