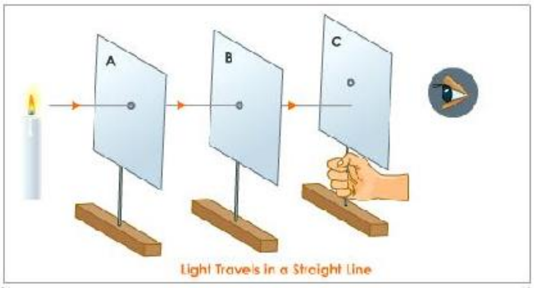
Physics Chapter 12: Light

Author comment: This is a very BIG chapter!

Chapter 12.1: What is Light?

1. Light is a form of **energy** that enables us to see!
   a. Our eyes detect light in a range of 7 colours from red to violet which forms a spectrum.
   b. Light travels at **3.0×10^8** metre per second. It can reach the Earth from the Sun in **8** minutes.
   c. The study of the physics of light is known as **optics**.

2. The *Rectilinear Propagation of Light* states that light travels in **straight lines**.
   a. Light cannot bend around corners and can only travel **straight**. Proof:



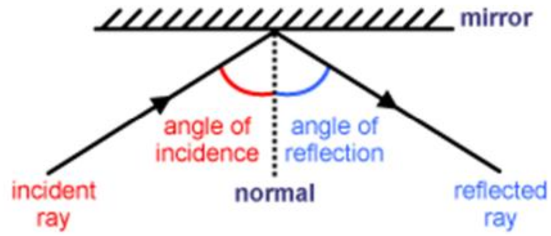
   b. The path in which light travels is known as a **light ray**. Arrows are added to indicate the direction of the light ray.
   c. A beam of light forms a bundle of light rays.

Laser beams are used in musical performance.

   d. There are 3 types of beams:
      i. Parallel (light rays are straight)
      ii. Converging (light rays converge at a point)
      iii. Diverging (light rays diverge from a point)

3. **Luminous objects** are objects that give out light. Some examples include the sun, TV, light bulb.
   a. Objects that do not give out light are non – luminous objects.
   b. We can see them as that object reflect light from a luminous object nearby into our eyes.
   c. Common mistake: *Do not draw light rays diverging out from the eye!*

Chapter 12.2: Reflection of Light



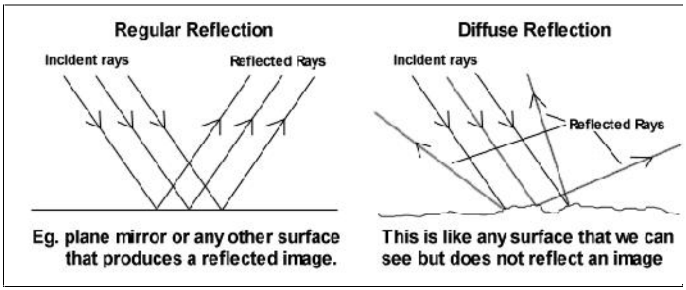
4. Important terms:
   a. **Incident Ray:** Light ray hitting the reflecting surface.
   b. **Reflected Ray:** Light ray reflected from the reflecting surface.
   c. **Normal:** The perpendicular to the reflecting surface at the point of incidence.
   d. **Angle of incidence (i):** The angle between the incident ray and the normal.
   e. **Angle of reflection (r):** The angle between the reflected ray and the normal.

5. Definitions... **Laws of Reflection**: (Words in red and bold are keywords you must include in your answer)

Angle of **incidence** is equal to the angle of **reflection** ($\angle i = \angle r$)

The **incident** ray, **reflected** ray and the **normal at the point of incidence** all lie **on the same plane**.

6. *Types of Reflection*: All surfaces reflect light. The difference is how smooth the surface is, which will affect how light is reflected.
   a. **Regular Reflection**: Occurs on smooth surfaces such as mirrors.
      i. The parallel light ray incident on the surface are reflected in the same direction.
      ii. The normal at all points of incidence are *parallel* to each other
   b. **Diffuse Reflection**: Occurs on rough surfaces (e.g. sandpaper)
      i. Parallel light rays are reflected in all directions.
      ii. Normals are point of incidence are not parallel.



