1. A **wave** is
   A) an oscillation in time only.
   B) an oscillation in space only.
   C) an oscillation in space propagated through time.
   D) an oscillation in time propagated through space.

2. Compare **sound** and **light** waves.
   A) Sound waves are transverse, and so are light waves.
   B) Sound waves are longitudinal, and so are light waves.
   C) Sound waves are transverse, light waves longitudinal.
   D) Sound waves are longitudinal, light waves transverse.

3. How do you make an electromagnetic wave?
   A) Oscillate an un-charged particle (only neutrons work). The motion of the mass creates an e·m wave.
   B) Oscillate a charged particle (like an electron). The accelerating electron creates the varying E and B fields.
   C) Keep a charged particle (like an electron) completely at rest. Any motion of the particle will collapse the wave.
   D) It's a mystery. Like Bigfoot and UFOs, no one really knows if e·m waves actually exist.

4. The time-varying electric (E) and magnetic (B) fields that comprise an electromagnetic wave are
   A) parallel. C) skew (neither // nor ⊥).
   B) perpendicular. D) non-existent.

5. Electromagnetic waves are
   A) longitudinal and require a material medium to travel through.
   B) transverse and require a material medium to travel through.
   C) longitudinal and do not require a material medium to travel through.
   D) transverse and do not require a material medium to travel through.

6. The electromagnetic spectrum includes
   A) radio, television, and sound waves.
   B) visible light, but no other types of waves.
   C) radio, sound, and seismic waves.
   D) radio, infrared, ultraviolet, and gamma rays.

7. The speed of light
   A) is fastest in a vacuum.
   B) is about 340 m/s.
   C) increases as the frequency increases.
   D) increases as the wavelength increases.

8. **True or false:** A gamma ray will travel faster through vacuum than visible light, and visible light travels faster than radio waves.

9. The **wavelength** of an electromagnetic wave
   A) is a measure of its speed.
   B) is a measure of its brightness.
   C) decreases with increasing frequency.
   D) increases with increasing frequency.

10. The **frequency** of an electromagnetic wave
    A) is a measure of its speed.
    B) decreases with increasing wavelength.
    C) increases with increasing wavelength.
    D) is unrelated to its wavelength.

11. The **energy** of an electromagnetic wave
    A) is a measure of its speed.
    B) decreases with increasing frequency.
    C) increases with increasing frequency.
    D) is unrelated to its frequency.

12. Ultraviolet (UV) waves have a much shorter wavelength than infrared (IR) waves.
    A) UV waves have lower frequency than IR.
    B) UV waves have the same frequency as IR.
    C) UV waves have higher frequency than IR.
    D) There is no correlation between frequency and wavelength; some wavelengths of UV have higher frequencies than visible light, and some have lower frequencies.

13. X–rays have a much higher frequency than visible light.
    A) X–rays have more energy than visible light.
    B) X–rays have less energy than visible light.
    C) X–rays have the same energy as visible light.
    D) There is no correlation between frequency and energy; some frequencies of X–rays have less energy than visible light, and some have more energy.

14. Why don't you also need to apply "radio screen" when you apply your ultraviolet-blocking sunscreen lotion before you spend the day outdoors?
    A) Because if the lotion blocks UV rays, it will automatically block all other forms of em radiation.
    B) Because radio waves have less energy, so they will not damage your skin the way UV rays do.
    C) Because humans have evolved to be immune from damage from everything except UV rays.
    D) Because none of the radio radiation from the sun gets down to the surface of the earth.

15. **True or false:** Like the sun, you are currently radiating electromagnetic waves. Just at a much lower frequency.

