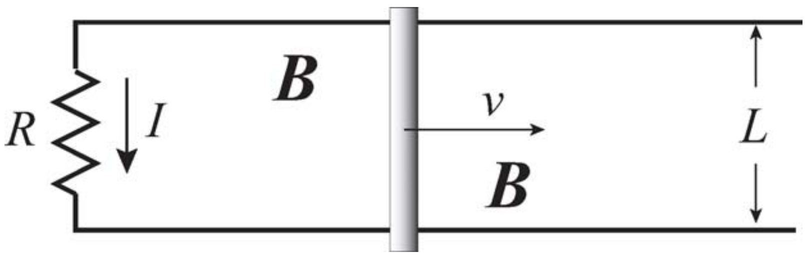
These solutions were ready on 21st, but due to slow DRES I was not allowed to post them. Sorry for our slow business. YO

The next two questions pertain to the situation described below.

On the horizontal plane is a pair of parallel, conducting wires separated by a distance L. The left ends are connected to a resistor R as shown in the figure.

Sliding frictionlessly on the wires is a conducting bar. The resistances of the wires and bar are negligible.

A uniform magnetic field ***B*** of a certain intensity *B* is applied perpendicular to the page.



$L = 2.2$
$R = 14\ \Omega$

1) The conducting bar is pulled to the right at a constant speed $v = 12$ m/s.

As the bar moves, a constant current $I = 1.2$ A flows in the direction indicated by the arrow.

What is the magnitude B of the magnetic field?

E = LvB I = V/R

a. $B = 0.9$ T
b. $B = 0.64$ T
c. $B = 1.3$ T
d. $B = 0.42$ T
e. $B = 4.4$ T

I = LvB/R -> B = IR/Lv = 1.2 x 14/2.2 x 12 = 0.636 T.

2) The direction of the magnetic field

a. cannot be determined.
b. is out of the page.
c. is into the page.

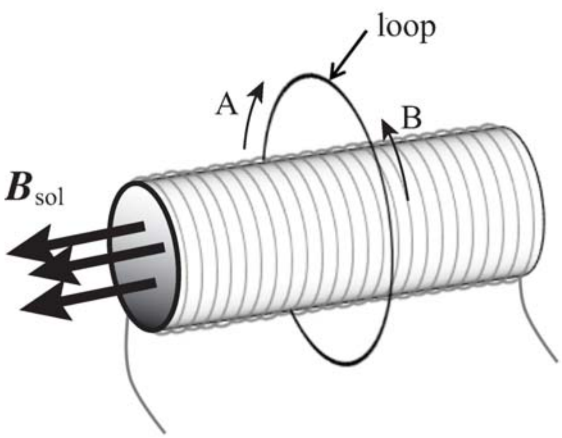
The next two questions pertain to the situation described below.

A single circular loop of wire of radius r_{loop} is placed around a very long solenoid.

The solenoid has a radius r_{sol} and $n = 10100$ turns/m of wire.

A current I runs through the solenoid, generating a magnetic field $\boldsymbol{B}_{\text{sol}}$ in the direction shown in the figure.

The current increases at a rate of 1.2 A/s.



$r_{loop} = 12$ cm
$r_{sol} = 4.6$ cm

3) In which direction, arrow A or arrow B, does the induced current flow around the loop?

a. There is no induced current.
b. Arrow A
c. Arrow B

4) What is the magnitude of the induced EMF $|E|$ in the loop?

a. $|E| = 0.101$ mV
b. $|E| = 1.21$ mV
c. $|E| = 0.689$ mV
d. $|E| = 2.77$ mV
e. $|E| = 0.394$ mV

B = mu_0 nI

Phi = AB

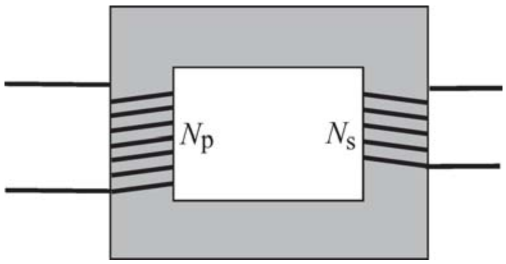
emf = | d Phi/dt |

```
B = ¥mu0 n I
  = 4 pi x 10^{-7} x 10100 x I
Phi = AB = 0.046^2 pi x 4 pi x 10^{-7} x 10100 x I
E = 0.046^2 pi x 4 pi x 10^{-7} x 10100 x dI/dt
  = (0.046xpi)^2 x 4 x10100 x 10^{-7} x 1.2
  = 1012.46 x 10^{-7}
  = 0. 101 mV
```

The next two questions pertain to the situation described below.

