**The next four questions pertain to the situation described below.**

A light bulb is placed in front of a converging lens. The lens has a focal length of $f$ = 2.5 cm. The bulb is initially placed at a distance of 17.5 cm from the lens.

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

1) The image is

a. upright and real.
b. inverted and real.
c. upright and virtual.

```
f = + 2.5
do = +17.5 -> di > 0 real -> m <0 inverted
```

2) What is the magnitude of magnification of the image?

a. $|m| = 2.9$
b. $|m| = 1$
c. $|m| = 0.17$
d. $|m| = 0.14$
e. $|m| = 7$

```
1/2.5 = 1/17.5 + 1/di -> di = 2.5x17.5/(17.5-2.5)= 2.917

m = -di/do = -2.917/17.5 = - 0.17
```

3) The bulb and lens are now surrounded by water (but remain the same distance apart). Assume that the index of refraction of the lens is larger than that of water. The distance between the image and the lens

a. increases.
b. decreases.
c. stays the same.

```
The effective index of refraction goes down to n/1.333, so f
increases -> di increases.
Notice that f cannot be larger than 5.
```

4) Consider the bulb and lens in air again. The bulb is now placed at a distance of 1.8 cm from the lens. The image is

a. inverted and real.
b. upright and real.
c. upright and virtual.

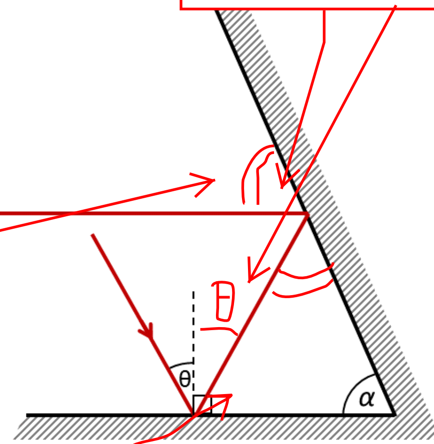
```
1/2.5 = 1/1.8 + 1/di, so di<0 virtual

m > 0 upright.
```

5) 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 $\theta$ and reflects off of both mirror surfaces.

What is the angle $\theta$ such that the beam emerges horizontally from the two mirrors?

They are the same <- the law of reflection




This must be alpha

theta + (180 - 2 alpha) = 90

a. $\theta = 110^\circ$

b. $\theta = 6^\circ$

c. $\theta = 38^\circ$  Therefore, theta = 2 alpha - 90 = 38 deg

d. $\theta = 19^\circ$

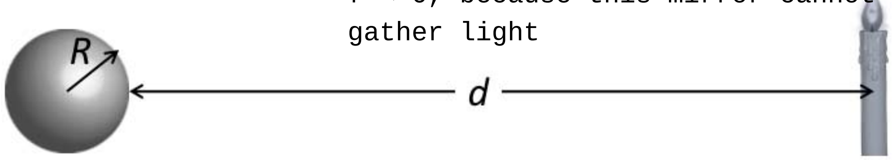
e. $\theta = 64^\circ$

**The next two questions pertain to the situation described below.**  |f| = R/2

A silvered sphere has a radius $R = 5$ cm. A candle of height $h_o = 7$ cm is placed at a distance of $d = 23$ cm from the surface of the sphere, as shown.

f < 0, because this mirror cannot gather light

1/f = 1/do + 1/di




6) Which of the following statements on the image formed by the sphere is TRUE?

-1/2.5 = 1/23 + 1/di -> di < 0 virtual

a. The image is virtual and upright

b. The image is virtual and inverted  m >0. upright

c. The image is real and upright  di = - 2.5x23/25.5 = - 2.2549

7) What is the height $|h_i|$ of the candle's image?

