P114 University of Rochester NAME Soln Key - SEM
S. Manly Spring 2006

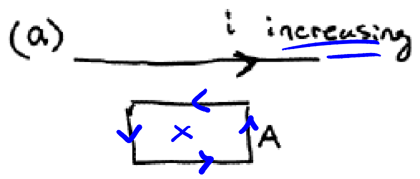
Exam 3 (April 25, 2006)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work. Partial credit will be given.

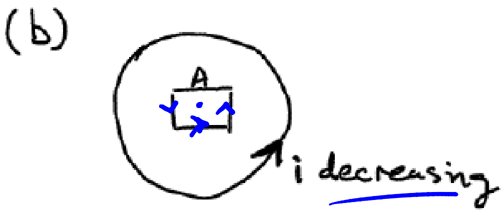
Problem 1 (16 pts, no partial credit for each part): No need to justify

In each of the four cases below, indicate the direction of current flow in the rectangular wire loop "A". In all instances, the rectangular loop is in the plane of the paper.

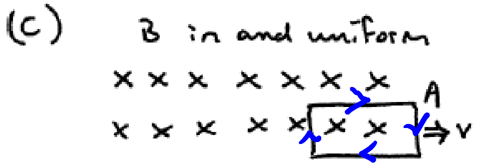
If no current is induced write "No induced current."



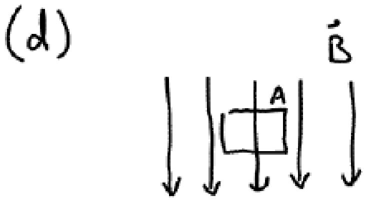
Straight Wire and loop A are in the same plane



Circular current loop Surrounding Loop A – in the same plane (of paper)



Loop A moving out of region w/ uniform B with velocity v



No induced current

$\vec{B}$ and loop A are both in plane of paper.
$\vec{B}$ is increasing in strength

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Problem 2 (12 pts, show work/logic to get credit):

You place a single loop of wire 0.5 m by 0.3 m perpendicular to a field of 2.0 T. In 30 ms you turn the loop until it is parallel with the field. The average emf induced in this loop is

- **a) 0.3 V**
- **[✓ b) 10 V]**
- **c) 5.0 V**
- **d) 67 V**
- **e) 20 V**

$\mathcal{E} = -\frac{d\Phi_B}{dt}$ $\quad |\mathcal{E}| = \frac{\Delta \Phi_B}{\Delta t} = \frac{[(.5)(.3)(2.0) - 0]\ T\text{-}m^2}{.03\ s}$

$|\bar{\mathcal{E}}| = 10\ V$

Problem 3 (15 pts, show work/logic to get credit):

A real object is placed 42 cm from a diverging lens with a focal length of 21 cm.

"–" because Diverging

a) What is the power of this lens (in diopters)?

$P(\text{in diopters}) = \frac{1}{f(\text{in m})}$ $\quad P = \frac{1}{-.21} = -4.8$ diopters

b) What is the location of the image?

$\frac{1}{i} + \frac{1}{o} = \frac{1}{f}$ $\quad \frac{1}{i} + \frac{1}{.42} = -4.8$ $\quad i = -.14\ m$

i = 14 cm from lens to same side as object

c) Is the image real or virtual?

Virtual – i is on same side of lens as object

d) How does the height of the image compare to the height of the object?

$m = \frac{h_i}{h_o} = -\frac{i}{o} = -\frac{-.14}{.42} = +\frac{1}{3}$ $\quad$ image is $\frac{1}{3}$ the height of object

e) Is the image upright or inverted?

mag. is "+" so image is upright

1)	/16
2)	/12
3)	/15
4)	/12
5)	/15
6)	/15
7)	/15
tot	/100

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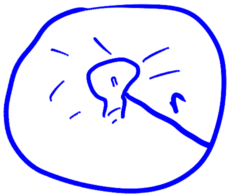
Problem 4 (12 pts, show work/logic to get credit):

