Section 9.4: Light: Wave or Particle?

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A. The Dominion Radio Astrophysical Observatory in Penticton, British Columbia, uses Very Long Baseline Interferometry (VLBI).

B. Answers may vary. Sample answer: Usually, data at each telescope are recorded digitally onto computer hard drives. The data from each telescope are combined to form an image.

C. Answers may vary. Sample answer: The signal is sampled at each telescope, then stored and shipped to a central location for later processing with data from other telescopes.

D. Answers may vary. Sample answer: Many scientists store the data on disc and ship the discs. Newer methods use Internet transfer to send the data to a central location.

E. Answers may vary. Sample answer: When the data are played back, an atomic clock is used to synchronize the data with the time at different telescopes.

F. Answers may vary. Sample answers: The word "interferometry" is from the word "interferometer." An interferometer uses interference patterns from electromagnetic radiation to form images. Interference is a wave-like property of light. The data from all the telescopes in a baseline array are combined to form interference patterns, which reveal information about the object under study. Another wave-like property used in interferometry is reflection. The electromagnetic radiation from the object reaches the large, parabolic radio telescope dishes, and the radio waves are reflected to a focus and then to a receiver. From the receiver, the signals are transmitted for image processing.

Additional information: Radio waves reveal different types of information in the object under study than visible light radiation. For example, quasars are massive, high-energy objects at the edges of the known universe. In visible light, through an optical telescope, for example, quasars appear as points of light. Images compiled from radio waves reveal the massive quantities of energy emanating from quasars, as well as their enormous size.

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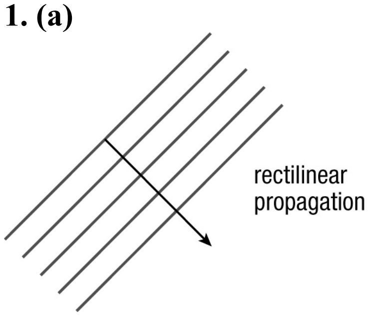
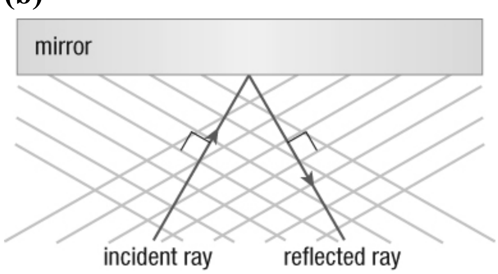
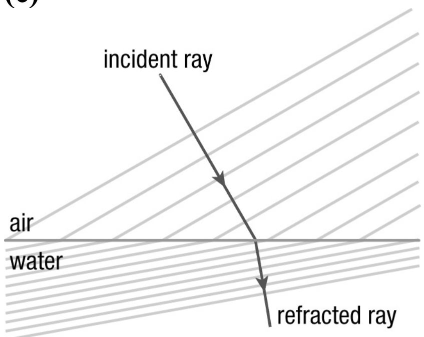
1. (a)



(b)



(c)



2. Answers may vary. Sample answer: Based on what I have learned in this section about the wave and particle properties of light, I think that the wave model explains properties of light better than the particle model. The wave model explains reflection, refraction, dispersion, and interference better than the particle model. The particle model partially explains rectilinear propagation.
Additional information: Newton's corpuscular model predicts that light does not need a medium in which to travel, which is true.
3. Sample answer: Double-slit interference patterns provide strong evidence that light is a wave.
4. Answers may vary. Sample answer: The frequency and wavelength of light do not change when light is reflected. So, according to the universal wave equation, $v = f\lambda$, the speed must stay the same.
5. Answers may vary. Sample answer: Newton did not detect any pressure from light, so he reasoned that the mass of a light particle is very low.
6. Answers may vary. Sample answer: Newton's theory of light was dominant for so long because Newton had a very high reputation in the physics community because of his successes in other studies, especially gravity. Another reason that Newton's theory took so long to refute was that the technology of Young's experiment did not exist until much later.
Additional information: Newton was also the powerful head of the British Royal Society and could influence the opinions of others.
7. Sample answer: Huygens' principle applies to all waves, including water and sound waves.
8. Answers may vary. Sample answer: Answers should indicate the student's understanding of the wave and particle models of light.
(a) Light travels from the Sun to Earth in a straight line, in a vacuum. Rectilinear propagation is explained by a particle model of light.
(b) The energy travelling for TV, radio, and X-ray technologies is best understood if light is considered to be a wave because waves carry energy.
9. (a) Answers may vary. Sample answer: The laser light passing through an open window shows no diffraction because the wavelength of the light is much smaller than the width of the window.

(b) Answers may vary. Sample answer: To have electromagnetic radiation diffract through a window, the wavelength of the radiation must be about the width of the window or somewhat greater. Based on my research for the Research This activity on baseline interferometry, I know that radio waves have long wavelengths and can reflect off the radio telescope dishes, so radio waves can probably also diffract, although it may not be enough to be noticeable. So I would use longer-wavelength and consider decreasing the size of the window, if that was an option. Additional information: Radio waves can penetrate walls, window frames, and glass.

10. Answers may vary. Sample answer: Young's double-slit experiment demonstrated that light waves can interfere, confirming that light is a wave. Therefore, Young's experiment contradicted Newton's corpuscular theory of light. Newton's corpuscular theory of light cannot account for the observed interference pattern.

11. (a) Answers may vary. Sample answer: Light waves cause the electrons to vibrate. These vibrations are called surface plasmons. A dielectric material is a material that does not conduct direct current. When a dielectric material is placed against a metallic surface, travelling waves of electron vibrations can be trapped in the interface between the materials. The travelling waves are called surface plasmon polaritons.

(b) Answers may vary. Sample answer: Surface plasmon polaritons have multiple applications in nanotechnology, for example, optical data storage.

12. Answers may vary. Sample answer: Newton believed that light was composed of particles, which he called corpuscles, and that corpuscles were subject to gravitational attraction. He therefore believed that these particles had mass. In explaining refraction, the attraction of a massive body (water or glass) caused the light to bend and speed up. Newton tried to disprove Grimaldi's beliefs about diffraction of light. Newton argued that Grimaldi's observations of light diffraction were a result of collisions between light particles at the edges of the slit, and not a result of waves of light spreading out. By the time Newton wrote *Opticks*, his book on light, he explained diffraction as a kind of refraction. This is since understood to be incorrect. Newton's greatest contribution to optics was the demonstration that light could be broken down into its spectral colours by a prism, and that after passing through a second prism the light would appear white. His theory could explain this at a time when other theories could not. However, in 1850, Foucault showed that light travels more slowly in water, not faster, and Newton's theory was put to rest. His entire theory of light has been demonstrated to be incorrect, except for the prediction that light does not need a medium in which to travel.

13. In his book *Micrographia*, published in 1665, Robert Hooke described light as vibrations, and compared the movement of light to the movement of water waves. Hooke suggested that the vibrations of light are perpendicular to the direction of travel. He also proposed that light was not made up of particles as Newton suggested.