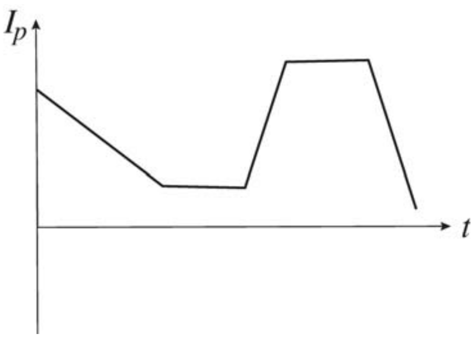
The primary side of the transformer has N_p turns around an iron core (the grey portion).

Its secondary side has N_s turns around the iron core.



$N_p = 200$
$N_s = 4600$

5) Suppose the primary current I_p changes as described in the following figure:

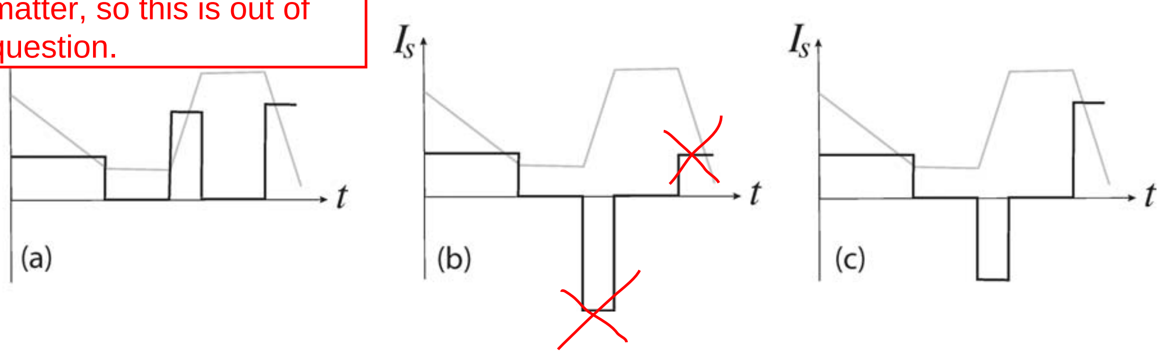


emf = - dPhi/dt
here - tells us that we should not
forget Lenz's law.

Qualitatively, which figure below describes the secondary current I_s? (For convenience I_p is described in the following diagrams as well (pale grey lines).)

The slope also matters.

The signs of slopes
matter, so this is out of
question.



a. Figure (b)
b. Figure (a)
c. Figure (c)

This suffix should be p.

6) Now, a 60 Hz AC current is supplied to the primary side, such that a mean power, $P_{mean} = 120$ W, is supplied to the primary coil.

The root-mean-square current on the secondary side is 1.2 A.

What is the root-mean-square voltage supplied to the primary side?

a. $V_s = 2.2$ V
b. $V_s = 4600$ V
c. $V_s = 2300$ V
d. $V_s = 120$ V
e. $V_s = 4.3$ V

