

Name KEY Student ID \_\_\_\_\_**Check your (CRN) section number (- 2 points if not checked):**

CRN	time
14291	8:00 - 8:50
14288	9:05 - 9:55
14296	10:10 - 11:00
14295	11:15 - 12:05

Students may also use their own two sided 8.5" x 11" formula sheet in addition to the formula sheet that is on the last 2 pages of this.

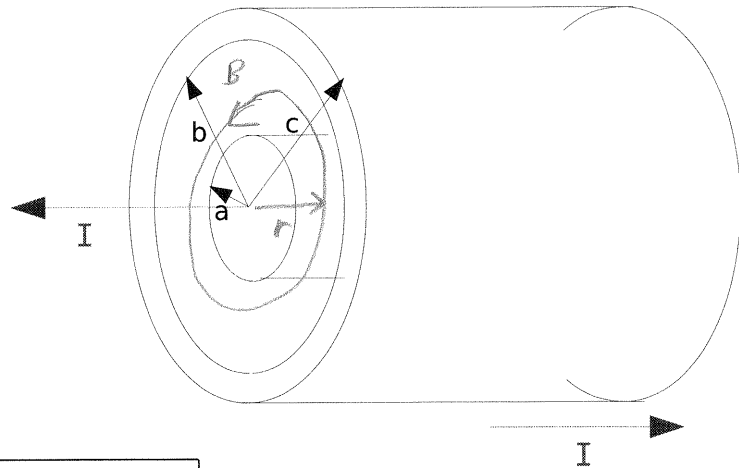
1,2. **Coaxial Cable:** A solid conductor with radius  $a$  is supported by insulating disks on the axis of a conducting tube with inner radius  $b$  and outer radius  $c$ . The central conductor and tube carry equal currents  $I$  in opposite directions. The currents are distributed uniformly over the cross sections of each conductor.

1. Find an expression for the magnitude of the magnetic field as a function of the radial distance from the center of the inner conductor,  $r$ , for  $a < r < b$ :

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{enc}$$

$$B \cdot 2\pi r = \mu_0 I$$

$$B = \frac{\mu_0 I}{2\pi r}$$



1	$\theta$	6	$\mu_0 NI$
2	$\mu_0 I / (2\pi r^2)$	7	$\mu_0 I / (4\pi r^2)$
3	$\mu_0 I / (2\pi r)$	8	$\mu_0 I / (4\pi r)$
4	$I / (2\pi\mu_0 r)$	9	$I / (4\pi\mu_0 r)$
5	$I / (2\pi\mu_0 r^2)$	10	$I / (4\pi\mu_0 r^2)$

2. Find an expression for the magnitude of the magnetic field as a function of the radial distance from the center of the inner conductor,  $r$ , for  $r > c$ :

