PHY2054 - Exam 3 - Fall 1997 - Selman Hershfield

1. Since this problem only asks for the magnitude of the force on the loop, it does not matter which direction the current is flowing in the loop. To be definite, let us take the current to be flowing clockwise in the loop. A counterclockwise current will give a force in the opposite direction, but with the same magnitude. The force on the left and right segments of the loop are:

$$\begin{aligned}\text{F on right segment} &= \frac{\mu_o(6A)(10A)(8cm)}{2\pi\, 2cm} \approx 4.8 \times 10^{-5}N \text{ to the left} \\ \text{F on left segment} &= \frac{\mu_o(6A)(10A)(8cm)}{2\pi\, 4cm} \approx 2.4 \times 10^{-5}N \text{ to the right,}\end{aligned}$$

   since wires with the current flowing in the same direction attract and wires with currents flowing in opposite directions repel. Adding these forces like vectors, the net force has magnitude $\mathbf{2.4 \times 10^{-5}N}$.

2. When the current is flowing in a wire out of the page, the magnetic field goes counterclockwise around the wire. When the current is flowing into the page, the magnetic field goes clockwise around the wire. Using these one can determine the direction of the magnetic field due to each wire individually:

wire	direction of magnetic field
top left wire	45 degrees
top right wire	315 degrees
bottom left wire	135 degrees
bottom right wire	45 degrees

   Since the currents are equal in magnitude, the fields created by the wires have the same magnitude at the center of the square. Adding the magnetic fields as vectors, the net magnetic field at C is at **45 degrees**.

3. The magnetic fields in regions I, II, and III are the sum of the magnetic fields due to the two wires. First determine the direction of the magnetic field produced by each wire.

	region I	region II	region III
1 A wire	out of page	into page	into page
2 A wire	into page	into page	out of page

   Only in regions I and III can the magnetic fields cancel; however, in order to cancel, the magnitudes must be equal. Since the 2 A wire carries more current, we must be further away from it. This occurs in region **I only**.

4. If the current in the wire increases, then the magnetic flux through the loop increases into the page. To oppose this, the induced current produces a flux out of the page – **(i) counterclockwise**. If the loop moves away from the wire, then the flux through the loop decreases (into the page). To oppose this change in flux, the induced current produces a flux into the page – **(ii) clockwise**.

5. Remembering that the magnetic field is measured relative to the normal in computing the flux, the initial and final fluxes are:

$$\begin{aligned}\text{initial flux} &= (0.3T)\pi(0.13m)^2\cos(60)\\ \text{final flux} &= (0.3T)\pi(0.13m)^2\cos(80).\end{aligned}$$

The change in flux per unit time gives the induced voltage or emf, which in turn gives the current via Ohm's law:

$$I = \frac{V}{R} = \frac{1}{250\Omega}\frac{|(0.3T)\pi(0.13m)^2(\cos(80)-\cos(60))|}{2sec} \approx \mathbf{1\times 10^{-5}A}.$$

6. As the loop enters the 1T field going into the page, the flux into the page increases. To oppose this change the induced current produces a flux out of the page – **(i) counterclockwise**. As the loop leaves the 1T into-the-page field and enters the 1T out-of-the-page field, the flux out of the page increases. To oppose this change the induced current produces a flux into the page – **(ii) clockwise**. Finally, as the loop leaves the 1T out-of-the-page region, the flux out of the page decreases. To oppose this change, the induced current produces a flux out of the page – **(iii) counterclockwise**.

7. First compute the induced emf or voltage in the loop, which by Faraday's law is equal to the change in flux per unit time. The change in flux arises because one is both leaving a 1T into-the-page field and entering a 1T out-of-the-page field. Both of these changes in flux lead to induced currents in the same direction. ⇒

$$V = (5m/s)(1T)(0.02m) + (5m/s)(1T)(0.02m) = 0.2\mathrm{V}olts.$$

The current is $I = 0.2V/200\Omega = 0.001A$. Using the right hand rule, the left and right segments of the loop both have a force to the left, while the forces on the top and bottom segments cancel each other. Thus, the net force due to the magnetic field is to the left and equal to

$$F = (0.001A)0.02m)(1T) + (0.001A)0.02m)(1T) = \mathbf{4\times 10^{-5}N}.$$

8. Since the generator is rotating counterclockwise, the flux going to the right through the loop is decreasing. To oppose this change the induced current produces a flux going to the right. In the picture, this is a counterclockwise current in the loop, which leads to the current going **from A to B in (i)**. Since this is a DC generator, the current will always be flowing in the same direction. Thus, when it rotates by 90 degrees the current will also be going **from A to B in (ii)**. You can verify this by examining the pictures on the Web.

