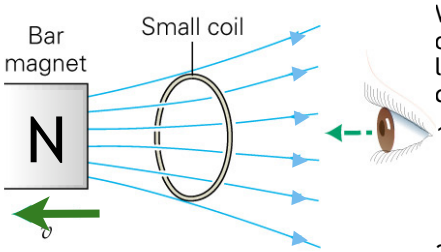
Exam IV: Chapters 20—23

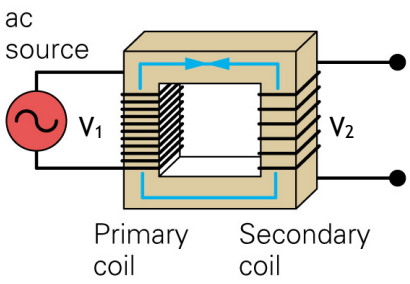


We want to use the magnet shown on the left to induce a current in the closed loop of wire. As shown in the picture, your eye is at some position +x, and you are looking at the loop in the yz-plane. The magnet is pulled away from you, in the −x direction.

1. The direction of the current in the loop is
   A) clockwise.
   B) counterclockwise.
   C) neither; no current is induced.

2. If we keep the magnet stationary, and spin the loop clockwise (loop is initially in the yz-plane, spin with respect to y-axis),
   A) the magnetic flux through the loop decreases until the loop is flat (in the xy-plane of the paper).
   B) the magnetic flux increases until the loop is flat.
   C) the magnetic flux does not change. It is zero no matter how you spin the loop of wire.
   D) the magnetic flux remains constant (and non-zero)because the magnetic field remains constant.
   E) the flux changes, but there is no way to tell if it is increasing or decreasing unless we have the area of the loop and the number of coils that make up the loop.

A transformer shown on the right. There are **N_1 = 60,000** primary coils and **N_2 = 20,000** secondary coils. With a voltage **V_1 = 150,000V**, the primary coil delivers **12MW** of power to the secondary circuit.



3. What is the **secondary voltage V_2**? Answer to the nearest integer.

$$\frac{N_1}{V_1}=\frac{N_2}{V_2}\Rightarrow V_2=\frac{N_2V_1}{N_1}=\frac{(20{,}000)(150{,}000\text{V})}{(60{,}000)}=50{,}000\text{V}$$

4. What is the **current I_2** through the secondary circuit? Answer to the nearest integer.

$$P=IV\Rightarrow I_2=\frac{P}{V_2}=\frac{12\times10^6\text{W}}{5\times10^4\text{V}}=240\text{A}$$

5. This is an example of a
   A) step-up transformer. **B) step-down transformer.**

6. True or false: The frequency of mid-range infrared radiation is literally 1000x higher than frequency of mid-range microwave radiation.

7. True or false: Low frequency radio waves travel more slowly through space than very high frequency gamma rays..

8. What is the **wavelength** in nm of green light which has a frequency **f = 5.1x10^{14}Hz**? Answer in nm (nm = 10^{-9}m) with two significant digits.

$$c=\lambda f\Rightarrow\lambda=\frac{c}{f}=\frac{3\times10^8\,\frac{\text{m}}{\text{s}}}{5.1\times10^{14}\,\text{Hz}}=5.88\times10^{-7}\text{m}=588\text{nm}$$

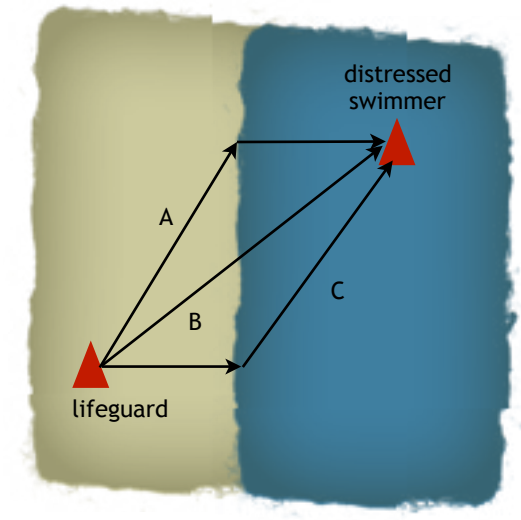
9. True or false: Ultraviolet radiation with frequency 10^{16}Hz is literally 1000 times more energetic than infrared radiation with a frequency of 10^{13}Hz.