Power is conserved. P = VrmpxIrmp

```
Vs = 120/1.2 = 100 V.
```

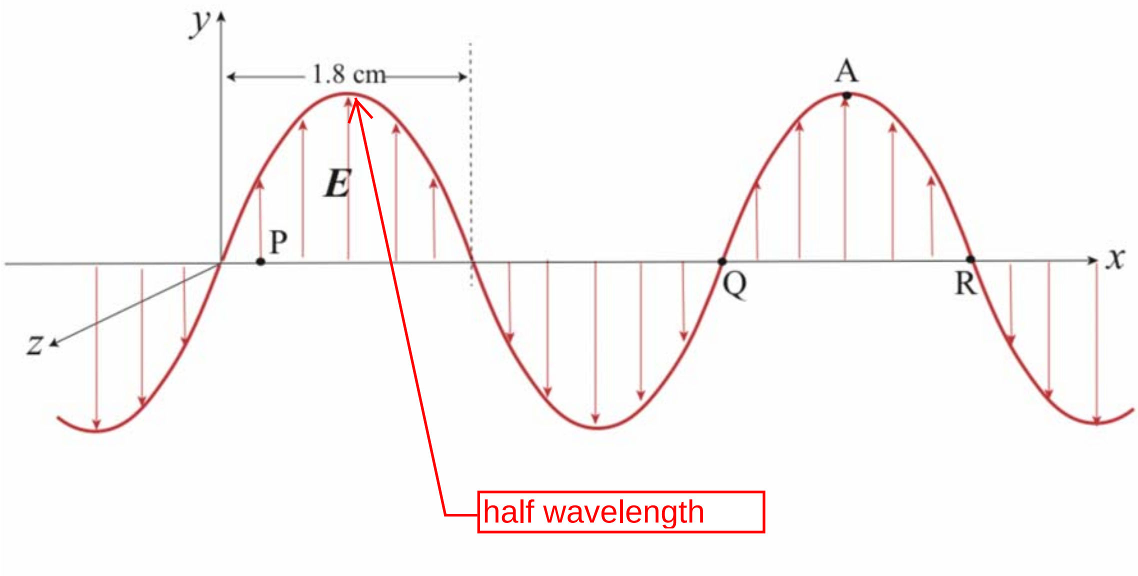
V/N is constant.

```
V/N = const. -> 100/4600 = Vp/200 -> Vp = 20000/4600 = 200/46 = 4.347 V.
```

The next three questions pertain to the situation described below.

An electromagnetic plane wave is propagating along the $+x$ direction in vacuum. The electric field $\boldsymbol{E}$ is parallel to the y-axis.

The sine wave in the figure describes the electric field along the x-axis at a single instant in time.



7) Consider point P as shown in the figure. The electric field is in the positive y direction.

At the same time, the magnetic field vector at point P points in the

E to B right-hand screw = propagation direction

a. $-y$ direction
b. $-z$ direction
c. $+z$ direction
d. $-x$ direction
e. $+x$ direction

8) What is the frequency, f, of this electromagnetic wave?

f = c/lambda

lambda = 3.6x10^{-2}

f = 3x10^8/ 3.6x10^{-2} = 0.833x10^{10} Hz

a. $f = 3.3$ GHz
b. $f = 5.5$ GHz
c. $f = 17$ GHz
d. $f = 12$ GHz
e. $f = 8.3$ GHz

9) What is the polarization of this electromagnetic wave?

Direction of E is the polarization.

a. linearly polarized in the z-direction
b. linearly polarized in the y-direction
c. unpolarized

10) A light bulb emits electromagnetic waves of various frequencies isotropically (i.e., evenly in all directions in space). Consider a light bulb which emits 100 W of power.

What is the total average magnetic energy density, u_B, at a point $d = 11$ m away from the bulb?

a. $u_B = 0.22\ \text{nJ/m}^3$
b. $u_B = 0.11\ \text{nJ/m}^3$
c. $u_B = 2.4\ \text{nJ/m}^3$
d. $u_B = 1.2\ \text{nJ/m}^3$
e. $u_B = 0.03\ \text{nJ/m}^3$

The energy flux I at d is Power/4 pi d^2
I = cu, u = 2u_B

```
I= 100/ 4pi 11^2 = 0.065765 W/m^2.
= cu -> u = 2.19x10^{-10} J/m^3
1/2 of this is the magnetic energy.

1.096 x 10^{-10} = 0.11 x 10^{-9}
```

11) Which of the following properly orders different types of electromagnetic radiation from highest to lowest frequency?

a. ultraviolet, visible light, infra-red radiation, radio waves
b. X-rays, infra-red radiation, visible light, radio waves
c. radio waves, X-rays, ultraviolet, visible light

Common sense.

The next two questions pertain to the situation described below.

Unpolarized light travels through a pair of linear polarizers as shown in the figure.

