Intermediate 2

WAVES and OPTICS
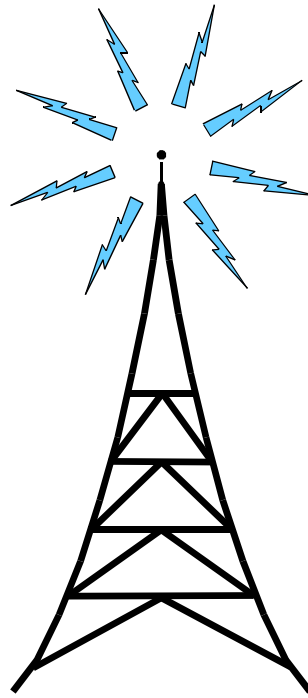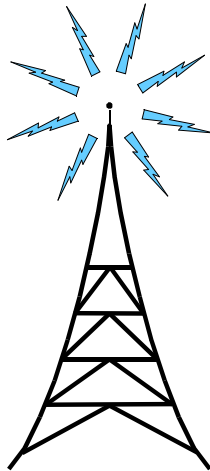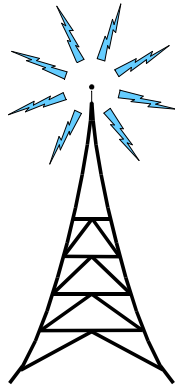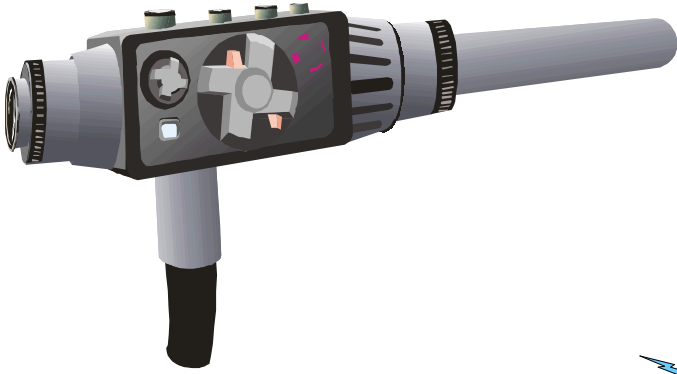
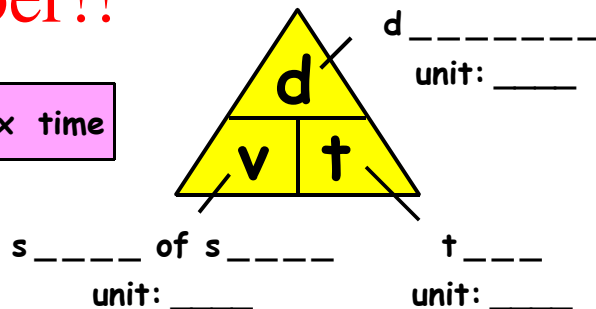**Name:** _____   **Class:** _____   **Teacher:** _____

Waves and Energy

All waves **transfer** (**carry**)
e _ _ _ _ _ from one place to
another - A tsunami sea wave
transfers an enormous amount of
e _ _ _ _ _ which can cause
extensive damage when the wave
reaches land.

Waves and Signal Transmission

Sound and **light signals** are **transmitted** (**sent**) from
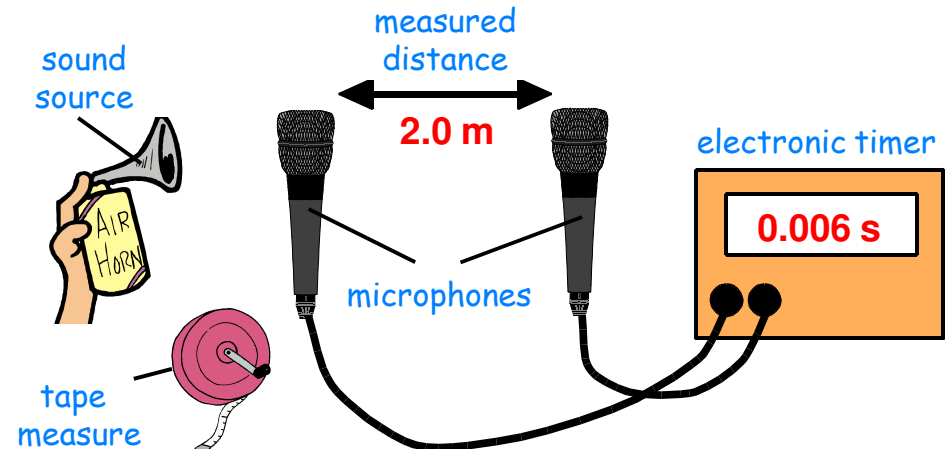one place to another by **w** _ _ _ _.