10. Compute the energy of violet visible light having a wavelength **λ = 4.5x10^{-7}m**. Planck's constant **h = 6.63x10^{-34}J·s**.

$$E=hf=\frac{hc}{\lambda}=\frac{\left(6.63\times10^{-34}\,\text{J}\cdot\text{s}\right)\left(3\times10^8\,\frac{\text{m}}{\text{s}}\right)}{4.5\times10^{-7}\,\text{m}}=4.4\times10^{-19}\,\text{J}$$

A) 9.9x10^{-49}J. B) 3.0x10^{-40}J. C) 9.0x10^{-32}J. D) 1.5x10^{-27}J. **E) 4.4x10^{-19}J**

11. Specular reflection occurs when
   A) randomly oriented rays of light pass through a narrow aperture. The result is a narrow beam of polarized light.
   B) randomly oriented rays of incoming light reflect off a smooth surface. The reflected rays are all normal to the surface.
   C) randomly oriented rays of incoming light reflect off a rough surface. The reflected rays are all random as well.
   D) parallel rays of light are reflected from a rough or uneven surface. The reflected rays are not parallel.
   E) parallel rays of incoming light are reflected from a smooth surface. The reflected rays are parallel.



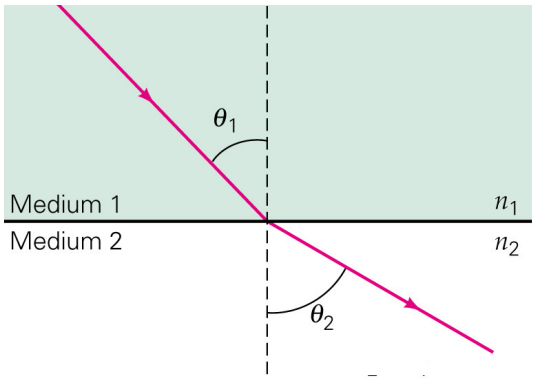
A lifeguard sees a distressed swimmer in the water. The guard can run faster across the sand than he can swim through the water.

12. To reach the swimmer in the least amount of time, which path should the lifeguard take? **A**
    D) Any of the paths marked; it does not make any difference.
    E) None of the paths; the swimmer is distressed because he is being eaten by a shark. If the lifeguard knows what's good for him, he will stay out of the water entirely.

13. What does the previous question have to do with the behavior of light?
    A) Nothing. Totally non sequitur.
    B) It illustrates that the shortest path from one point to another is always a straight line. Light will always follow the shortest length path from one point to another.
    C) It demonstrates the concept of least time. The path that takes the least time may not be the path of least distance. Light will always follow the fastest path from one point to another.
    D) It proves that light has a particle-wave duality. Sometimes light behaves like a particle (metaphorically, the sand), but sometimes it manifests wave behavior (analogous to the water).

14. When light passes from one medium to another,
    A) it changes speed. The wave will change direction, bending toward the slower medium.
    B) it continues to travel at 3×10^8 m/s regardless of the type of medium or the angle of incidence.
    C) it always slows down, and it always refracts by the same amount regardless of the angle of incidence.
    D) it always speeds up, and it never refracts unless the angle of incidence is less than the critical angle.
    E) it bends only when it strikes the boundary between the media at a 90° angle to the surface.

A beam of light is shown on the right striking a boundary between two media. Neither medium is vacuum or air, and Medium 1 is not the same as Medium 2. Answer Questions 15 through 17 using this ray diagram.



15. At what angle of incidence will the incident ray experience no refraction as it crosses the boundary into Medium 2?
    A) When $\theta_1 = 90°$, $\theta_2 = 0°$.
    B) When $\theta_1 = 45°$, $\theta_2 = 45°$. This is zero refraction.
    C) When θ_1 = zero, θ_2 also = 0°.
    D) There is no possible incident angle for zero refraction, since the two media are not the same.

16. **True** or false: The index of refraction n_1 must be greater than the index of refraction n_2.

17. **True** or false: There exists a critical angle of incidence θ_c beyond which any incident light will be totally internally reflected back into Medium 1.