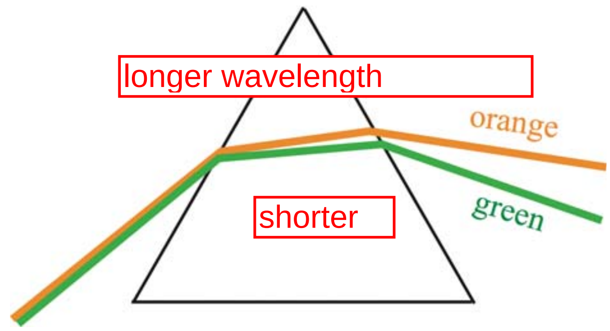
a. $|h_i|= 0.85$ cm  |h| = ho x m = ho x di/do = 7 x 2.25/23 = 0.686

b. $|h_i| = 0.69$ cm

c. $|h_i| = 1.3$ cm

8) White light passes through a glass prism in a way similar to the sketch shown at right (the sketched angles are not precise). Assume that the prism is surrounded by vaccuum.

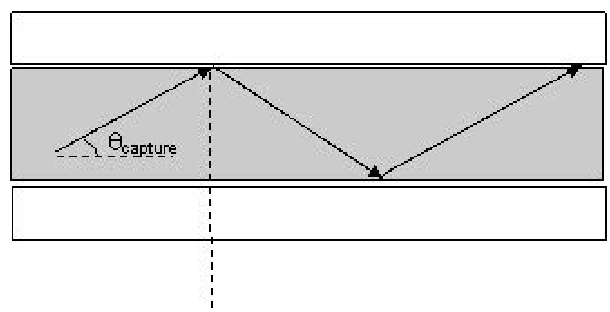
Which one of the statements below is **wrong**?




a. The index of refraction of the prism depends on the wavelength of light. ✓
b. The index of refraction of the prism is ~~greater~~ for red light than for blue light.
c. Red light gets deflected less by the prism than blue light. ✓
d. No dispersion will occur if the index of refraction of the prism does not depend on the wavelength of light. ✓
e. The index of refraction in vacuum is independent of the wavelength of light. ✓

**The next two questions pertain to the situation described below.**

A fiber optic line can transport light over long distances by using total internal reflection to reflect the light back into the fiber. The fiber shown has a core (with the index of refraction $n_{core} = 1.5$) surrounded by a material of a different index of refraction ($n_{cladding} = 1.33$). Assume there is ***NO GAP*** between the core of the fiber and the surrounding material.




9) Inside the fiber, what is the maximum angle $\theta_{capture}$ at which the light can reflect off the walls and still undergo total internal reflection?

a. $\theta_{capture} = 31.7^\circ$
b. $\theta_{capture} = 18.8^\circ$
c. $\theta_{capture} = 54.3^\circ$
d. $\theta_{capture} = 27.5^\circ$
e. $\theta_{capture} = 37.5^\circ$

```
theta capture = 90 - critical angle.

sin critical = 1.33/1.5 -> critical = 62.45
90 - 63.45 = 27.54
```