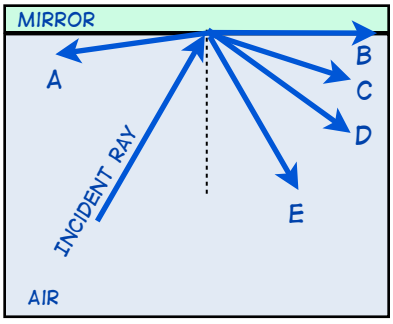
16. When sunlight strikes a clear glass windowpane, about 85% of the incident light is transmitted. What happens to the remaining 15% of the incident light?
    A) It is also transmitted. 100% of the light must pass through the transparent glass.
    B) It is mostly reflected, but some light will be absorbed.
    C) It is lost, and 15% of the initial energy disappears.
    D) No one knows. Like the Loch Ness monster or the true identity of Jack the Ripper, no one ever will.

17. Light incident on a surface may be
    A) transmitted, if the medium is transparent.
    B) absorbed, causing the medium to heat up.
    C) reflected, causing the medium to cool down.
    D) either A or B; reflection is not a cooling process.

18. If a material is **opaque**, visible light that strikes it
    A) will pass through to the other side.
    B) will bounce off the surface.
    C) will be completely absorbed.
    D) will be some combination of reflected and absorbed, but none will be transmitted.

19. The glass windshield of your car is
    A) opaque to all forms of electromagnetic radiation.
    B) transparent to all forms of electromagnetic waves.
    C) transparent to UV and IR, but opaque to visible light.
    D) reflective to UV, absorptive to visible, and permeable to IR frequencies.
    E) transparent to visible, but virtually opaque to UV and IR frequencies of radiation.

20. Which is the reflected ray? **Use the multiple choices on the figure on the right.**




21. **True or false:** When applying the law of reflection, always measure the angles of incidence and reflection with respect to the surface that the light is striking.

22. The **law of reflection** states that the angle of incidence is equal to the angle of reflection. However, if a mirror is curved slightly outward (like the side-view mirror on a car),
    A) the angle of reflection will be greater than the angle of incidence.
    B) the angle of reflection will be less than the angle of incidence.
    C) the angle of reflection will be 0°, no matter what the angle of incidence.
    D) the angles will still be equal regardless of the shape or curvature of the mirror.

23. You are standing on the bridge, looking down onto the surface of the river. If you see a **specular reflection** on the surface, the water must be
    A) calm and smooth.
    B) rough and choppy.
    C) solid ice. Liquid water cannot reflect light.
    D) Trick question! There will be no reflection at all, because water cannot *reflect* light, it can only *refract* it!

24. A **diffuse reflection** will appear
    A) sharp, clear, and well-focused.
    B) blurry and poorly focused.
    C) the opposite color of the original object.

25. Using either a mirror or a lens, a **real image** will always
    A) appear right side up.
    B) appear upside down (inverted).
    C) appear larger than the original object.
    D) appear smaller than the original object.

26. Using either a mirror or a lens, a **virtual image** will always
    A) appear right side up.
    B) appear upside down (inverted).
    C) appear larger than the original object.
    D) appear smaller than the original object.

For questions 21–26 below, use the following multiple choices:
    A) Concave mirror *only*.
    B) Convex mirror *only*.
    C) *Both* concave and convex mirrors.
    D) *Neither* concave nor convex mirrors.

27. Reflective surface is curved outward.

28. Reflective surface is curved inward.

29. Reflected light converges to a real focal point.

30. Reflected light diverges away from a virtual focus.

31. Angle of incidence less than angle of reflection.

32. Can form only real images.

33. Can form only virtual images.

34. Can form either real or virtual images.

35. Parallel rays of light strike a convex mirror. The reflected rays
    A) diverge away from each other. The real rays will never intersect.
    B) are parallel as well. They bounce back along their original path.
    C) are perpendicular. They make a 90° angle with the incoming rays.
    D) converge at the focal point in front of the mirror.
    E) are everywhere. Curved mirrors can only reflect diffusely, so the rays go in all directions randomly.