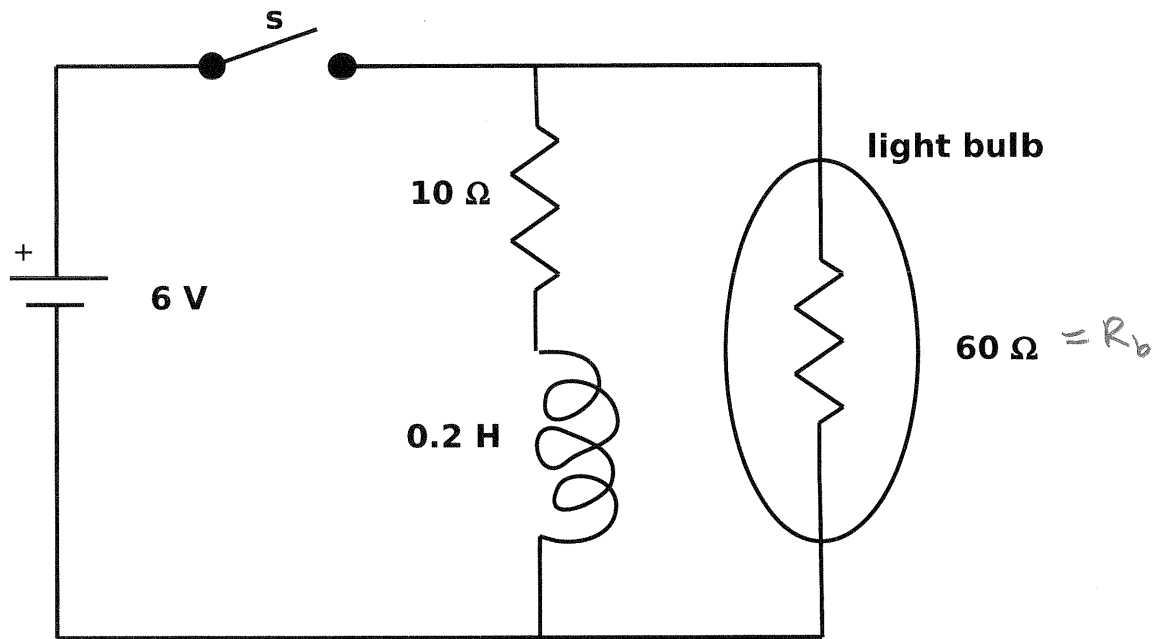
$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{enc}$$

$$I_{enc} = 0$$

$$\Rightarrow B = 0$$

1	$\theta$	6	$\mu_0 NI$
2	$\mu_0 I / (2\pi r)$	7	$\mu_0 I / (4\pi r)$
3	$\mu_0 I / (2\pi r^2)$	8	$\mu_0 I / (4\pi r^2)$
4	$I / (2\pi\mu_0 r)$	9	$I / (4\pi\mu_0 r)$
5	$I / (2\pi\mu_0 r^2)$	10	$I / (4\pi\mu_0 r^2)$

3-5



As in a lecture demonstration: After a long time the switch, **s**, above, is closed.

3. What is the current going through the inductor at the instant the switch is closed?

*Inductor is like an open circuit.*

$$i(0) = \boxed{0}$$

1	0	6	1 A
2	0.01 A	7	6 A
3	0.06 A	8	10 A
4	0.1 A	9	30 A
5	0.6 A	10	60 A

4. A long time after the switch is closed, what is the power emitted by the light bulb?

$$P = VI = (6V) \left( \frac{6V}{60\ \Omega} \right) = \boxed{0.6\ W}$$

1	0	6	0.6 W
2	0.1 W	7	3.6 W
3	0.12 W	8	21.6 W
4	0.441 W	9	42 W
5	0.514 W	10	60 W

5. After the switch has been closed for a long time the switch is opened. What will be the power emitted by the light bulb at the instant after the switch is opened?

$$i_L(\infty) = \frac{6V}{10\Omega}$$

$$P = i^2 R_b = \left(\frac{6V}{10\Omega}\right)^2 60\Omega$$

$$= \frac{6^2}{10^2} 60\text{ W} = \boxed{21.6\text{ W}}$$

1	0	6	0.6 W
2	0.1 W	7	3.6 W
3	0.12 W	<b>8</b>	21.6 W
4	0.441 W	9	42 W
5	0.514 W	10	60 W

6. A long, straight wire carries a time-varying current,  $i(t) = I_0 + \alpha t$ , where  $I_0$  and  $\alpha$  are positive constants. This means that the current in the long wire is increasing with time. The long wire and a rectangular conducting loop are positioned in the same plane as shown in the picture below. The loop has a total resistance  $R$ . The position of the wire and loop are held fixed. Find the current that is in the loop.