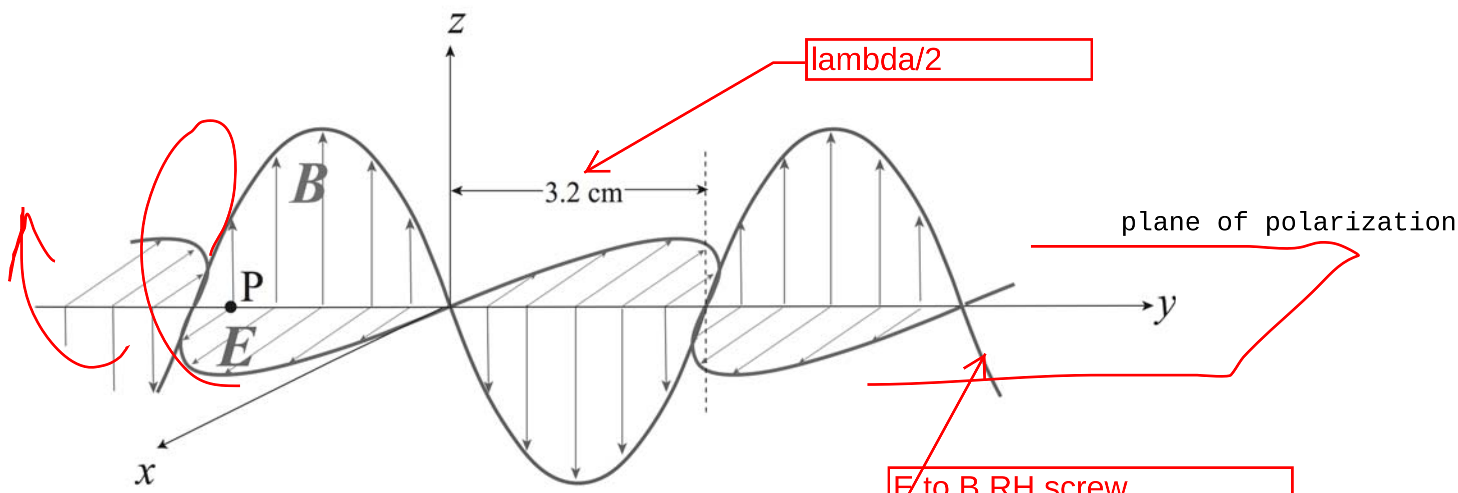
10) If the index of refraction of the cladding material is changed to 1.6, what will happen?

```
this is larger, so no internal total
reflection is possible
```

a. Total internal reflection will no longer be possible for light traveling through the core of the fiber.
b. $\theta_{capture}$ will increase.
c. $\theta_{capture}$ will decrease.

**The next five questions pertain to the situation described below.**

Consider the plane electromagnetic wave shown in the diagram below. The wave is propagating through a vacuum along the *y*-axis. The electric field of the wave is parallel to the *x*-axis and is a sine wave of amplitude 120 V/m. The accompanying magnetic field is parallel to the *z*-axis.




E to B RH screw

11) In which direction is this electromagnetic wave propagating?

a. Not enough information is given to determine the direction.
b. +*y*-direction
c. −*y*-direction

12) What is the frequency of this electromagnetic wave?

c = f lambda

a. 2.4 GHz
b. 4.7 GHz
c. 9.4 GHz

```
lambda = 6.4x10^{-2} m
f = c/lambda = 4.6875 x 10^9
```

13) Choose the correct statement from the following choices.

a. This wave is polarized along the y-axis.
b. This wave is polarized along the x-axis.
c. This wave is polarized along the z-axis

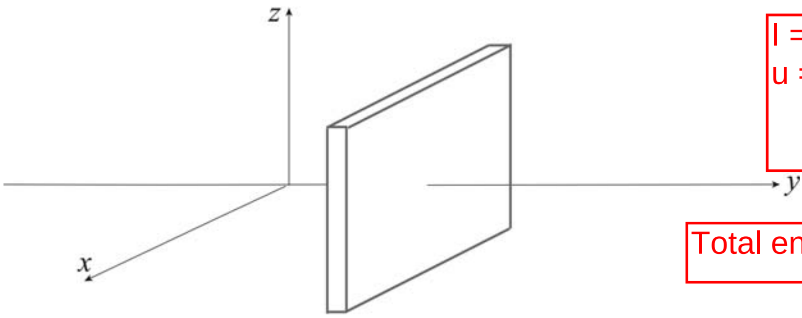
14) What is the amplitude of the magnetic field of this wave?

E = cB

a. $2 \times 10^{-7}$ T
b. $3.2 \times 10^{-7}$ T
c. $4 \times 10^{-7}$ T

```
Amp of E = 120 V/m
120/3x10^8 = 4 x 10^{-7}
```

15) A perfect absorber of the electromagnetic wave of area A = 150 $m^2$ is placed perpendicular to the y-axis as illustrated below. What is the energy this absorber receives, if it absorbs the electromagnetic wave for 10 seconds?