36. Explain the difference between a concave mirror and a convex mirror.
    A) Both can form either real or virtual images. Concave mirrors curve outward, convex curve inward.
    B) Concave mirrors form only virtual images. Convex form only real images. Both curve outward.
    C) Concave mirrors form only real images. Convex form only virtual images. Both curve inward.
    D) Convex mirrors curve outward and form only virtual images. Concave mirrors are curved inward.
    E) Convex mirrors cannot form either type of image. Concave can form either real or virtual images.

37. When light passes from one medium to another,
    A) it continues to travel at 300,000 km/s regardless of the type of medium.
    B) it always slows down, and it refracts regardless of the angle of incidence.
    C) it bends only when it strikes the boundary between the media at a 90° angle.
    D) it may slow down or speed up, depending on the medium. The amount of refraction depends on the angle at which the light strikes the boundary.
    E) it enters another dimension. Like the aliens at Roswell, no one knows where it came from or where it will go.

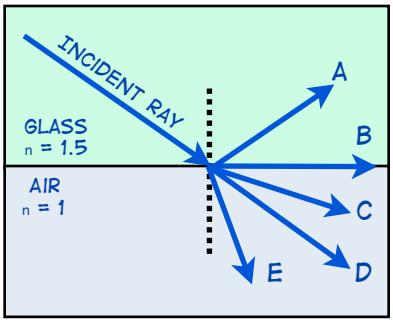
38. As a light wave passes from glass to air,
    A) it slows down and bends toward the normal.
    B) it slows down and bends away from the normal.
    C) it speeds up and bends toward the normal.
    D) it speeds up and bends away from the normal.
    E) it does not bend because the speed does not change.

39. Under what circumstance would light traveling from air to glass remain un-refracted (un-bent)?
    A) Under all circumstances. The angle of incidence = the angle of refraction, and no bending occurs.
    B) When the index of refraction of the glass exactly equals the index of refraction of the air.
    C) If the light is traveling parallel to the normal to the surface when it strikes the boundary, it will not refract.
    D) If the light is traveling perpendicular to the normal to the surface, it will not refract.

40. Glass has an index of refraction of $n_g = 1.5$, and water has an index of refraction of $n_w = 1.3$. A beam of light traveling from air (index of refraction $= 1$) to glass has an incident angle of 30°. A second beam of light, this one traveling from air to water, also has an incident angle of 30°.
    A) The glass will bend the light more.
    B) The water will bend the light more.
    C) They will both bend the light by the same amount.
    D) Neither glass nor water will bend the light at all.

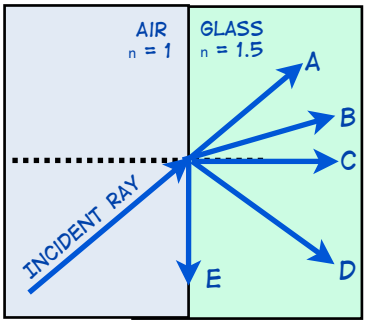
41. Glass has an index of refraction of approximately $n_g = 1.5$. Diamond, however, has an index of refraction of $n_d = 2.4$.
    A) The speed of light is the same through either medium, $c = 3\times10^8$m/s. Index of refraction does not matter.
    B) The speed of light is faster through glass because its index is smaller.
    C) The speed of light is faster through diamond. The higher the index of refraction, the faster the medium.
    D) You cannot say for sure which medium is faster; it will depend on the color of the glass.

42. In the figure shown on the right, which ray represents the **refracted** beam of light? **Use the multiple choices labeled on the diagram.**




43. **True or false:** In the figure shown above, if you increase the angle of incidence enough (to 60° or more, for example), the result will be a total internal reflection of the light beam, and no light will emerge into the air.

44. In the figure shown on the right, which ray represents the **refracted** beam of light? **Use the multiple choices labeled on the diagram.**




For questions 35–44 below, use the following multiple choices:
    A) Converging lens *only*.
    B) Diverging lens *only*.
    C) *Both* converging and diverging lenses.
    D) *Neither* converging nor diverging lenses.