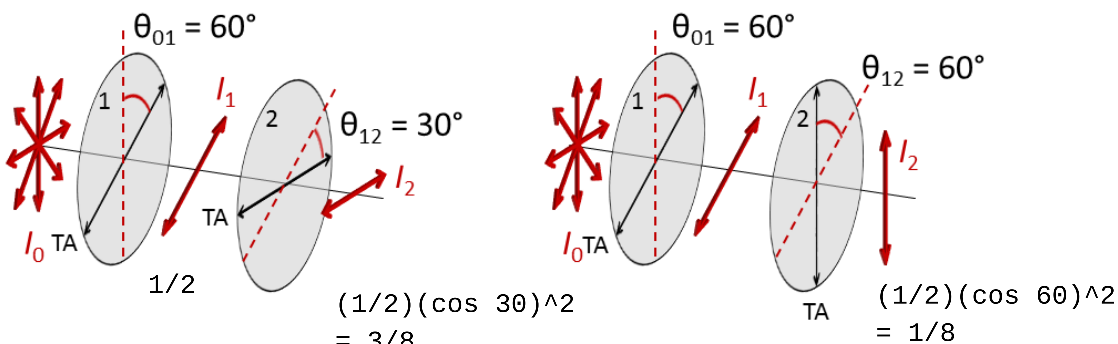


Figure A **Figure B**

12) How does the intensity of the light $I_{2,A}$ emerging from the second polarizer in Figure A compare to the intensity $I_{2,B}$ of the light emerging from the second polarizer in Figure B?

a. $I_{2,A} > I_{2,B}$
b. $I_{2,A} < I_{2,B}$
c. $I_{2,A} = I_{2,B}$

13) Now consider the sequence of polarizers shown in the figure below.

In Figure A_1 the light incident on polarizer 1 is *linearly polarized*.

The light incident of polarizer 2 (Figure B) is *unpolarized*.