7. Characteristics of Image formed by plane mirror:
   a. Same Size

b. Laterally Inverted
c. Upright
d. Virtual
e. Distance from image from mirror = Distance of object from mirror.

8. Applications of Mirrors:
   a. Optical Testing (Mirrors can make letters appear further away, saving space)
   b. Blind Corners (for drivers)
   c. Periscopes

Chapter 12.3: Refraction at Plane Surfaces

9. The bending effect of light as it passes from one transparent material to another is known as **refraction**.
   a. Refraction is caused by the **change in speed of light**.
   b. At the boundary of 2 optical media, if there is a sudden change in the speed of light, it will cause the path of light to bend.
   c. Light travels fastest in air/vaccum.

10. *Laws of Refraction*: (Words in red and bold are keywords you must include in your answer)

Definitions...

Snell's Law: The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant. ($\frac{\sin i}{\sin r} = \text{constant}$)

The **incident** ray, **refracted** ray and the **normal at the point of incidence** all lie **on the same plane**.

11. The **refractive index** of a medium is a **ratio** between the speed of light in air and the speed of light in a medium.
   a. Therefore, $\frac{\text{Speed of light in air}}{\text{Speed of light in medium}} = n$
   b. Since the constant $\frac{\sin i}{\sin r} = \text{constant}$, we can say: $\frac{\sin i}{\sin r} = \text{refractive index}$
   c. The greater the value of refractive index of a medium, the greater the bending of light, and the more denser the material is.
   d. Some common refractive indexes (useful to ensure your answer is not too far off):

Medium	Refractive Index,
Diamond	2.40
Glass	1.48 – 1.96
Water	1.33
Air	1.00

   e. Note the position of the numerator and denominator. The denser medium is the bottom, air is always at the top. Snell's law cannot be used if neither media is air/vaccum.
   f. Light can be both reflected and refracted at the boundary of 2 optical medium (to be explored later)

12. When light travels from a less dense medium to a denser medium, the ray of light moves **towards** the normal.
   a. Likewise, when light travels from a denser to a less dense medium, the ray of light moves **away from** the normal.
   b. When light enter a medium **perpendicularly**, regardless of its density, no deviation of the ray is observed.

13. The **Principle of Reversibility of Light** states that light will follow exactly the same path if its direction of travel is reversed.
   a. Therefore, $\frac{\sin r}{\sin i} = \frac{1}{n}$

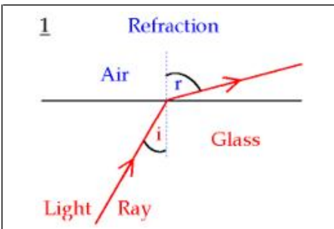
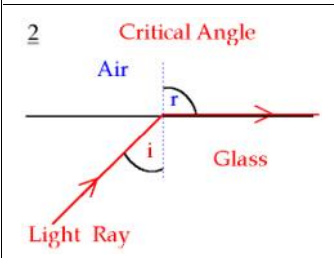
14. Phenomena/applications of refraction:
   a. Swimming pool appears shallower than it really is. To find refractive index,
   $\frac{\text{Real depth}}{\text{Apparent depth}} = n$

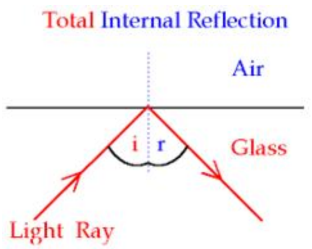
Chapter 12.4: Total Internal Reflection

15. **Total Internal Reflection** occurs when light travels from an **optically denser medium** to a less dense medium.

16. **Critical Angle** is the angle of incidence in the optically denser medium where the angle of refraction in the less dense medium = 90°.

17. 3 important cases of light reflection/refraction.

	a. **When angle of incidence < Critical Angle: Normal Refraction** b. There is still a faint reflected ray back into the glass.
	a. **When angle of incidence = Critical Angle**: Travels perpendicular to the surface (90°) b. As *i* is made bigger, the refracted ray gets closer and closer to the surface of the glass.

	c. Can be found by taking $c = \sin^{-1}\left(\frac{1}{n}\right)$
	a. **When angle of incidence > Critical Angle: Total Internal Reflection.** b. No light is being refracted through the glass-to-air boundary. c. Light is *totally reflected* back into the glass block.