I = c u
u = epsilon Ermp^2 = (\epsilon/2)Eamp^2

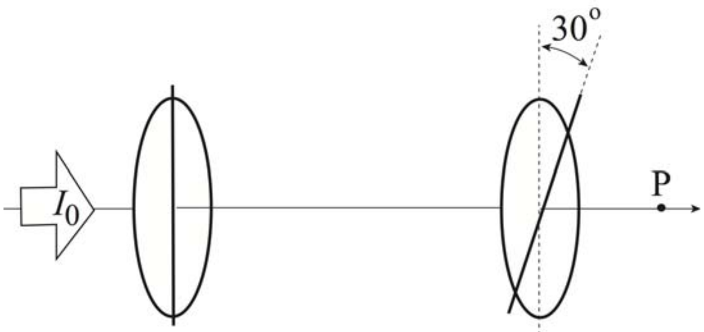
Total energy = I x A x time

a. 28.7 kJ
b. 57.4 kW
c. 57.4 kJ
d. 28.7 kW
e. 230 kW

```
E = IAt = 1500 I
I = cu
u = e_0 Emax^2/2 = 8.85x10^{-12} x 120^2/2 = 6.3 x 10^{-8}

E = 28674 J
```

**The next two questions pertain to the situation described below.**

Initially, there are two polarizers as shown in the figure below. *Unpolarized* light of intensity $I_0$ is incident from left. The transmission axis of the second polarizer makes an angle of 30 ° with the transmission axis of the first polarizer as shown in the figure.



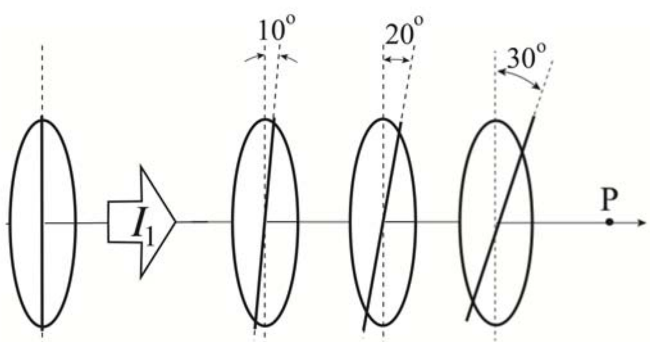

I0 -> I0/2 if unpolarized
I = I0 cos^2 theta

16) What is the intensity $I_P$ of the light at P?

a. $I_P = I_0$
b. $I_P = 3I_0/8$
c. None of the other solutions.
d. $I_P = I_0/2$
e. $I_P = 3I_0/4$

(I0/2) cos^2(30) = I0(1/2)(\sqrt{3}/2)^2 = I03/8

17) Between the above two polarizers are placed two more linear polarizers with their axes of transmission as illustrated in the following figure. (That is, each transmission axis is tilted by an additional 10 degrees relative to the previous polarizer.) The intensity of light just after the first polarizer is $I_1$.