At what distance will a 75-Watt light bulb have the same apparent brightness as a 120-Watt bulb viewed from a distance of 15 m?

brightness ≈ intensity WATTS/m^2



get this by taking total WATTS + ÷ by Area of sphere at radius r

$$\frac{120}{4\pi(15)^2} = \frac{75}{4\pi r^2}$$

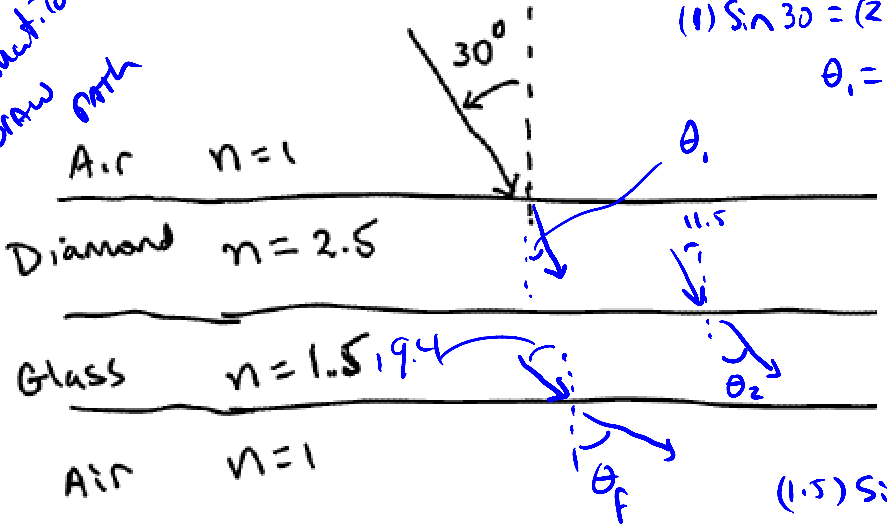
$$r^2 = \frac{75}{120}(15)^2$$

$$\boxed{r = 11.9\ \text{m}}$$

Problem 5 (15 pts, show work/logic to get credit):

The Donald decides that his new building, Trump Castle, needs distinctive windows. So, he has a talented team of window makers coat all of the windows in the building with diamond. If a light ray is incident on one of the Donald's new windows at an angle of 30 degrees with respect to the normal, at what angle with respect to the normal will this light leave the window on the other side. That is to say, what angle will the transmitted ray make with the normal to the window?