9. **Done correctly.**

10. The speed of light in a material with index of refraction, n, is $v = c/n$. The circumference of the earth is $2\pi r$, where r is the radius of the earth. Thus, the time it takes to go around the earth is

$$t = \frac{2\pi r}{c/n} = \mathbf{0.2s}.$$

11. Using Malus's law, the intensity of the outgoing light is

$$I = I_o \cos^2(160 - 130) \cos^2(0 - 160) \cos^2(50 - 0) = \mathbf{0.27I_o}.$$

12. Remember, the angle of incidence is measured relative to the normal. The angle of incidence for the first interface is 20 degrees. $\Rightarrow$ The angle of transmittance is

$$1.1 \sin(20) = 1.2 \sin(\theta) \rightarrow \theta = 18.27\ .$$

This same angle of 18.27 degrees is also the angle of incidence for the second interface because the two interfaces are parallel $\Rightarrow$

$$1.2 \sin(18.27) = 1.8 \sin(\theta') \rightarrow \theta' = 12.06\ .$$

Again, the transmitted angle is measured relative to the normal. Since the normal is 30 degrees above the horizontal, the transmitted light is 30 - 12 = **18 degrees** above the horizontal.

13. Since the image is virtual, $d_i < 0$, and the magnification is positive,

$$m = -\frac{d_i}{d_o} = \frac{h_i}{h_o} = \frac{0.4cm}{1cm} = 0.4 \rightarrow d_i = -0.4d_o = -0.4(5cm) = -2cm.$$

Using the equation relating the object and image distances, the radius of curvature is then

$$\frac{1}{5cm} + \frac{1}{-2cm} = \frac{1}{f} \rightarrow f = -3.33cm \rightarrow |R| = 2|f| = \mathbf{6.7cm}.$$

14. First determine the image distance and the magnification:

$$\begin{aligned} \frac{1}{18cm} + \frac{1}{d_i} &= \frac{1}{36cm} \rightarrow d_i = -36cm \\ m &= -\frac{-36cm}{18cm} = 2. \end{aligned}$$

The image is **virtual** because $d_i < 0$. It is **upright** because $m > 0$, and it is **larger than the object** because $|m| > 1$.

15. The image is at **D**. It is real and inverted.

16. The image is at **B**. It is virtual and upright.

17. This problem may be solved either by drawing another set of ray diagrams with objects slightly closer or by reasoning from the equations. Here, we present the result derived from the equation approach.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \rightarrow 1 + \frac{d_o}{d_i} = \frac{d_o}{f} = 1 - \frac{1}{m}.$$

For the converging lens case, $f > 0$ and $m < 0$. As d_o decreases, $-1/m$ must also decrease, which means that the magnitude of m increases. The image becomes **larger in (i)**.

For the convex mirror case, $f < 0$ and $m > 0$. As d_o decreases, $-1/m$ must become more negative, which means that m increases. The image becomes **larger in (ii)**.

18. In order for the image to be real, d_i must be positive:

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} > 0.$$

Since $f < 0$ for a diverging lens, we see that d_o must be negative for d_i to be positive. Thus, the above equation can be rewritten as

$$\frac{1}{|d_o|} - \frac{1}{|f|} > 0 \rightarrow |f| > |d_o|.$$

The only region where $d_o < 0$ and $|d_o| < |f|$ is **region III**.

19. The object distance for the first lens is $d_o = |-4cm - -17cm| = 13cm$ so the image distance is

$$\frac{1}{13cm} + \frac{1}{d_i} = \frac{1}{2cm} \rightarrow d_i = 2.36cm.$$

This image is located at $x = -4 + 2.36 = -1.63cm$ on the x-axis and is a distance $d'_o = 2 - -1.63 = 3.63cm$ from the second lens. The image created by the second lens is thus at

$$\frac{1}{3.63cm} + \frac{1}{d_i} = \frac{1}{-8cm} \rightarrow d_i = -2.5cm,$$

which corresponds to $x = 2 + -2.5 = -\mathbf{0.5cm}$.

20. The net magnification is the product of the magnifications for the individual lenses:

$$m = \left(-\frac{2.36cm}{13cm}\right)\left(-\frac{-2.5cm}{3.63cm}\right) \approx -\mathbf{0.12}.$$