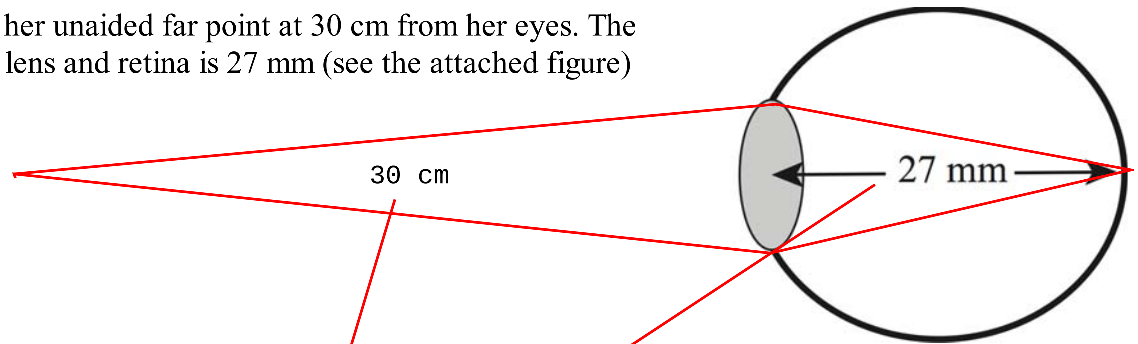

What is the intensity of light at P?

a. $I_P = 0.91I_1$
b. $I_P = 0.96I_1$
c. None of the other solutions.
d. $I_P = 0.5I_1$
e. $I_P = 0.83I_1$

I1 (cos 10)^6 = 0.912 I_1

**The next two questions pertain to the situation described below.**

A myopic person has her unaided far point at 30 cm from her eyes. The distance between her lens and retina is 27 mm (see the attached figure)



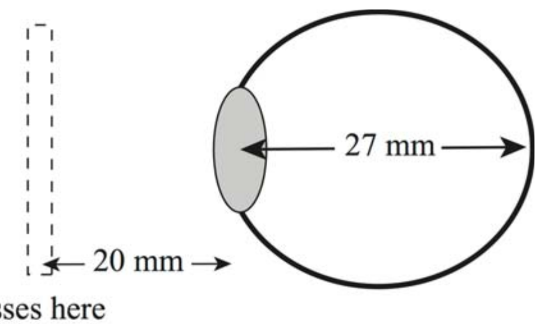

18) What is the focal length $f$ of her own lens when it is relaxed (i.e., when she is trying to see a distant object without any visual aid)?

```
1/f = 1/30 + 1/2.7  ->  f = 30x2.7/32.7 = 2.477 cm
```

a. $f$ = 2.97 cm
b. $f$ = 2.48 cm
c. $f$ = 2.7 cm

19) She needs glasses to see the scenery clearly. The lens of the glasses is held 2 cm from her eye's own lens (see the figure). What should be the focal length $f$ of lenses required for her glasses?

Place the illusion where one can see it clearly.




30 cm
the virtual image position

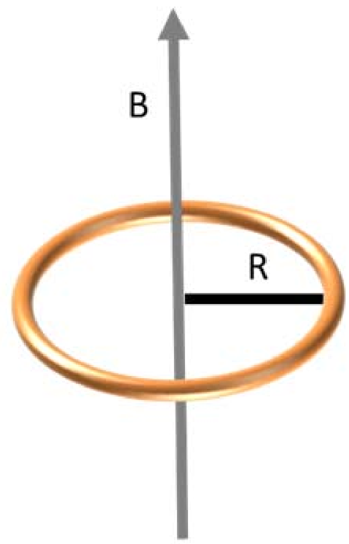
a. $f$ = + 0.33 m
b. $f$ = − 0.3 m
c. $f$ = + 0.3 m
d. $f$ = + 0.28 m
e. $f$ = − 0.28 m

```
do = infty
di = -(30 - 2) = -28.

1/f = -1/28
```

**The next two questions pertain to the situation described below.**

A uniform magnetic field with magnitude $B$ passes through a circular loop of wire of radius $R = 0.2$ m.

Throughout the following two problems the direction of the uniform magnetic field $B$ is kept **fixed,** to point **vertically up**, as shown in the figure.




20) Initially the magnitude of the magnetic field is held at a constant value of $B = 4 \times 10^{-4}$ T. When the orientation of the *loop* is altered, what is the largest possible value of the magnetic flux $\phi$ through the wire loop?