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = -\frac{d}{dt} \int_{r=a}^{r=3a} B(r) (b dr)$$

$$= -\frac{d}{dt} \int_{r=a}^{r=3a} \frac{\mu_0 i}{2\pi r} (b dr) = -\frac{\mu_0 b}{2\pi} \ln(r) \Big|_{r=a}^{3a} \left(\frac{di}{dt}\right)$$

$$= -\frac{\mu_0 b \ln\left(\frac{3a}{a}\right) \alpha}{2\pi} = -\frac{\mu_0 b (\ln 3) \alpha}{2\pi}$$

1	0	6	$\mu_0 \alpha b \ln(5)/(2\pi R)$
2	$\mu_0 \alpha b \ln(2)/(2\pi R)$	7	$\mu_0 \alpha b \ln(2)/(4\pi R)$
<b>3</b>	$\mu_0 \alpha b \ln(3)/(2\pi R)$	8	$\mu_0 \alpha b \ln(3)/(4\pi R)$
4	$\mu_0 \alpha b \ln(4)/(2\pi R)$	9	$\mu_0 \alpha b \ln(4)/(4\pi R)$
5	$\mu_0 \alpha b \ln(1/2)/(2\pi R)$	10	$\mu_0 \alpha b \ln(1/2)/(4\pi R)$

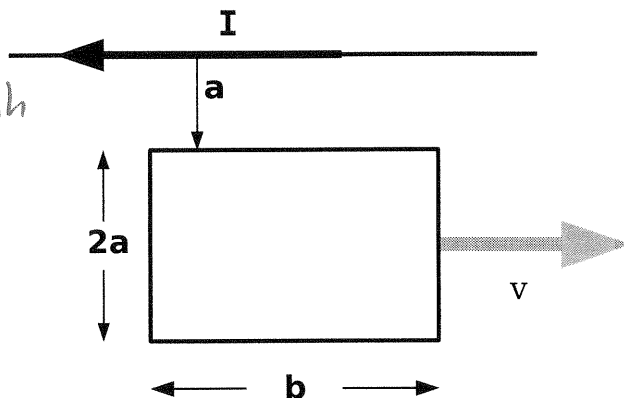
$$i_R = \frac{-\mathcal{E}}{R}$$

$$= \boxed{\frac{\mu_0 b (\ln 3) \alpha}{2\pi R}}$$

7. A long, straight wire carries a constant current  $I$ . The long wire and a rectangular conducting loop are positioned in the same plane as shown in the picture below. The loop has a total resistance  $R$ . The position of the wire is held fixed while the loop is moved to the right at constant speed  $v$ . Find the current that is in the loop.

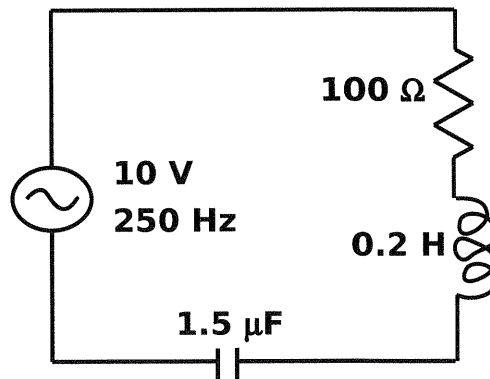
No  $\Phi_B$  is hanging through the loop.

$$\mathcal{E} = \frac{-d\Phi_B}{dt} = 0 \Rightarrow i = 0$$



1	0	6	$\mu_0 I v b \ln(5)/(2\pi R)$
2	$\mu_0 I v b \ln(2)/(2\pi R)$	7	$\mu_0 I v b \ln(2)/(4\pi R)$
3	$\mu_0 I v b \ln(3)/(2\pi R)$	8	$\mu_0 I v b \ln(3)/(4\pi R)$
4	$\mu_0 I v b \ln(4)/(2\pi R)$	9	$\mu_0 I v b \ln(4)/(4\pi R)$
5	$\mu_0 I v b \ln(1/2)/(2\pi R)$	10	$\mu_0 I v b \ln(1/2)/(4\pi R)$

8-10. The amplitude of the voltage source in the circuit shown is 10V with frequency 250 Hz.