45. Has a convex shape.
46. Has a concave shape.
47. Can form only real images.
48. Can form only virtual images.
49. Can form either real or virtual images.
50. Can form magnified images ($h_i > h_o$).
51. Can form "mini-fied" images ($h_i < h_o$).
52. The type of lens found in the human eye.
53. Can correct near-sightedness.
54. Can correct far-sightedness.
55. An object is placed at the focal point of a **diverging** lens, $d_o = f$. What kind of image will be formed?
    A) None; the rays of light will all be parallel on both sides of the lens. No real or virtual image forms.
    B) A real image. Real rays of light will intersect on the side of the lens opposite the object.
    C) The real image is formed when real rays intersect on the same side of the lens as the object.
    D) Virtual. Real rays diverge. Virtual rays intersect on the opposite side of the lens as the object.
    E) A virtual image forms, but the virtual rays intersect on the same side of the lens as the object.
56. An object is placed at the focal point of a **converging** lens, $d_o = f$. What kind of image will be formed?
    A) None; the rays of light will all be parallel on both sides of the lens. No real or virtual image forms.
    B) A real image. Real rays of light will intersect on the side of the lens opposite the object.
    C) The real image is formed when real rays intersect on the same side of the lens as the object.
    D) Virtual. Real rays diverge. Virtual rays intersect on the opposite side of the lens as the object.
    E) A virtual image forms, but the virtual rays intersect on the same side of the lens as the object.
57. When you shine white light through a triangular glass prism,
    A) white light emerges, unbent.
    B) the colors are dispersed according to wavelength. Red light, having the longest wavelength, bends the most.
    C) the prism scatters the blue light, and only red light emerges.
    D) Don't do it!! Do the words **Bermuda Triangle** mean *nothing* to you?
58. When you see a rainbow in the sky,
    A) sometimes the red band is on top, sometimes the blue band is. It's completely random.
    B) the primary will have red on top, blue on bottom. The secondary will have blue on top, red on bottom.
    C) the primary will have blue on top, red on bottom. The secondary will have red on top, blue on bottom.
    D) both the primary and secondary rainbows will have the same color order: VIB G ROY, from top to bottom.
59. **True or false:** The Earth's atmosphere is not transparent to all frequencies of electromagnetic waves.
60. Why don't humans have x-ray vision–like Superman?
    A) Some humans do. The ability see x-rays is uncommon, but there are plenty of people who have x-ray vision.
    B) You cannot see what cannot be seen! There is no known method for detecting x-rays, so there is no way for any eye (human or otherwise) to see x-rays.
    C) X-rays cannot penetrate the Earth's atmosphere. Eyes (human or otherwise) would not evolve to see wavelengths which are not abundant at the Earth's surface.
61. Your polarized sunglasses are great for driving, since they diminish reflected glare from the highway. The fact that light can be polarized proves that
    A) light is a longitudinal wave.
    B) light is a transverse wave.
    C) particles of light can pass through glass.
    D) it's dangerous to drive without eye protection. You should probably wear a helmet, as well.
62. **True or false:** Light is a particle.
63. **True or false:** Light is a wave.
64. What is the **photoelectric effect**?
    A) The observation that oscillating an electric charge creates an electromagnetic wave.
    B) The observation that a beam of electrons will fog unexposed (and well-shielded) photographic film.
    C) When a photograph is bombarded with electrons, it gets yellowed and dingy. That's why old-timey photographs are all sepia-toned.
    D) When a metallic foil is bombarded with photons of light of a particular frequency, electrons are ejected. But using a different frequency has no effect.

65. **Reflection** of light is
    A) a **wave** property only.
    B) a **particle** property only.
    C) **both** wave and particle behavior.

66. **Interference** of light is
    A) a **wave** property only.
    B) a **particle** property only.
    C) **both** wave and particle behavior.

67. The **photoelectric effect** is
    A) a **wave** property only.
    B) a **particle** property only.
    C) **both** wave and particle behavior.