Phi = AB

a. $\phi = 1.6 \times 10^{-4}$ T m$^2$
b. $\phi = 4.1 \times 10^{-5}$ T m$^2$
c. $\phi = 5 \times 10^{-5}$ T m$^2$

pi(0.2)^2 x 4x10^{-4} = 0.502x10^{-4} Wb

21) Now the magnetic field is decreased to $B = 0$ T at a constant rate over $t = 15$ ms. What is the largest possible magnitude of the induced EMF in the wire loop during this time?

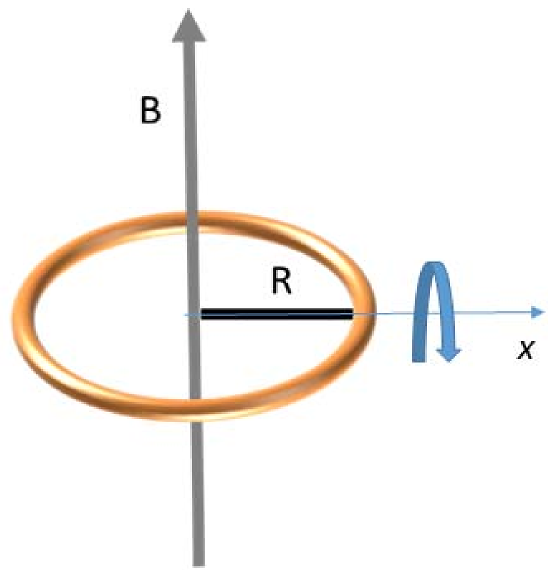
Faraday: emf = D Phi/Dt

a. $|\varepsilon| = 3.35$ mV
b. $|\varepsilon| = 66.7$ mV
c. $|\varepsilon| = 6.7$ mV
d. $|\varepsilon| = 1.66$ mV
e. $|\varepsilon| = 33.5$ mV

emf = D Phi/Dt = 5.02x10^{-5}/15x10^{-3} = 3.347 x 10^{-3} V

**The next two questions pertain to the situation described below.**

A single circular loop of wire with radius $R$ and area $A = 0.02\ \text{m}^2$ is rotating at constant angular velocity around the horizontal $x$-axis in a constant uniform magnetic field of magnitude $|B| = 0.04$ T that is pointing vertically up, as shown in the figure. An induced EMF is measured in the loop with a maximum value of $\varepsilon_{max} = 10$ mV.




The changing rate of Phi is MAX when the loop can cut B vectors most efficiently.

22) Which of the following statements about the magnetic flux through the loop is true when the induced EMF is at its maximum value?

a. The magnetic flux though the loop is zero.
b. The magnetic flux is at its maximum negative value.
c. The magnetic flux is also at its maximum value.

D Phi/D t = 0

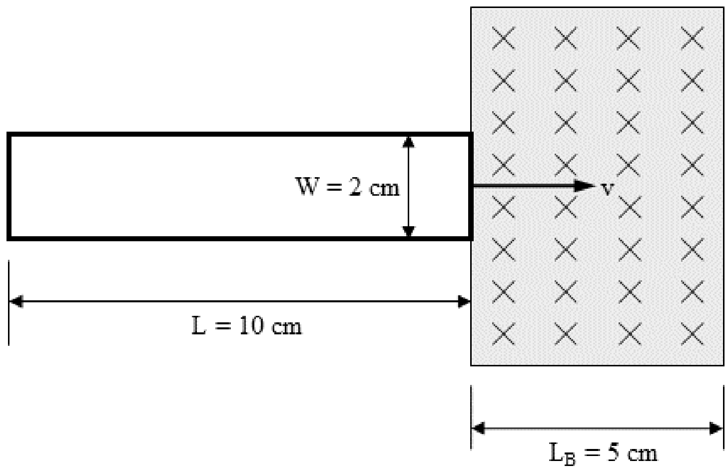
23) As the loop rotates, over time, does the EMF ever change sign ?