8. Find the amplitude of the current,  $I$ , in the circuit above.

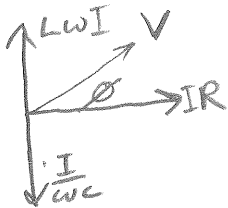
1	0	6	1 A
2	3.8 mA	7	1.3 A
3	67.2 mA	8	4.4 A
4	100 mA	9	7 A
5	200 mA	10	8.67 A

$$I = \frac{V}{Z} = \frac{V}{\sqrt{(2\pi fL - \frac{1}{2\pi fC})^2 + R^2}}$$

$$= \frac{10V}{\sqrt{(2\pi \cdot 250 \cdot 0.2 - \frac{1}{2\pi \cdot 250 \cdot (1.5 \times 10^{-6})})^2 + 100^2}}$$

$$\approx 0.067183 \approx \boxed{67.2 \text{ mA}}$$

9. Find the phase angle,  $\phi$ , between the current and the source voltage, where we define the current as  $i = I \cos \omega t$ , and the voltage source as  $v = V \cos(\omega t + \phi)$ , where  $V = 10 \text{ V}$ ,  $\omega = 2\pi \cdot 250/\text{s}$ .



$$\phi = \tan^{-1} \left[ \frac{X}{R} \right] = \tan^{-1} \left[ \frac{2\pi(250)(.2) - \frac{1}{2\pi \cdot 250 \cdot 1.5 \times 10^{-6}}}{100} \right]$$

$$\approx -47.792^\circ$$

1	0 °	6	-26.6 °
2	6.6 °	7	-47.8 °
3	26.5 °	8	-67.3 °
4	34.2 °	9	-72.4 °
5	67.8 °	10	-87.8 °

10. If the 250 Hz source voltage frequency can be varied, at what frequency will the power through the resistor be maximized?

$$X_L = X_C \Rightarrow \omega L = \frac{1}{\omega C} \Rightarrow \omega^2 = \frac{1}{LC} = (2\pi f)^2$$

$$\Rightarrow f^2 = \frac{1}{(2\pi)^2 LC}$$

1	0.29 Hz	6	291 Hz
2	0.91 Hz	7	913 Hz
3	1.83 Hz	8	1825 Hz
4	50 Hz	9	11,470 Hz
5	200 Hz	10	15,150 Hz

$$\Rightarrow f = \frac{1}{2\pi} \left[ \frac{1}{(.2) \cdot 1.5 \times 10^{-6}} \right]^{1/2} \text{ Hz}$$

$$= 290.576 \text{ Hz}$$

11. A space probe  $2 \times 10^{10} \text{ m}$  from a star measures the total intensity of electromagnetic radiation from the star to be  $5 \times 10^3 \text{ W/m}^2$ . If it radiates uniformly in all directions, what is the total average power output from the star?

$$I = \frac{P}{4\pi r^2} \Rightarrow P = (4\pi r^2) I = 4\pi (2 \times 10^{10})^2 5 \times 10^3 \frac{\text{W}}{\text{m}^2}$$

$$= 80\pi \cdot 10^{23} \text{ W} \approx 2.5133 \times 10^{25} \text{ W}$$

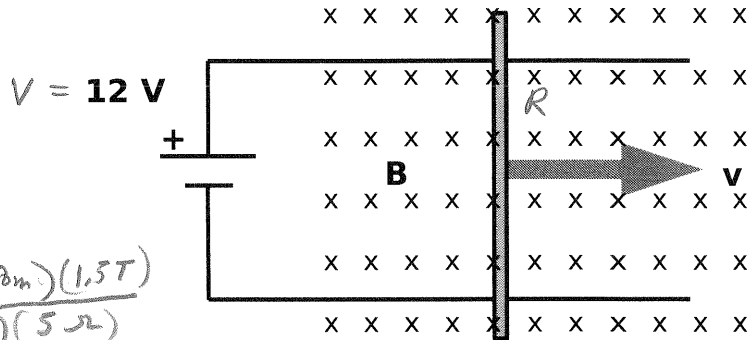
1	0	6	$1.26 \times 10^{15} \text{ W}$
2	$9.95 \times 10^{-19} \text{ W}$	7	$2 \times 10^{24} \text{ W}$
3	$1.25 \times 10^{-17} \text{ W}$	8	$1.26 \times 10^{25} \text{ W}$
4	$1 \times 10^{14} \text{ W}$	9	$2.5 \times 10^{25} \text{ W}$
5	$6.28 \times 10^{14} \text{ W}$	10	$5 \times 10^{25} \text{ W}$

