SPH4U UNIVERSITY PHYSICS

THE WAVE NATURE OF LIGHT

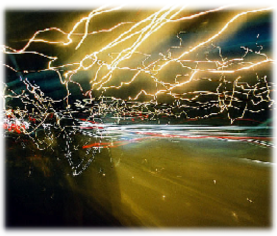
☞ Light: Wave or Particle? (P.470-476)

The Nature of Light

Light carries energy with it. It is a form of energy. This is obvious to anyone standing out in the sun on a hot summer's day. But (a) how does light travel, and (b) how is the energy of light carried from a source of energy, such as the sun?

The Nature of Light

The earliest recorded views on the nature of light come to us from the Greeks. Plato thought that light consisted of "streamers," or filaments, emitted by the eye and that when these streamers came in contact with an object, sight was achieved. Euclid agreed with him, arguing, "How else can we explain that we do not see a needle on the floor until our eyes fall on it?"



The Nature of Light

Not all Greeks held the same view. The Pythagoreans believed that light travelled as a stream of fast-moving ***particles****, while Empedocles taught that light travelled as a* ***wave****-like disturbance.*

PYTHAGORAS

EMPEDOCLES

The Nature of Light

By the 17th century, these apparently contradictory views of the nature of light placed scientists in two camps. Newton was the principal advocate of the ***particle theory****. He was supported by the French mathematician, physicist, and astronomer La Place.*

Sir Isaac Newton (1642-1727)

The Nature of Light

On the other hand, the ***wave theory*** *was upheld principally by Christiaan Huygens of Holland, also a mathematician, physicist, and astronomer. He, in turn, was supported by Robert Hooke of England, president of the Royal Society and a vigorous personal opponent of Newton.*

Sir Isaac Newton (1642-1727) Christiaan Huygens (1629-1695)

The Nature of Light

And because of the plausibility of both theories, a scientific debate developed between the followers of Newton and the followers of Huygens that continued for over 300 years.

Sir Isaac Newton (1642-1727) Christiaan Huygens (1629-1695)

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The Nature of Light

NOTE!

The basic properties of light that were understood at the time, and that any acceptable theory had to be able to explain, were:

- *straight-line propagation*
- *reflection*
- *refraction*
- *dispersion*
- *the ability of light to travel undisturbed across millions of kilometres of space*

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Newton's Particle Theory of Light

Isaac Newton's fascination with the ability of prisms to produce colours from white light (dispersion) led to his development of the particle theory of light. Building on an earlier theory by Descartes, Newton proposed that light corpuscles (little particles) with exceedingly small masses travel in straight lines with a maximum velocity and therefore have kinetic energy. Newton's theory does not require a medium for the light to travel in. Furthermore, he was able to explain the properties of reflection and refraction using his theory. However, Newton's explanation of diffraction showed the shortcomings of his theory.

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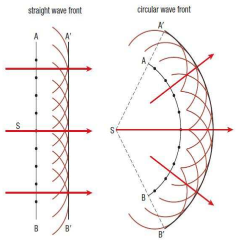
Newton's Particle Theory of Light

NOTE!

Newton was not entirely convinced of the correctness of his own particle theory of light and was surprised that some of his proponents approved of it so strongly. Nevertheless, until stronger evidence of wave-like properties was obtained, Newton would not accept a wave model of light.

Huygens' Principle & the Wave Theory of Light

Christiaan Huygens refined and expanded the wave theory of light, originally proposed by Robert Hooke. Hooke rejected the particle theory partly because two beams of light can pass through each other without scattering each other, as particles do. However, Huygens encountered difficulty when he tried to explain rectilinear propagation using the wave theory of light. According to the wave theory, mechanical waves require a medium through which to move. So what medium was carrying the light energy? This was the primary reason for Newton's rejection of the wave theory.



Huygens' principle *states that all points on a wave front can be thought of as new sources of spherical waves.*

Huygens' Principle & the Wave Theory of Light

NOTE!

Huygens' wave theory accurately explained the properties of light as strongly or even more strongly than did Newton's theory in terms of reflection, refraction, partial reflection, partial refraction, diffraction, dispersion, and rectilinear propagation. At that time, however, there were no tests or observations that could eliminate either theory, so Newton's stature in the scientific community (gained for his many and varied contributions, including the laws of motion) resulted in his winning the approval of other scientists for his less eloquent particle theory.

Light: Wave or Particle?

	NEWTON	HUYGENS
theory	particle	wave
supporter	La Place	Hooke
reflection	✔	✔
refraction	✔	✔
rectilinear propagation	✔	✘
diffraction	✘	✔

THE WINNER!

NOTE!

Since no tests could eliminate either theory, and because of Newton's stature, the particle theory was the accepted theory of light.

The Nature of Light

PRACTICE

1. You shine laser light through an open window. The window is like a slit, but the laser light does not diffract at all as it passes through the window. Instead, it travels in a straight line.
   (a) What does your observation imply about the relative magnitude of the laser's wavelength and the width of the window?

   (a) since no diffraction occurred then $\lambda/w < 1$ or $\lambda < w$ (i.e. the wavelength of the laser light < width of window)

The Nature of Light

PRACTICE

1. You shine laser light through an open window. The window is like a slit, but the laser light does not diffract at all as it passes through the window. Instead, it travels in a straight line.
   (b) How must you change this experiment so that the electromagnetic radiation (light) does diffract through the window?

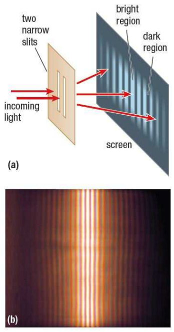
   (b) the wavelength of the laser light cannot be changed so the width of the window must be changed so that $\lambda/w \geq 1$

The Nature of Light

PRACTICE

2. Thomas Young showed that light passing through two parallel narrow slits produces a pattern of light and dark fringes. Did this support or contradict Newton's corpuscular theory of light? Explain.

   the pattern of light and dark fringes contradicted Newton's corpuscular theory – if light were like a particle then two bands of light would appear and no more



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TEXTBOOK

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