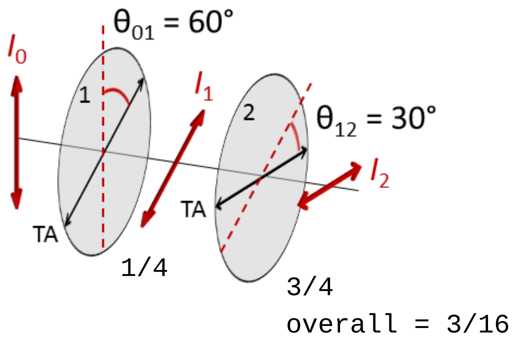


Figure A_1

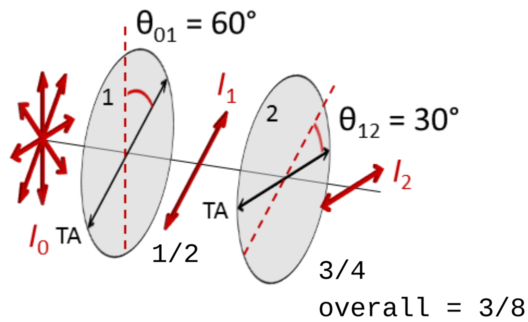


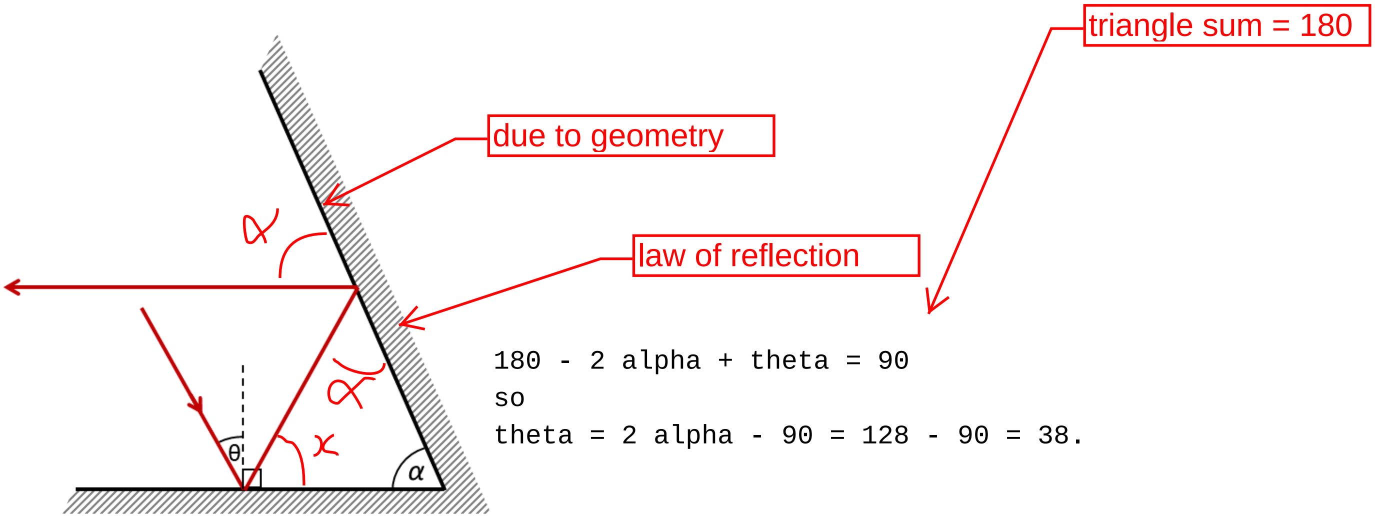
Figure B

Which of the following is true about the intensities of the light exiting polarizer 2?

a. $I_{2,A_1} = I_{2,B}$
b. $I_{2,A_1} < I_{2,B}$
c. $I_{2,A_1} > I_{2,B}$

14) Two flat mirrors are joined at one end at an angle $\alpha = 64^\circ$, as shown in the figure.

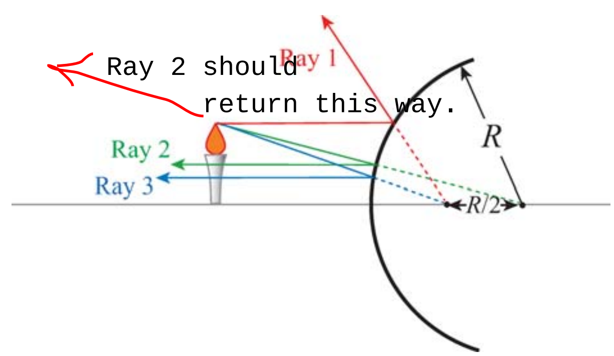
A beam of light hits the horizontal mirror at an incidence angle θ and reflects off of both mirror surfaces.



What is the angle θ such that the beam emerges horizontally from the two mirrors? (Hint: remember that the angles of a triangle sum to 180°).

a. $\theta = 19^\circ$
b. $\theta = 6^\circ$
c. $\theta = 110^\circ$
d. $\theta = 64^\circ$
e. $\theta = 38^\circ$

15) A candle is placed in front of a convex mirror with radius R as shown in the figure.

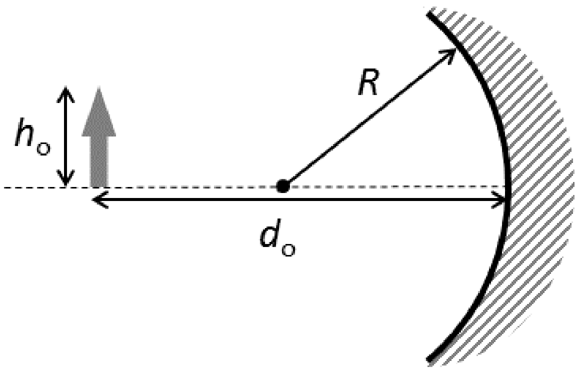


Which ray trace is ***incorrect*** for a principle ray?

a. Ray 1
b. Ray 3
c. Ray 2

The next two questions pertain to the situation described below.

An object of height h_o is placed a distance d_o from a concave mirror of radius R .



$h_o = 1.4$ cm
$d_o = 6.5$ cm
$R = 4.5$ cm

f = R/2

16) What is the reflected image height $|h_i|$?

a. $|h_i| = 3.2$ cm
b. $|h_i| = 0.74$ cm
c. $|h_i| = 0.57$ cm

1/f = 1/do + 1/di
m = - di/do

```
f = 2.25 cm
1/di = 1/f - 1/do = 1/2.25 - 1/6.5 = 1/3.44
so
m = - 3.44/6.5 = -0.529
image size = 1.4 x 0.529 = 0.74 cm
```

17) The mirror produced an image which

a. is inverted.
b. is upright.
c. cannot be determined.