Sinusoidally changes around 0.

a. Yes
b. No
c. Not enough information to answer this question

**The next three questions pertain to the situation described below.**

At $t = 0$, a rectangular single-loop coil of resistance $R = 5\ \Omega$ and dimensions $W = 2$ cm and $L = 10$ cm enters a region of constant magnetic field $B = 2.5$ T directed into the paper. The loop lies in the plane of the paper. The length of the region containing the magnetic field is $L_B = 5$ cm as shown. The rectangular loop is observed to move at a constant velocity $v = 2$ cm/s to the right.




F = LIB
motional emf = LvB
I = V/R (Ohm's law)

24) What is the force required at time $t = 0.5$ s to maintain this velocity?

a. $4.0 \times 10^{-5}$ N
b. 0
c. $1.0 \times 10^{-5}$ N
d. $5.0 \times 10^{-5}$ N
e. $2.5 \times 10^{4}$ N

```
Note that the right edge is 1 cm into the field.

F = ILB
I = LvB/R
-> F = (LB)^2v/R
F = (0.02x2.5)^2 x 0.02/5 = 10^{-5} N
```

25) What is the force required at time $t = 3$ s to maintain this velocity?

```
Both the edges are outside the field, so Phi does not change.
```

a. $4.0 \times 10^{-5}$ N
b. $1.0 \times 10^{-5}$ N
c. 0

26) In which direction will the induced current flow through the loop when the loop has just begun to enter the region with the magnetic field ?

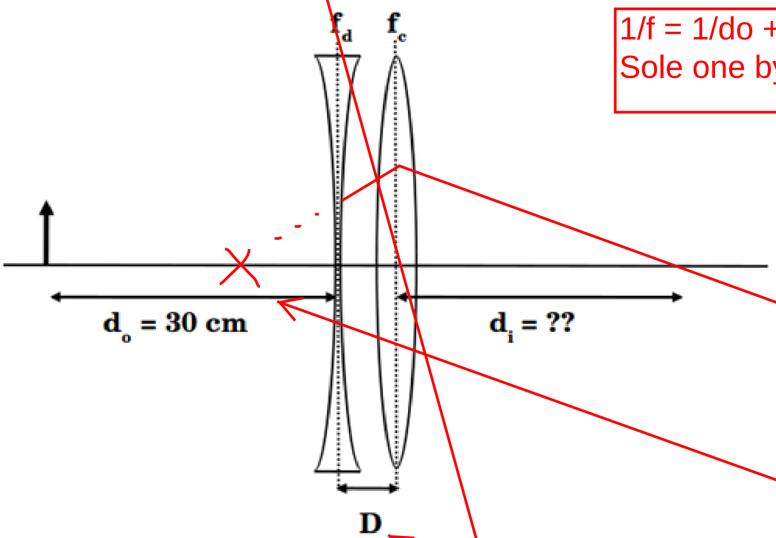
Lenz

a. Clockwise
b. Counterclockwise
c. no current will flow ever through the loop.

```
Phi into the page increases
  -> the loop wishes to kill this
    -> B  out of page must be made
-> RH screw tells us `counterclockwise
```

27) A diverging lens of focal length $f_d$ = -15 cm is placed a distance D = 5 cm to the left of a converging lens of focal length $f_c$ = +10 cm. An object is placed at **$d_0$=30 cm** to the left of the diverging lens.

1/f = 1/do + 1/di
Sole one by one




Where is the final image of the two-lens system, indicated by the distance $d_i$ in the picture above?

a. -45 cm
b. 5 cm
c. 10 cm
d. 30 cm
e. -20 cm

```
Lens 1: -1/15 = 1/30 + 1/di -> 1/di = -3/30 -> do = -10
That is, 10 cm to the left of the first lens.

Therefore, as a light source it acts as a real object for the
second lens: do = 10 + 5

Lens 2: 1/10 = 1/15 + 1/di ->
    1/di = 1/10 - 1/15 = 3/30 - 2/30 = 1/30
```