18. Applications of total internal reflection:
    a. Glass prisms
    b. Optical fibres: Made up of plastic fibres that transmit light over long distances through total internal reflection.
        i. An optical fibre has a core of high refractive index, coated with another material of lower refractive index.
        ii. Light rays entering the fibre will be internally reflected at the boundary between these 2 refractive materials.

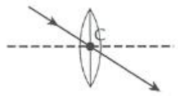
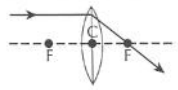
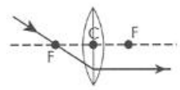
Chapter 12.5: Thin Converging Lens

19. A lens is a clear plastic or glass with curved surfaces. They are used in magnifying glasses, projectors, etc.
    a. There are 2 types of lenses: Converging and diverging lens.

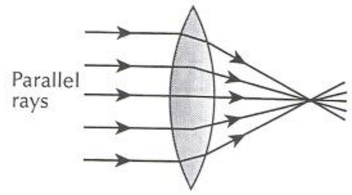
20. Main features of a converging lens (just briefly know this terms will do):
    a. *Optical Centre (C):* The midway point between the lens surface on the principal axis
    b. *Principal axis*: The line passing symmetrically through the optical centre of the lens
    c. *Principal focus (F):* Point on the principal axis where rays of light converge after passing through the lens
    d. *Focal length (f):* Distance between the optical centre, C and the principal focus F.
    e. *Focal plane*: Plane which passes through F and P. It is perpendicular to principal axis.

21. There are 3 definite paths of light travelling through a thin converging lens. Using 2 of these paths, we can find the position of an image formed by a lens.

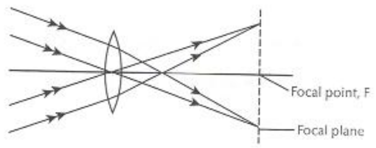
➢ Ray Diagrams – construction rules

S/n	Rules	Ray diagram
1	An incident ray through the optical centre C passes without bending.	
2	An incident ray parallel to the principal axis is refracted by the lens to pass through F.	
3	An incident ray passing through F is refracted parallel to the principal axis.	

22. Some examples:



Action of a thin converging lens on a **parallel beam of light parallel to the principal axis.**



Action of a thin converging lens on a **parallel beam of light NOT parallel to the principal axis.**

Chapter 12.6: Ray Diagrams for Lenses

Step 1: Setting up the ray diagram.
a. *Principle Axis:* Draw a horizontal line to represent the principal axis.
b. *Lens*: Draw a line perpendicular to the horizontal line with arrowheads.
c. *Focal Point*: Mark a point F on the principle axis on both sides. The length of each F from the optical centre should be equal.

Step 2: Placing the object
a. *Object*: Place the object on the left of the lens by marking it with an upright arrow.

Step 3: Tracing the light rays and drawing the image
a. Select 2 of the 3 definite paths. Usually the first 2 paths are selected.
b. The point where the 2 paths intersect on the right side of the lens is the position of the image.
c. Draw a downward arrow from the principle axis to the intersection point, and mark it as I. (*This denotes that the image is inverted*)

Step 4: Reading the ray diagram
a. An image is inverted if it is **below the principle axis**.
b. An image is diminished if the distance from it to the optical centre is lesser than the distance of the object from the optical centre.

c. An image is real and inverted if it is behind the lens, else it is virtual and upright.

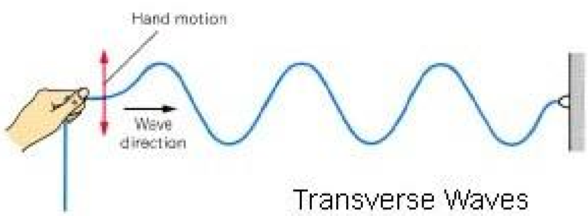
23. Applications of converging lenses
    a. Magnifying glass: It is a thin converging lens that can be used to make objects look bigger.
    b. Camera
    c. LCD Projector