12-14 A bar of length  $L=0.8\text{m}$  is free to slide without friction on horizontal rails, as shown in the figure. There is a uniform magnetic field  $B=1.5\text{T}$  directed into the plane of the figure. At one end of the rails there is a battery with emf of  $12\text{V}$ . The bar has a mass of  $0.9\text{ kg}$  and resistance  $5\text{ ohms}$ , and all other resistance in the circuit can be ignored. The bar starts at rest ( $v=0$ ).

$$I = \frac{V}{R}$$

$$F = I l B = \frac{V l B}{R}$$

$$a = \frac{F}{m} = \frac{V l B}{m R} = \frac{12\text{V} (0.8\text{m}) (1.5\text{T})}{(0.9\text{kg}) (5\Omega)}$$



12. What is the acceleration of the bar when it is just released ( $v=0$ )?

$$\approx \boxed{3.2 \text{ m/s}^2}$$

1	0	6	3.2 m/s <sup>2</sup>
2	0.64 m/s <sup>2</sup>	7	4 m/s <sup>2</sup>
3	2 m/s <sup>2</sup>	8	8 m/s <sup>2</sup>
4	2.56 m/s <sup>2</sup>	9	16 m/s <sup>2</sup>
5	2.88 m/s <sup>2</sup>	10	32 m/s <sup>2</sup>

13. What is the acceleration of the bar when the speed of the bar is  $v=2\text{m/s}$ ?

$$a = \frac{(V - \mathcal{E}) l B}{m R} = \frac{(V - v B l) l B}{m R} = \frac{(12\text{V} - 2\text{m/s} (1.5\text{T}) (0.8\text{m})) (0.8\text{m}) (1.5\text{T})}{(0.9\text{kg}) (5\Omega)}$$

$$= 2.56 \text{ m/s}^2$$

1	0	6	3.2 m/s <sup>2</sup>
2	0.64 m/s <sup>2</sup>	7	4 m/s <sup>2</sup>
3	2 m/s <sup>2</sup>	8	8 m/s <sup>2</sup>
4	2.56 m/s <sup>2</sup>	9	16 m/s <sup>2</sup>
5	2.88 m/s <sup>2</sup>	10	32 m/s <sup>2</sup>

14. What is the terminal speed of the bar? Put another way: what is the speed of the bar after a long time (assuming that the rails are very long)?

$$V - v_t B l = 0 \Rightarrow v_t = \frac{V}{Bl} = \frac{12V}{(1.5T)(.8m)} = 10 \text{ m/s}$$

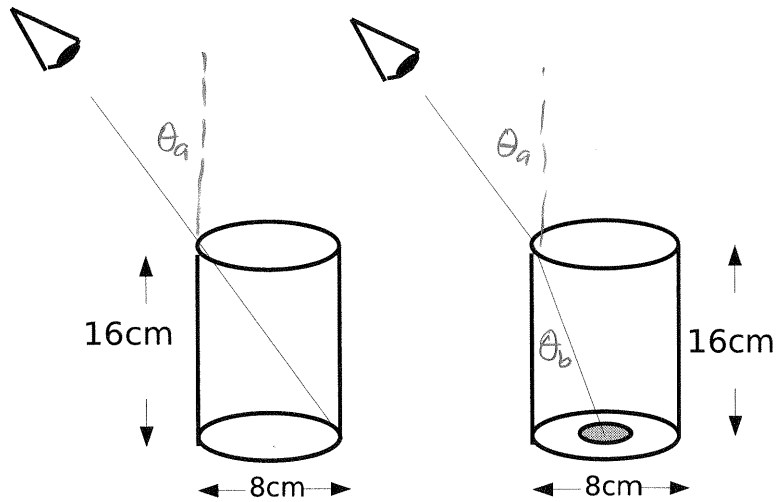
1	0	6	10 m/s
2	1 m/s	7	12 m/s
3	2 m/s	8	13.5 m/s
4	3.2 m/s	9	15 m/s
5	8 m/s	10	20.25 m/s