!!Remember!!

| distance = speed × time |

d _ _ _ _ _ _ _
unit: _ _ _ _

v   t

s _ _ _ _ _ of s _ _ _ _ _   t _ _ _
unit: _ _ _ _   unit: _ _ _ _

You can use this equation to calculate
the speed of sound in air..............

2

Experiment to Measure the Speed of Sound in Air

We can perform an experiment to measure the
speed of sound in air.

measured distance

2.0 m

sound source

electronic timer

0.006 s

microphones

tape measure

● We use a **t** _ _ _ **m** _ _ _ _ _ _ to measure the
d _ _ _ _ _ _ _ _ between the 2 **m** _ _ _ _ _ _ _ _ _ _ _ .

● We make a sharp **s** _ _ _ _ next to the left hand
m _ _ _ _ _ _ _ _ _ _ .

● The **s** _ _ _ _ travels through the **a** _ _ between the
2 **m** _ _ _ _ _ _ _ _ _ _ _ . The **t** _ _ _ this takes is
recorded on the electronic **t** _ _ _ _ .

● We calculate the speed of sound in air using the formula:

$$\text{speed} = \frac{\text{distance between microphones}}{\text{time for sound to pass between microphones}}$$

1) (a) What value
for the speed of
sound in air do you
obtain using the
values shown on the
apparatus above?

(b) How could you improve
this experiment?

Comparing the Speed of Sound and Light in Air

In air, speed of sound = _ _ _ m/s

In air, speed of light = _ _ _ _ _ _ _ _ _ m/s (_ × 10⁻ m/s) } In air, light travels almost _____ times faster than sound.

Light travels so quickly that we see an event happening at the instant it happens - light from the event reaches our eyes instantly (even when we are far away).

Use the **word bank** to complete the passage below.

hear	less	light	light	lightning	see
	sound	sound	thunder		

During a storm, **thunder** and **lightning** are produced at exactly the same time.

We _____ the _____ before we _____ the _____ because, in air, the speed of _____ is **less** than the speed of _____ .

The _____ reaches us before the _____ .

2) At a fireworks display, a rocket explodes high above your head, producing a loud explosion and a bright flash of light at the same time.

(a) What will reach you first? - the sound of the explosion or the flash of light:

_____

(b) Explain why:

_____
_____
_____
_____
_____
_____

3) On a golf course, you observe a golfer in the distance hitting a golf ball with her club.

(a) What will you observe first? - the ball moving through the air or the sound of the club hitting the ball:
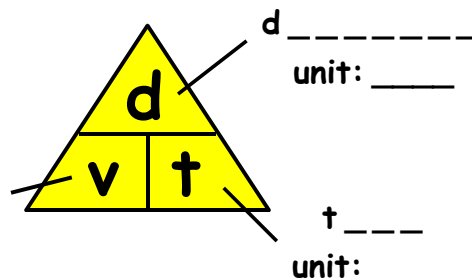
_____

(b) Explain why:

_____
_____
_____
_____
_____

3

We can use this **formula** to solve problems about sound travelling through the air (or other materials):

distance = speed x time

d _ _ _ _ _ _ _ _
unit: _ _ _ _

s _ _ _ _ _ of s _ _ _ _ _
unit: _ _ _ _

t _ _ _
unit: _ _ _ _

4) Calculate the distance sound will travel through the air in 2 seconds.

5) How far will the sound of an explosion travel through the air in 5 seconds?

6) Calculate the time it will take sound to travel 1 020 metres through the air.

7) How long will it take the sound of a bell to travel 850 metres through the air?

8) Calculate the speed of sound in air if it takes 4 seconds for the sound to travel 1 360 metres.