schematically Draw path



$(1)\sin 30 = (2.5)\sin\theta_1$

$\theta_1 = 11.5°$

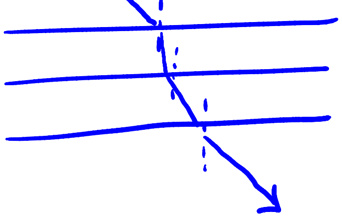
$(2.5)\sin 11.5 = (1.5)\sin\theta_2$

$\theta_2 = 19.4°$

$(1.5)\sin(19.4) = (1)\sin\theta_f$

$$\boxed{\theta_f = 29.9°}$$

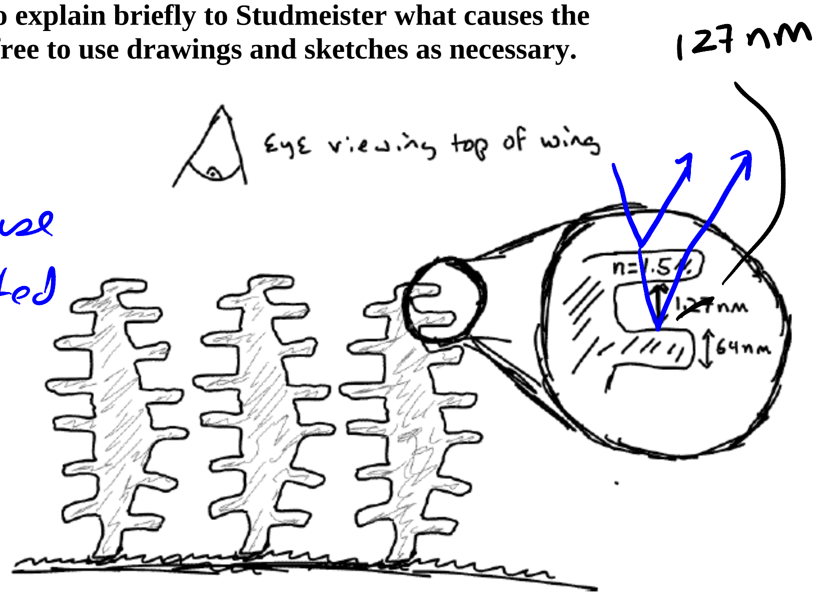
Path of light



use Snell's law at 3 successive interfaces

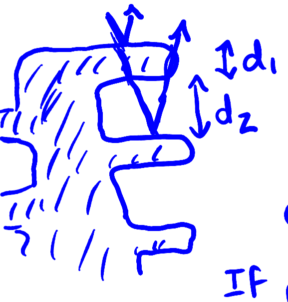
Problem 6 (15 pts, show work/logic to get credit):

Stanly Studmeister, biologist extraordinaire, likes to study butterflies. Recently, he's been trying to figure out the cause of the shimmering blue color on the wings of the *Morpho* butterfly. Knowing that you are a local physics god, Studmeister asks you to help him out. Below is sketch that Stanly made of what he saw through an electron microscope when he inspected the surface of a *Morpho* butterfly's wing. The sketch shows a cross-section of part of the wing. In other words, the wing in the drawing is oriented perpendicular to the paper. What you see are overlapping scale structures as shown in the sketch. Please use the concepts that we have discussed recently to explain briefly to Studmeister what causes the shimmering blue color of the wings. Feel free to use drawings and sketches as necessary. For your reference, the central wavelength of the blue color of the wings is approximately 440 nm.



The Morpho wings look blue because of interference between light reflected from the different layers of the overlapping scales.

Let us look at the interference between rays of light reflected off two successive scales.



There is phase change of π upon reflection for each ray so that effect factors out of problem.

If pathlength difference is equal to mλ than there will be constructive interference.

$$\Delta \text{PATH} = \frac{2d_1}{(\lambda_0/n)} + \frac{2d_2}{\lambda_0} = m\lambda_0$$

λ inside scale material (n=1.5)

let $m=1$ $\lambda_0 = 2nd_1 + 2d_2$

$$\lambda_0 = 2nd_1 + 2d_2$$

$$\lambda_0 = (2)(1.5)(64) + 2(127) = \underline{\underline{446\,nm}}$$

~440nm
→ color of wing

This calculation assumes that you are viewing the wing straight on. If you view it from an angle the visible wavelength with constructive interference changes making the color change. This makes the wing color shimmer.

Problem 7 (15 pts, show work/logic to get credit):

A beam of light is a mixture of linearly polarized light and unpolarized light. When it is sent through a Polaroid sheet (a linearly polarizing sheet), it is found that the transmitted intensity can be varied by a factor of four depending on the orientation of the Polaroid sheet. Find the relative intensities of the two components of the incident beam.

$I = I_{pol} + I_{unpol}$ Before sheet

$I' = \underbrace{\cos^2\theta}_{\text{ranges from } 0 \text{ to } 1} I_{pol} + \frac{1}{2} I_{unpol}$ After sheet

at lower end $I' = \frac{1}{2} I_{unpol} \Rightarrow \boxed{I_{unpol} = 2I'}$

at upper end $4I' = I_{pol} + \frac{1}{2} I_{unpol} = I_{pol} + I'$

$$\boxed{3I' = I_{pol}}$$

$$\frac{3I'}{2I'} = \frac{I_{pol}}{I_{unpol}}$$

$$\boxed{\frac{3}{2} = \frac{I_{pol}}{I_{unpol}}}$$