15.

$$n_a \sin \theta_a = n_b \sin \theta_b$$

$$\Rightarrow n_b = n_a \frac{\sin \theta_a}{\sin \theta_b}$$

$$= n_a \frac{\frac{8}{\sqrt{8^2+16^2}}}{\frac{4}{\sqrt{4^2+16^2}}}$$



You sight along the rim of a glass with vertical sides so that the top rim is lined up with the opposite edge of the bottom. The glass is a thin-walled hollow cylinder 16cm high and has a diameter of 8cm. While you keep your eye in the same position, a friend fills the glass with a transparent liquid, and then you see a dime that is lying at the center of the bottom of the glass. Ignore the size of the dime. What is the index of refraction of the liquid?

$$= n_a \frac{\sqrt{4^2+16^2}}{\sqrt{8^2+16^2}} = n_a \frac{(4)\sqrt{1+16}}{(8)\sqrt{1+4}}$$

$$= \sqrt{\frac{17}{5}} \approx 1.84391$$

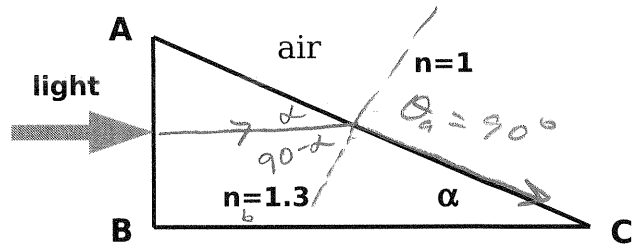
1	0.54	6	1.4
2	0.8	7	1.5
3	1	8	1.6
4	1.2	9	1.7
5	1.3	10	1.8



16.

$$n_b \sin \theta_b = n_a \sin \theta_a$$

$$\Rightarrow n_b \sin(90^\circ - \alpha) = n_a$$



Light is incident along the normal on the face A B of a glass prism of refractive index 1.3, as shown in the figure. Find the largest value the angle  $\alpha$  can have without any light being refracted out of the prism face A C if the prism is immersed in air.

$$\Rightarrow \sin(90^\circ - \alpha) = \frac{n_a}{n_b} \Rightarrow -\sin(\alpha - 90^\circ) = \frac{1}{n_b} \Rightarrow \cos \alpha = \frac{1}{n_b}$$

$$\Rightarrow \alpha = \cos^{-1}\left(\frac{1}{1.3}\right) = 39.715^\circ$$

1	0	6	41.1 °
2	12.2 °	7	50.3 °
3	22.2 °	8	62 °
4	28.7 °	9	70 °
5	39.7 °	10	-10 °

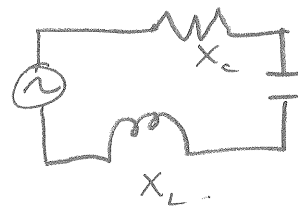
17,18 A resistance R, and capacitance C, and inductance L are connected in series with a voltage source with amplitude V and variable angular frequency  $\omega$ . If the angular frequency,  $\omega$ , is set to the resonant angular frequency  $\omega_0$ :

$$\omega_0^2 = \frac{1}{LC}$$

17. What will be the maximum current through the resistor? and

$$I = \frac{V}{Z} = \frac{V}{R}$$

1	LC/R	6	$\frac{1}{2} L (V/R)^2$
2	VLC/R	7	$\frac{1}{2} C (L/R)^2$
3	R/V	8	$\frac{1}{2} C V^2$
4	V/R	9	$\frac{1}{2} V (1/LC)^2$
5	V/(LC)	10	$\frac{1}{2} R (V/C)^2$



$$X_L = X_C \Rightarrow Z = R$$

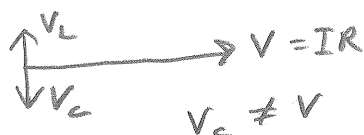
18. What will be the maximum energy stored in the capacitor?