9) The sound of a car horn is heard 1 190 metres away, 3.5 seconds after it has been sounded. Calculate the speed of the horn sound in air.

10) Susan shouts at a brick wall. After 0.8 seconds, she hears her "echo" - the sound of her shout reflected off the wall.

Calculate how far away from the wall Susan is. **BE CAREFUL !** - It might help if you draw the path taken by the sound on the diagram.

Susan

wall

Sound has a different speed in different materials. For example:

Speed of sound in steel = 5 200 m/s.
Speed of sound in water = 1 500 m/s.

11) A steel wire is 6 760 metres long. Calculate the time it will take sound to travel along the wire.

12) To find out the depth of water beneath its hull, a fishing boat sends a pulse of sound through the water from its hull to the sea bed. After 1.2 seconds, the fishing boat detects the sound pulse reflected from the sea bed.
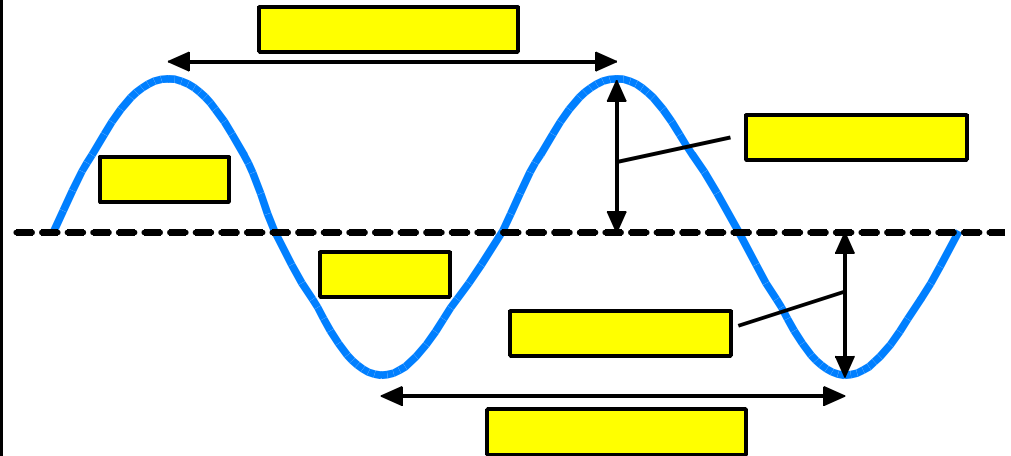
How deep is the sea?

sea bed
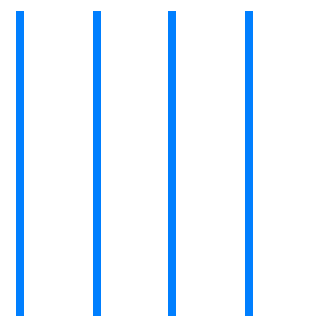
4
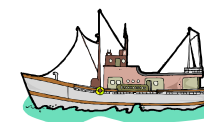
Understanding Waves

13) What is a wave?

14) Do all waves transfer energy?

15) Do all waves have certain things in common?

Use the **word bank** to label the **wave diagram**:
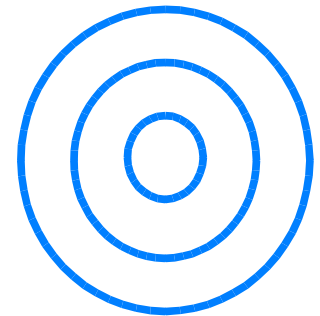
> **amplitude   amplitude   crest   trough**
> **wavelength   wavelength**