18) An object placed in front of an unknown lens generates a real, inverted, and reduced image.

Consider the three statements below about this system:

Statement A: The lens is a converging lens.
Statement B: The object is further than one focal length from the lens.
Statement C: The image is formed at a distance closer to the lens than the object is to the lens.

Which statement or statements is or are true about the object-lens system?

a. Statements A and B, but not Statement C
b. Statements A, B, and C
c. Statement A only

```
do>0 di>0 reduced -> 0<di<do
1/f = 1/do + 1/di > 2/do  -> do > 2f >0
```

19) A light source and a converging lens are assembled in an empty fish tank (Figure A).

The light source is placed at the focal point of the lens in air, and the refracted light rays emerge parallel to the principal axis.

The fish tank is filled with water (Figure B) without changing the separation of the light source and lens.

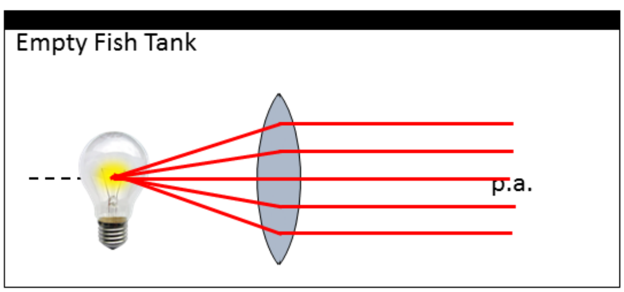


Figure A

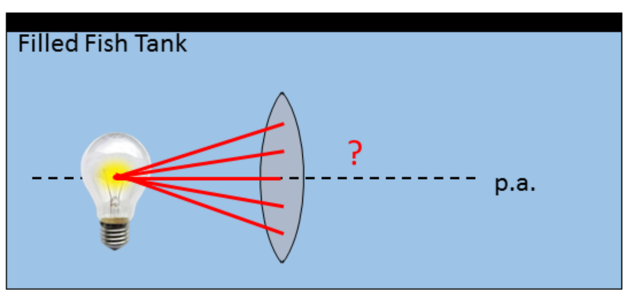


Figure B

Which statement on the refracted rays is true?

a. The light rays converge toward the principal axis
b. The light rays diverge from the principal axis
c. The light rays are parallel to the principal axis

Look at Snell's law
sin theta1 = (n2/n1) sin theta2

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Therefore, in water effectively the
refractive index is `scaled down' by
1.333. Thus, rays are bent less at the lens.
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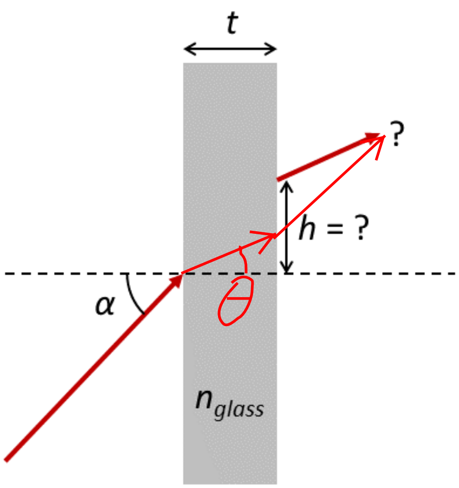
The next two questions pertain to the situation described below.

A beam of light travels in air and hits a vertical slab of glass at an incidence angle α, as shown in the figure.



$\alpha = 49^\circ$
$t = 2.5$ mm

The slab has thickness t and its two surfaces are perfectly parallel.

The index of refraction of the slab is $n_{glass} = 1.5$.

20) At what angle relative to the horizontal axis (shown in the dotted line) does the beam exit the slab?