Physics Chapter 13: Waves

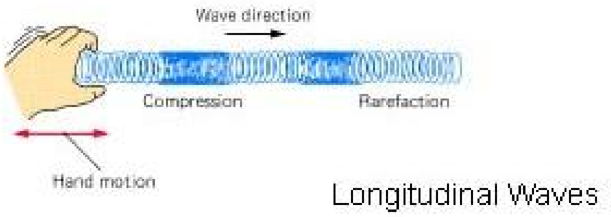
Chapter 13.1: Describing Waves

1. A wave is made up of **periodic motion**, which is motion *repeated at regular intervals*.
    a. A wave is a phenomenon where energy is transferred through **vibrations**.
    b. One complete motion from one extreme position to another and back is known as an **oscillation/vibration**.
    c. Waves can be formed by moving a rope up and down, using a ripple tank or using a slinky spring.
    d. The source of any wave is a vibration or oscillation.

2. There are 2 types of wave motion: **Transverse** and **Longitudinal**.

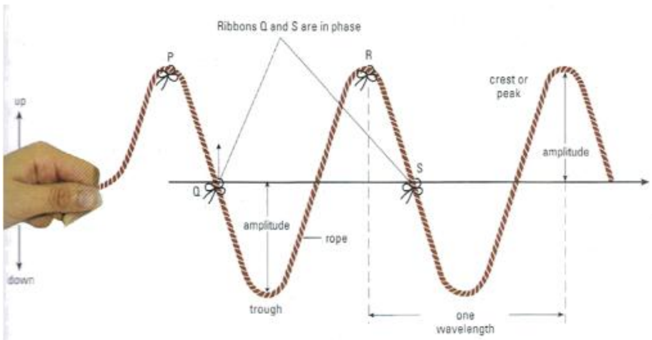


1. Transverse waves are waves that travel perpendicular to the direction of motion.
2. Examples of such waves include rope waves and water waves.
3. The crest is the highest points of the wave whereas the trough is the lowest points of the wave.



1. Longitudinal Waves are waves that travel parallel to the direction of motion.
2. Examples are sound wave and pressure waves.
3. They form compressions and rarefactions.
4. Compressions are region where the air particles are close together, creating high pressure.
5. Rarefactions are areas where the air particles are far apart, creating low pressure.

Chapter 13.2: Properties of Wave Motion



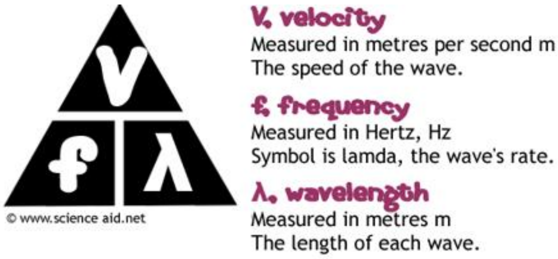
▲Figure 13.10 A transverse rope wave and some terms used to describe a wave

3. Terms used to describe wave motion:
    a. *Crests and troughs*: The highest and lowest points of a transverse wave respectively. For longitudinal waves, they are the regions of compressions and rarefactions.
    b. *Phase*: Any 2 points are in phase when they move in the same direction, have the speed and displacement from rest position. (e.g. 2 crests and 2 troughs)
    c. *Wavelength* λ : The shortest distance between any 2 points in a wave in phase (e.g. distance between 2 sucessive crests).
        i. SI unit: Metre (m)
    d. *Amplitude A*: It is the maximum displacement from the rest position; the height of the crest/ depth of a trough from the rest position.
        i. SI unit: Metre (m)

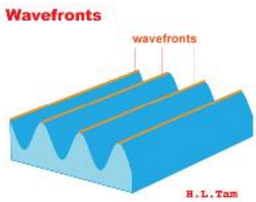
4. 2 types of graphs used to plot waves:
    a. *Displacement-distance graph*: Plotting the displacement of the wave at a certain instant of time.
    b. *Displacement-time graph*: Used to observe the displacement of a specific point on a graph over a

period of time.