These diagrams represent **waves** viewed from above. The lines show the middle of **wave crests**. No **wave troughs** are shown.
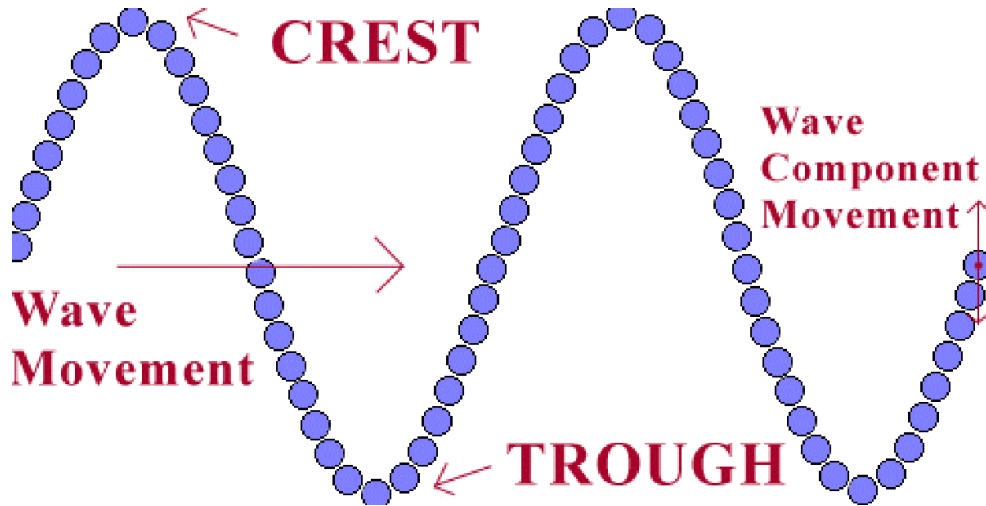
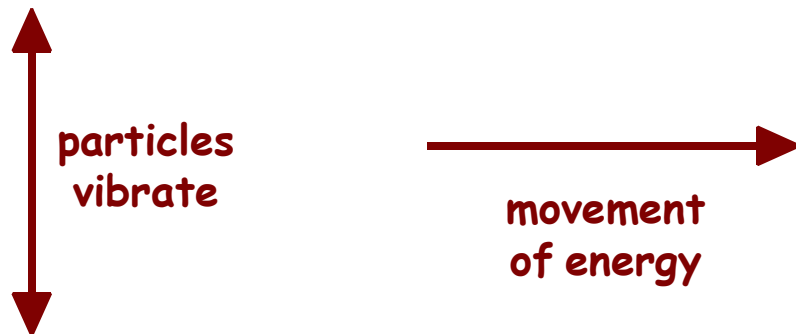**straight waves**

circular waves

On each diagram, show the **wavelength**.
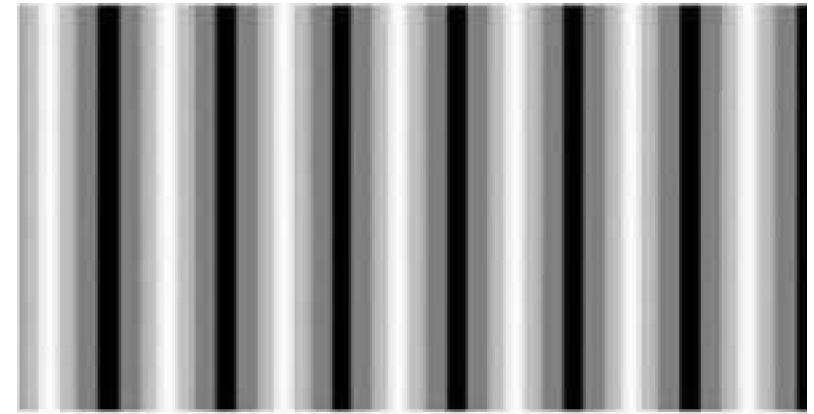
5

Types of Waves

Transverse

In a **transverse wave**, the particles vibrate up and down at **right-angles** (**90º**) to the direction in which **energy** is being carried.

particles vibrate

movement of energy

Longitudinal

In a **longitudinal wave**, the particles vibrate back and forward **along** the direction in which **energy** is being carried.

particles vibrate

movement of energy

6

Describing Waves

above	amplitude	amplitude	below
distance	second	wavelength	
f	Hz	λ	m m m/s v

Quantity	Symbol	Unit	Description
wave crest	■	■	Part of wave _____ centre line.
wave trough	■	■	Part of wave _____ centre line.
	■		Height of wave crest or wave trough measured from the centre line. The higher the _____ of a wave, the more energy it carries.
	lambda		Distance between 2 identical neighbouring points on a wave, e.g., distance between 2 neighbouring wave crests.
frequency		hertz	Number of wavelengths (or crests or troughs) every _____.
speed			_____ wave travels every second.