If parallel boundaries, you may ignore the intervening layer(s).

a. 59°
b. 24.5°
c. 49°

21) At what height above the horizontal axis (shown in the dotted line) does the beam exit the slab?

h = t tan theta

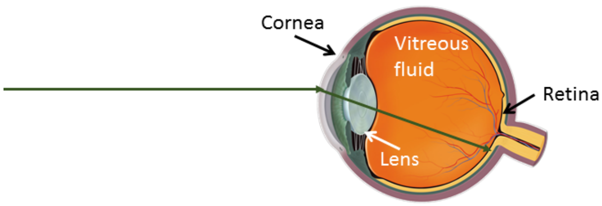
sin alpha = n sin theta

a. $h = 3.42$ mm
b. $h = 0.234$ mm
c. $h = 1.46$ mm
d. $h = 1.14$ mm
e. $h = 2.88$ mm

sin 49 = 1.5 sin theta -> theta = 30.2 deg
h = 2.5 tan 30.2 = 1.455

22) Consider the human eye.

The different structures of the eye have different indices of refraction.



Cornea: $n_c = 1.352$
Lens: $n_l = 1.438$
Vitreous Fluid: $n_v = 1.332$

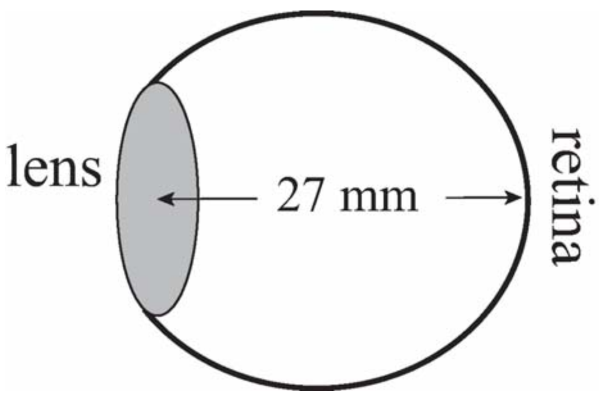
Light of frequency $f = 5.45 \times 10^{14}$ Hz, in vacuum, enters the eye.

Which of the following statements is *false* about the light in the structures of the eye?

a. The frequency changes in each structure, but the speed of light in each structure is the same as in vacuum.
b. The wavelength of light in each structure changes in response to the change in the speed of light in the structure.
c. The frequency stays the same in each structure, but the speed of light in the structure depends on the index of refraction.

The next three questions pertain to the situation described below.

The distance between the center of the lens and the retina of an extremely near-sighted person's eye is 27 mm. Her uncorrected far point is 11 cm from the center of the lenses of her eyes.



23) What is the focal length of the lens of this person's eyes when the eye is relaxed?

a. $f_{eye} = 0.11$ cm
b. $f_{eye} = 2.9$ cm
c. $f_{eye} = -1.1$ cm
d. $f_{eye} = 2.2$ cm
e. $f_{eye} = -1.4$ cm

```
1/f = 1/11 + 1/2.7 = 1/2.167
```

24) When she looks at an object placed at her uncorrected near point, the focal length of her strained lens is 18 mm.

What is the power P_{cont} (in diopters) of the contact lenses needed to correct her vision to focus on a book placed 25 cm from her eyes? Assume the contact lens is placed directly next to the lens of the person's eye.

We need the uncorrected near point.

a. $P_{cont} = -14.5$ diopters
b. $P_{cont} = -5.94$ diopters
c. $P_{cont} = -8.56$ diopters
d. $P_{cont} = 3.19$ diopters
e. $P_{cont} = 11.5$ diopters

The uncorrected near point is 1/do = 1/f - 1/di = 1/18 - 1/27
54 mm is the uncorrected near point.

To correct is to place a virtual image where you can see. do= 250 mm, di = -54mm

1/f = 1/250 - 1/54 f = - 68.8 mm or -14.52 D.

25) She has sensitive eyes, and prefers glasses to contact lenses. The lenses of her glasses sit about 2.5 cm from the lens of her eye.

Let P_{cont} be the power of the contact lenses prescribed for her to read books and P_{glass} be the power of the lenses of her glasses for the same purpose.

Choose the correct relation from below.

a. $|P_{cont}| > |P_{glass}|$
b. $|P_{cont}| = |P_{glass}|$
c. $|P_{cont}| < |P_{glass}|$

For example, if the lens is 2.c away from her eyes,
do = 225, di = -29, so
1/f = 1/225 -1/29 = -1/33.29
-30 D