$$E_{Cmax} = \frac{1}{2} C V_c^2 = \frac{1}{2} C \left(\frac{I}{\omega C}\right)^2 = \frac{1}{2} C \left(\frac{V/R}{\omega C}\right)^2 = \frac{1}{2} R \frac{V^2}{R^2 \omega_0^2 C}$$

1	LC/R	6	$\frac{1}{2} L (V/R)^2$
2	VLC/R	7	$\frac{1}{2} C (L/R)^2$
3	R/V	8	$\frac{1}{2} C V^2$
4	V/R	9	$\frac{1}{2} V (1/LC)^2$
5	V/(LC)	10	$\frac{1}{2} R (V/C)^2$

$$= \frac{1}{2} \frac{V^2}{R^2} \frac{LC}{C} = \frac{1}{2} L \left(\frac{V}{R}\right)^2$$

same as max energy in inductor.



19. Three polarizing filters are stacked, with the polarizing axis of the second and third filters at  $23^\circ$  and  $62^\circ$ , respectively, to that of the first. If unpolarized light is incident on the stack, the light has intensity  $75 \text{ W/cm}^2$  after it passes through the stack. If the incident light is kept constant, what is the intensity of the light after it has passed through the stack if the second polarizer is removed?

$$I = \left(\frac{I_0}{2}\right) \cos^2 23^\circ \cos^2 (62^\circ - 23^\circ)$$

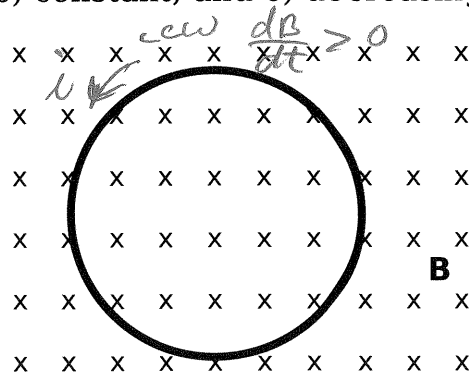
$$I' = \left(\frac{I_0}{2}\right) \cos^2 62^\circ \Rightarrow I' = \frac{I \cos^2 62^\circ}{\cos^2 23^\circ \cdot \cos^2 (62^\circ - 23^\circ)}$$

$$= \frac{75 \text{ W/cm}^2 \cos^2 62^\circ}{\cos^2 23^\circ \cos^2 (62^\circ - 23^\circ)}$$

$$= \boxed{32.3015 \text{ W/cm}^2}$$

1	0	6	41 W/cm <sup>2</sup>
2	9.7 W/cm <sup>2</sup>	7	55 W/cm <sup>2</sup>
3	19.5 W/cm <sup>2</sup>	8	67.3 W/cm <sup>2</sup>
4	24.3 W/cm <sup>2</sup>	9	71 W/cm <sup>2</sup>
5	32.3 W/cm <sup>2</sup>	10	75 W/cm <sup>2</sup>

20. A circular loop of wire is in a region of spatially uniform magnetic field. The magnetic field is directed into the paper. Determine the direction (clockwise=cw, counterclockwise=ccw, or none) of the current in the loop when the the magnetic field is a) increasing, b) constant, and c) decreasing.



	a	b	c		a	b	c
1	cw,	none,	ccw	6	none,	ccw,	cw
2	ccw,	none,	cw	7	none,	ccw,	ccw
3	none,	cw,	none	8	cw,	none,	none
4	none,	ccw,	none	9	cw,	none,	cw
5	cw,	ccw,	ccw	10	ccw,	none,	ccw