The **frequency** of a wave is:

_____

_____

This can be represented by the formula:

$$frequency = \frac{number\ of\ wavelengths\ (or\ crests\ or\ troughs)}{time\ in\ seconds}$$

n _____ of
w _____
or c _____ or
t _____

N
f | t

f _____
unit: _____

t ___
unit: _____
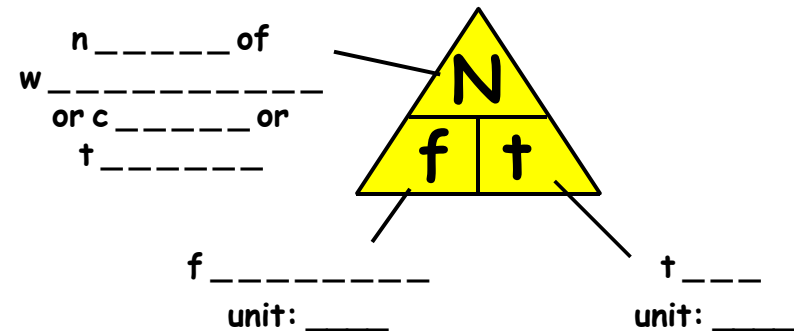
The **speed** of a wave is:

_____

_____

This can be represented by the formula:

d _____
unit: _____

distance = speed × time

d
v | t

s _____ of w ____
unit: _____

t ___
unit: _____

7
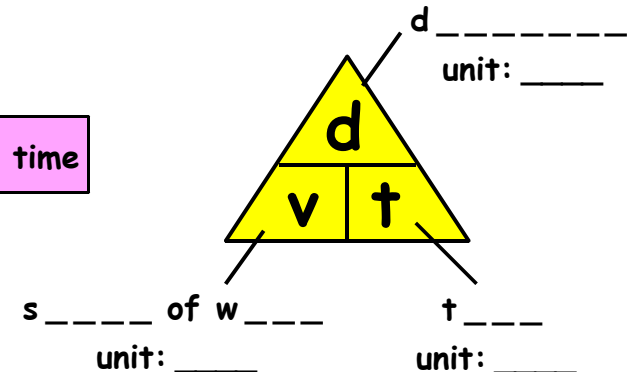
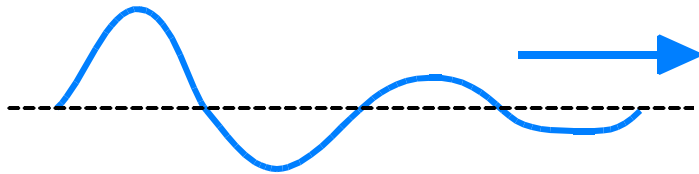# Water Wave Problems/Calculations

16) (a) Which of these waves is carrying the most energy? _____

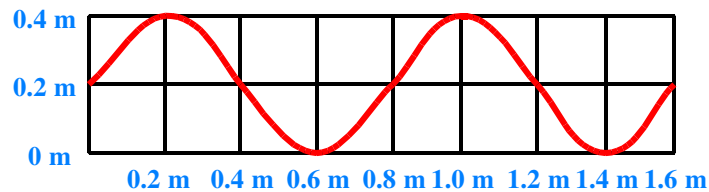(b) Explain you answer: _____

_____

A. **B.**

17) The wave shown below is travelling to the right.

(a) As the wave travels, what happens to its amplitude?

_____

(b) What must be happening to the wave's energy? _____

_____

18) (a) State the value for this wave's:

(i) amplitude: _____ (ii) wavelength: _____

0.4 m

0.2 m

0 m
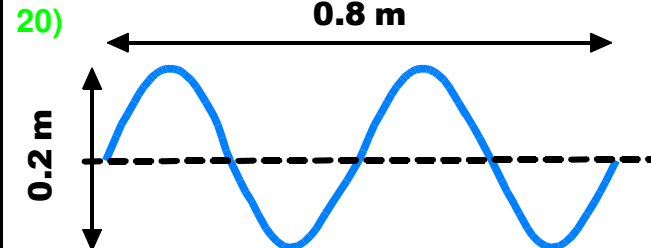
0.2 m 0.4 m 0.6 m 0.8 m 1.0 m 1.2 m 1.4 m 1.6 m
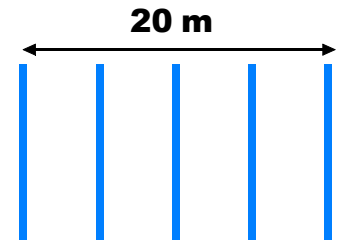
(b) The wave was produced in 1 second.