5. Some wave terms used in the displacement-time graph:
   a. *Period (T)*: Time taken for 1 point on the wave to complete 1 oscillation, or time taken to produce 1 complete wave. SI unit: second (s)
   b. *Frequency (f)*: The number of waves produced per second. SI unit: Hertz.
      i. Formula: $f = \frac{1}{T}$
      ii. When the frequency of the wave increases, the period of the wave decreases.
   c. *Wave speed (v)*: It is the distance of the wave moved in 1 second in the medium.
      i. SI unit: Metre/second (m/s)
      ii. Formula: $v = \frac{\lambda}{T}$
      iii. From, $f = \frac{1}{T}, v = f\lambda$



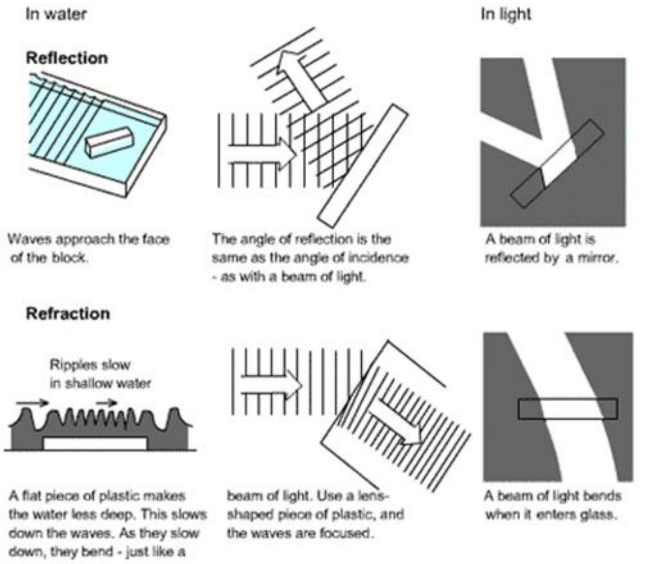
   d. *Wavefront*: A imaginary line on a wave joining all points in the same phase; usually drawn by joining the wave crests.



      i. Can be of concentric circles (spherical dipper), plane straight lines or any other shape.

Chapter 13.3: Wave Production and the Ripple Tank

6. A ripple tank can be used to generate water waves to demonstrate wave properties such as **reflection and refraction**.

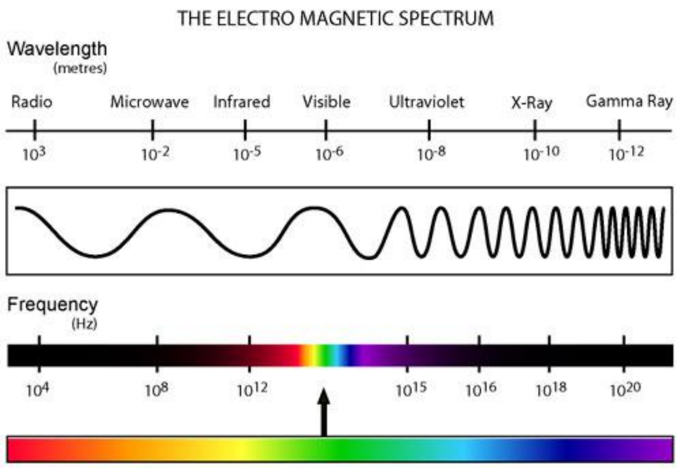


7. **Wave refraction**: By placing a piece of plastic in the ripple tank, a region of shallow water is created.
   a. The wavelength shortens but the frequency remains the same as it is determined by the dipper.
   b. Thus by the equation $v = f\lambda$, the velocity of the wave will also decrease.

8. **Wave reflection**: By placing a plastic sheet *at an angle to the incoming waves*, the waves will reflect, just like light waves.

Physics Chapter 14: Electromagnetic Waves

Chapter 14.1: Electromagnetic Waves



1. IMPT: Memorise the order of the waves!
   a. From longest to shortest wavelength: Radio, microwaves, infrared, visible, ultraviolet, X-rays, Gamma Rays
   b. Alternatively, **R**onald **M**cDonald **I**s **V**ery **U**gly e**X**cept **G**ary!

2. Properties of electromagnetic waves:

a. Electromagnetic waves are **transverse waves**. They are electric and magnetic fields that oscillate at 90° to each other.
b. They **transfer energy from one place to another**.
c. They can travel through vacuum (**do not require any medium to travel**)
d. They travel at **3.0 x 10^8** per second in vacuum. They will slow down when travelling through water or glass.
e. The wave equation $v = f\lambda$ is applicable here too.
f. They **obey the laws of reflection and refraction**.
g. They carry **no electric charge** (they are neither positively or negatively charged)
h. Their frequencies **do not change** when travelling from one medium to another. Only their **speeds and wavelength** will change.