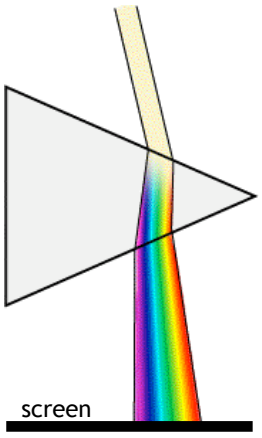
18. The index of refraction for lucite is **n = 1.495**. What is the speed of light through this medium?

$$v = \frac{c}{n} = \frac{3\times10^8 \frac{\text{m}}{\text{s}}}{1.495} = 2.0\times10^8 \frac{\text{m}}{\text{s}}$$

A) v = 2.0x10⁸m/s. B) v = 2.3x10⁸m/s. C) v = 3x10⁸m/s. D) v = 4.5x10⁸m/s.

19. Light traveling through water strikes the surface of the air at an angle of **30°** with respect to the normal. The index of refraction for water is **n = 1.33**. Find the angle of refraction, and answer with two sig figs.

$$n_1\sin\theta_1 = n_2\sin\theta_2 \Rightarrow \theta_2 = \sin^{-1}\left[\frac{n_1\sin\theta_1}{n_2}\right] = \sin^{-1}\left[\frac{1.33\sin 30°}{1}\right] = 41.7°$$



20. What is the **critical angle** for total internal reflection for water (n=1.33) and air (n=1)?

$$\sin\theta_c = \frac{n_2}{n_1} \Rightarrow \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1}{1.33}\right) = 48.8°$$

White light shines through a prism and strikes a screen as shown on the right.

21. Reading from **left to right**, in what order do the colors appear on the screen?
    A) ROY G BIV **B) VIB G YOR** C) BRI G VOY D) GIB V YOR
    E) The colors might appear in any order at all. It depends on the index of refraction of the glass used to make the prism.

You are vacationing in Hawaii, and after a late afternoon rainshower, you see a rainbow. No, wait! It's a *double* rainbow!

22. Who doesn't love a rainbow?
    A) The primary rainbow reads "ROYGBIV" from top to bottom. So does the secondary rainbow, just fainter.
    B) The primary rainbow reads "ROYGBIV" from bottom to top. So does the secondary rainbow, just fainter.
    C) The primary rainbow reads "ROYGBIV" from bottom to top. But the secondary rainbow reads "ROYGBIV" from top to bottom.
    D) The primary rainbow reads "ROYGBIV" from top to bottom. But the secondary rainbow reads "ROYGBIV" from bottom to top.
    E) The primary rainbow has a pot of gold guarded by a genial (slightly drunk) leprechaun. The secondary rainbow has a pot of haggis guarded by a surly (slightly drunk) Scotsman. Who knows how either one of them got to Hawaii.

23. If a mirror has a concave shape,
    A) the law of reflection states that the angle of reflection is always smaller than the angle of incidence. This is why concave mirrors can only make smaller reflected images.
    B) the law of reflection states that the angle of reflection is always larger than the angle of incidence. This is why the images formed are always magnified larger than the object.
    C) the angle of reflection may be larger or smaller than the angle of incidence. It will depend on the object distance from the mirror. When $\theta_i < \theta_r$ you see a magnified image, but when $\theta_i > \theta_r$ when the reflected image is smaller.
    D) the law of reflection is the same as for any other shape mirror: $\theta_i = \theta_r$.

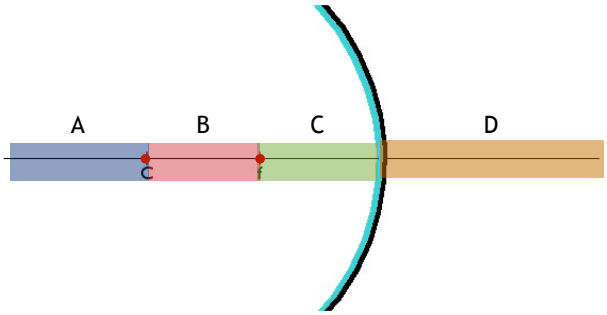
24. True or **false**: To increase the field of view of a plane mirror, just hold it farther away from you. Double the distance, double the field of view.

25. True or **false**: When the image of a real object is formed by a plane mirror, the image distance d_i will be less than the object distance, d_o.