State the value for its frequency: _____

**19)** Determine the frequency of the wave in each case:

(a) 5 wavelengths are produced every second.

(b) 10 water waves pass the end of a pier in 2 seconds.

(c) 12 circular waves spread across a pond in 20 seconds

20)

0.8 m

0.2 m

(a) For this wave, state the value of:

(i) the amplitude

_____

(ii) the wavelength

_____

(b) The wave was produced in 2 seconds. State the value for its frequency.

21) (a) Determine the wavelength of these water waves.

20 m

(b) These 5 wave crests were produced in 25 seconds. Determine the frequency of the waves.

6 m
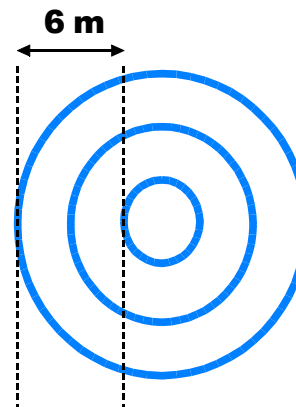
22) (a) What is the wavelength of these circular water waves?

(b) The 3 wave crests were produced in 0.5 seconds. What is the wave frequency?

23) A tsunami sea wave takes 6 seconds to travel up a beach with a speed of 15 metres per second.

What distance does the wave travel up the beach?

24) When Sajidha threw a stone into a pond, circular waves travelled 7.5 metres across the water in 2.5 seconds.

Calculate the speed of these water waves.

25) Sea waves approach a cliff at 4 metres per second.

What time will the waves take to travel 20 metres?

26) Sid the surfer rides the crest of a sea wave travelling at 6 metres per second for 8 seconds.

Calculate how far the wave carries Sid in this time.

27) A drop of water from a leaking tap causes waves on the surface of Brenda's bath water.

If these waves travel 0.4 metres in 1.6 seconds, at what speed are they travelling?

28) As the tide goes out, sea waves travel 50 metres with a speed of 2.5 metres per second.

How long do the waves take to travel this distance?

9

Another Wave Formula

For any wave, the **time** taken (**T**) to produce **1 wavelength** (**1** λ) is related to the **frequency** (**f**) of the wave by the formula:

$$\text{frequency} = \frac{1}{\text{time}}$$

$$f = \frac{1}{T}$$

If **1 wavelength** (**1** λ) is produced in **time** (**T**), a wave will travel a **distance** (**d**) of **1 wavelength** (**1** λ) in **time** (**T**):
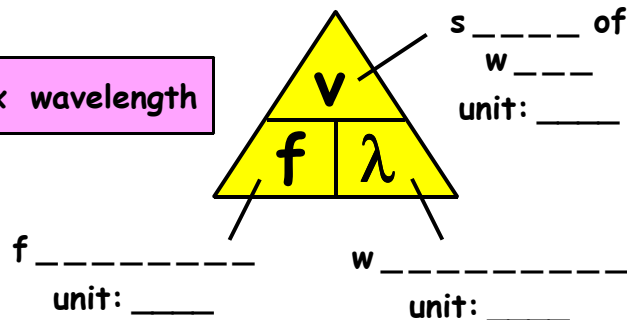
$$\text{speed (v)} = \frac{\text{distance (d)}}{\text{time (T)}} = \frac{1\lambda}{T} = \frac{1}{T} \times \lambda$$

$$= \underline{f \times \lambda}$$

$$\text{since } f = \frac{1}{T}$$

We have another **formula** which applies to **waves**:

$$\boxed{\text{speed} = \text{frequency} \times \text{wavelength}}$$

s _ _ _ _ _ of
w _ _ _
unit: _ _ _ _ _

f _ _ _ _ _ _ _ _ _ _
unit: _ _ _ _ _

w _ _ _ _ _ _ _ _ _ _ _
unit: _ _ _ _ _

Explain the **equivalence** of the 2 **wave formulae**:

$$\text{speed (v)} = \text{frequency (f)} \times \text{wavelength } (\lambda)$$

and

$$\text{speed (v)} = \frac{\text{distance (d)}}{\text{time (T)}}$$

Speed, Wavelength and Frequency Calculations for Water and Sound Waves

29) Calculate the speed of water waves which have a frequency of 2 hertz and a wavelength of 5 metres.