3. Uses of electromagnetic waves:

Wave	Uses	Dangers
Radio Waves	Radio transmitters Radar Television	None
Microwaves	Microwave ovens Communication system	Internal heating of body tissue
Infra-red	Thermal imaging Remote controls	Burns skin
Light	Optic fibres Seeing!	Strong light causes damage to vision.
Ultra-violet	Washing powder (whiter than white) Security marking	Skin cancer and blindness
X rays	Taking images of the skeleton	Mutations in cells and severe burns to the skin.
Gamma Rays	Cancer treatment Sterilisation of equipment	Cancers and cell mutation

Just memorise some of these…

Physics Chapter 15: Sound

Chapter 15.1: What's sound?

1. Sound is a form of energy which enables us to hear.
   a. The energy is passed on from one point to another as a **wave**.
   b. Sound is a form of **longitudinal wave**.

2. Sound is produced by **vibrating sources** placed in a **medium** (usually air).
   a. Sound cannot travel in vacuum.
   b. E.g. of vibrating source: *Tuning Fork*.

3. As sound is a longitudinal wave, it travels in a series of **compressions** and **rarefactions**.
   a. Compressions: Air molecules are close together, forms high pressure.
   b. Rarefactions: Air molecules are far apart, forms low pressure.

Chapter 15.2: Transmission of Sound

4. Sound waves need a medium in order to travel.
   a. Expt: The bell jar experiment; a bell is placed in a jar where the air is slowly sucked out. The sound gradually faints till there is no air inside.

5. Approximate speed of sound in various mediums (use this to check answers – ensure not too far off):
   a. Air: 300 – 340m/s (Measured by firing pistol and calculating time difference between the 2 sounds). Source of error: Human reaction time. Improve result: Repeat expt, take avg. value and exchange positions of observers.
   b. Water: 1500 m/s
   c. Glass: 5000 m/s

Chapter 15.3: Reflection of Sound

6. **Echos** refer to the repetition of a sound resulting from reflection of the sound waves.
   a. An echo is formed when a sound is reflected off hard, flat surfaces such as a wall/cliff.
   b. **Reverberation** occurs when the surface is too close, causing any reflected sound to follow closely behind the direct sound and prolonging the original sound.

Chapter 15.4: Ultrasound

7. The range of frequencies which a person can hear is known as the **range of audibility**.
   a. Human: Between 20 Hz and 20 kHz[1]
   b. Dog: <20 kHz
   c. Bats: Between 10 kHz and 120 kHz.

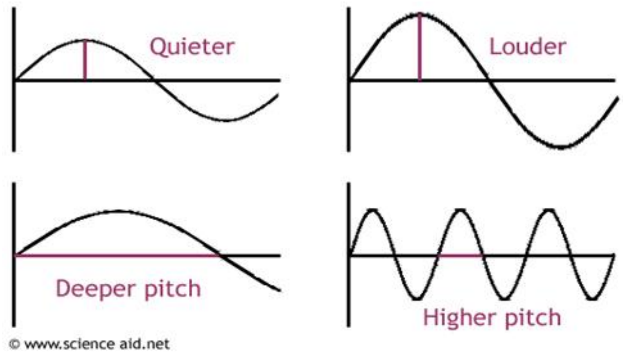
8. Ultrasound is the sounds with frequencies above the upper limit of the human range of audibility.

Its small wavelength means less diffraction and the echo formed is more precise in direction.

9. Applications for ultrasound include:
    a. Determining depth of seabed
    b. Locating sunken ships / shoals of fish
    c. Cleaning small dirt from jewellery.
    d. Quality control (checking for cracks) in concrete
    e. Medical applications (development of foetus)

Chapter 15.5: Pitch and Loudness

Loudness and Pitch



10. **Loudness** is a factor distinguishing between various sounds.
    a. The larger the **amplitude** of vibration, the louder the sound
    b. Sound is measured by **decibels (dB)**.

11. **Pitch** is a factor distinguishing various sounds
    a. The higher the **frequency** of a note, the higher the pitch
    b. Pitch is measured in **hertz (Hz)**.