26. You have a really tall friend. Really, *really* tall: he is 80 inches tall, head to toe. As you are walking through the Target store, he suddenly remembers that he needs a full-length mirror. They have several to choose from, and he picks the one that is 36" because it's the least expensive.
    A) The Target is amazing. They always have exactly what you need. The 36" mirror is perfectly adequate, no matter how tall you are. He just needs to mount it higher on the wall than a shorter person would.
    B) The mirror is too short for him. He needs a longer mirror to be able to see his full image. He needs an 80" mirror to match his 80" height, so he probably should return that 36" mirror.
    C) The 36" mirror is shorter than he is, but if he steps away from the mirror he will see his entire image. He just needs to stand at a distance twice his height away from the mirror.
    D) Tell your friend to return the 36" mirror and get a 48" instead. He doesn't actually need a full 48", but a 4-ft mirror is definitely large enough for him to see a full-length image of himself, even if he is wearing a tall tophat of the style favored by Abraham Lincoln.

27. When you use a second mirror to look at the back of your head, you are seeing
    A) the real image of a real object.
    B) the real image of a virtual object.
    C) the virtual image of a real object.
    D) the virtual image of a virtual object.
    E) an optical illusion invented by Alfred Hitchcock, and used thematically to great effect in his classic thriller "Psycho."

28. A convex mirror
    A) is also known as a converging mirror.
    B) affects light the same way a converging lens does.
    C) can be used to form an image exactly the same height as the object.
    D) is most useful for the correction of farsightedness.
    E) None of the above.

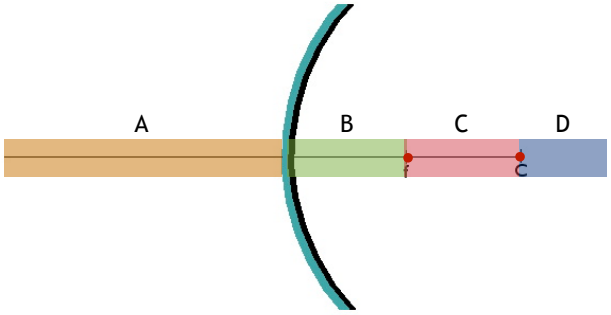


A concave mirror is placed as shown on the left. The light source is to the left of the mirror, and you are going to place a real object. Answer questions 26 and 27 using the letters on the picture for your responses A through D. *If you think that the correct response is* **T** *or* **F**, *use the* **TRUE** *or* **FALSE** *keys on your responder.*

29. In order to form an image that is upright, where should you position an object? **C**
    E) Either region A or B will create an upright reflection.
    F) Nowhere! A concave mirror cannot form an upright image.
    T) Anywhere! A concave mirror can only form upright images.

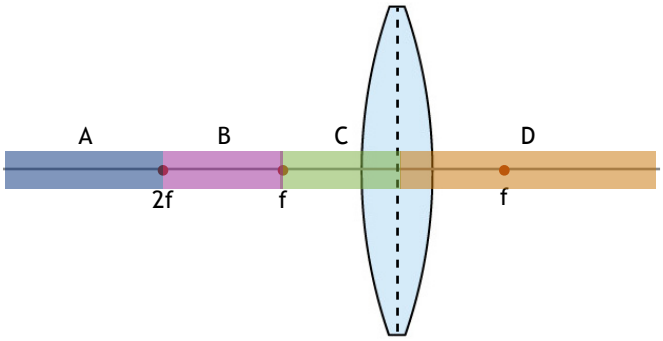
30. In order to form an image that is smaller than the object ($h_i < h_o$), where should you position an object? **A**
    E) Either region B or C will create a magnified image.
    F) Nowhere! A concave mirror cannot magnify.
    T) Anywhere! A concave mirror only forms magnified images.

A convex mirror is placed as shown on the right. The light source is to the left of the mirror, and you are going to place a real object. Answer questions 28 and 29 using the letters on the picture for your responses A through D. *If you think that the correct response is* **T** *or* **F**, *use the* **TRUE** *or* **FALSE** *keys on your responder.*



31. In order to form an image that is inverted, where should you position an object?
    E) Any region A, B, C, or D will create an inverted reflection.
    F) Anywhere! A convex mirror can only form real images.
    T) Nowhere! A convex mirror cannot invert an image.