32) Every second, 2 waves are produced on Alan's bath water by water dripping from a tap. If these waves have a wavelength of 0.05 metres, calculate their speed.

35) Calculate the speed of sound waves in air which have a frequency of 500 hertz and a wavelength of 0.34 metres.

38) A submarine sends a pulse of sound through the sea. Determine the speed of the sound pulse if it has a frequency of 7 500 hertz and a wavelength of 0.2 metres.

30) Calculate the frequency of water waves in a harbour if they travel at 3 metres per second and have a wavelength of 4 metres.

33) The wind causes waves to travel across a puddle at 2.4 metres per second. If the waves have a wavelength of 0.6 metres, determine their frequency.

36) Calculate the frequency of sound waves in air which travel at 340 metres per second and have a wavelength of 1.7 metres.

39) Sound travels through steel at 5 200 metres per second. In the steel, sound waves have a wavelength of 2 metres. Calculate their frequency.

31) Calculate the wavelength of water waves on a pond which travel at 0.75 metres per second and have a frequency of 1.5 hertz.
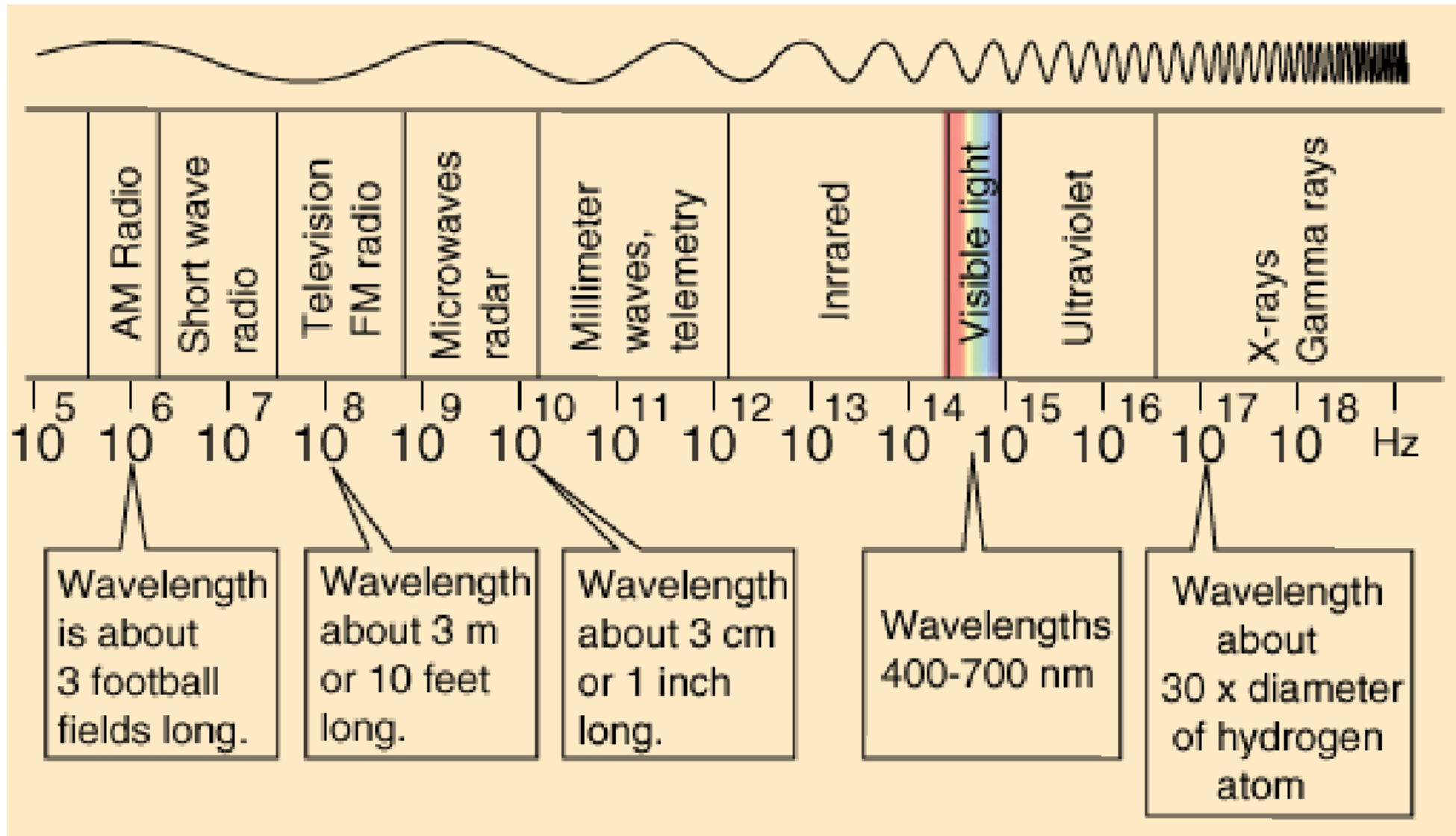
34) A wave generator in a swimming pool produces 2.5 waves every second. The waves travel across the pool at 1.2 metres per second. Determine their wavelength.