32. In order to form an image that is magnified, where should you position an object?
    E) Either region C or D will create a magnified image.
    F) Anywhere! A convex mirror can only magnify images.
    T) Nowhere! A convex mirror cannot magnify an image.



A convex lens is placed as shown on the left. The light source is to the left of the lens, and you are going to place a real object. Answer questions 33 through 35 using the letters on the picture for your responses A through D. *If you think that the correct response is* **T** *or* **F**, *use the* **TRUE** *or* **FALSE** *keys on your responder.*

33. **True** or false: An object placed somewhere in region B will form an image that is inverted and magnified.

34. In order to form a real image, where should you place an object?
    E) Either region A or B will create a real image.
    F) Either region B or C will create a real image.
    T) Nowhere! A convex lens cannot form a real image.

35. In order to form an image that is magnified, where should you position an object?
    E) Either region B or C will create a magnified image.
    F) Anywhere! A convex lens can only magnify images.
    T) Nowhere! A convex lens cannot magnify an image.

36. True or **false**: An object placed before a converging lens at precisely at $d_o = +2f$ will form an image located at $d_i = -2f$.

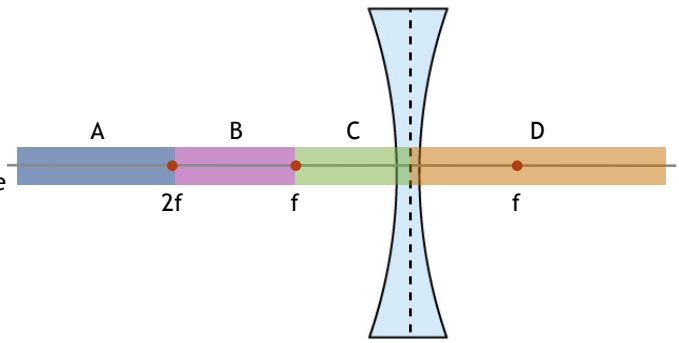
37. True or **false**: An object placed before a converging lens precisely at $d_o = +f$ will form an image located at $d_i = +f$.

38. The converging lens above has a focal length **f = 15cm**. Locate the image (d_i) formed when an object (**h_o = 2cm**) is placed at a distance **d_o = 20cm**. Answer with two sig figs, and include sign where appropriate.

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}\Rightarrow d_i=\left[\frac{1}{f}-\frac{1}{d_o}\right]^{-1}=\left[\frac{1}{15\text{cm}}-\frac{1}{20\text{cm}}\right]^{-1}=+60\text{cm}$$

39. The image formed in question 38 is
    A) real, inverted, magnified.
    B) real, inverted, minified.
    C) real, upright, unmagnified.
    D) virtual, upright, magnified.
    E) virtual, upright, minified.

A concave lens is placed as shown on the left. The light source is to the left of the lens, and you are going to place a real object. Answer questions 36 and 37 using the letters on the picture for your responses A through D. *If you think that the correct response is* **T** *or* **F**, *use the* **TRUE** *or* **FALSE** *keys on your responder.*



40. An object placed anywhere in region A will form an image located somewhere in region C.
    E) B or C.
    F) C or D.

41. In order to form a virtual image, where should you position an object?
    E) Either region A or B will create a virtual image.
    F) Anywhere! A concave lens can only form virtual images.
    T) Nowhere! A concave lens cannot create virtual images.

42. In order to form an image that is magnified, where should you position an object?
    E) Either region B or C will create a magnified image.
    F) Anywhere! A concave lens can only magnify images.
    T) Nowhere! A concave lens cannot magnify an image.

43. True or false: An object placed before a diverging lens precisely at $d_o = 2f$ will form an image that has a magnification $M = -1$.

44. A diverging lens has a focal length **f = -15cm**. When an object is placed at **d_o = 20cm**, where does the image form? Answer with two sig figs, and include sign.

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}\Rightarrow d_i=\left[\frac{1}{f}-\frac{1}{d_o}\right]^{-1}=\left[\frac{1}{-15\text{cm}}-\frac{1}{20\text{cm}}\right]^{-1}=-8.57\text{cm}$$

45. What is the magnification of the image formed in question 44? Answer with two sig figs, and include sign.

$$M=-\frac{d_i}{d_o}=-\frac{(-8.57)}{20}=+0.429$$