37) Calculate the wavelength of sound waves in air if they travel at 340 metres per second and have a frequency of 6 800 hertz.

40) Ultrasound (frequency 21 000 hertz) travels through human muscle at 1 600 metres per second. Calculate the wavelength of ultrasound in the muscle.

The Electromagnetic Spectrum

The electromagnetic (EM) spectrum is a name that scientists give to groups of transverse waves which have different wavelengths/frequencies but all travel at the same speed in air (300 000 000 m/s, i.e., 3×10^8 m/s).
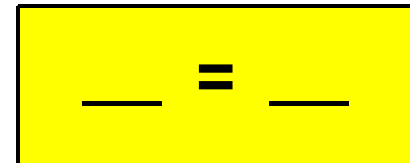
AM Radio	Short wave radio	Television FM radio	Microwaves radar	Millimeter waves, telemetry	Infrared	Visible light	Ultraviolet	X-rays Gamma rays

10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} Hz

Wavelength is about 3 football fields long.

Wavelength about 3 m or 10 feet long.

Wavelength about 3 cm or 1 inch long.

Wavelengths 400-700 nm

Wavelength about 30 x diameter of hydrogen atom

Optics

Reflection of Light

Light travels in **straight lines** called **light r** _ _ _.

When a **light ray** hits a surface like a **plane mirror**, the **light ray** is **r** _ _ _ _ _ _ _ _ off the surface.

A <u>normal</u> is a dashed line drawn at 90º to a surface where a light ray hits the surface.

plane mirror

i **r**

normal
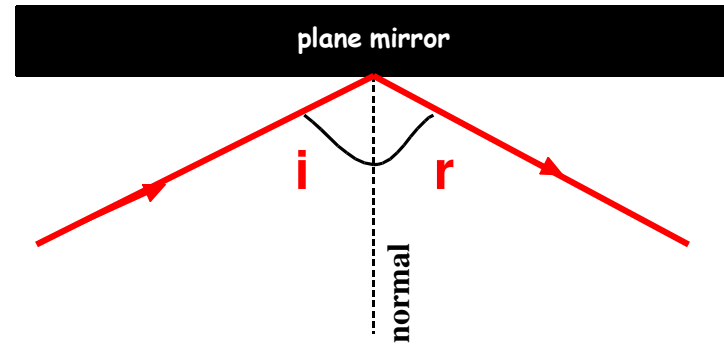
During **r** _ _ _ _ _ _ _ _ _ _,
the **angle of i** _ _ _ _ _ _ _ _ _ (**i**) is always
<u>equal</u> <u>to</u> the **angle of r** _ _ _ _ _ _ _ _ _ (**r**).

_ _ **=** _ _

The Principle of Reversibility of Ray Paths

If a **light ray** is shone from **A** to **C** via **B** or from **C** to **A** via **B**,
it will follow **<u>exactly</u>** **<u>the</u>** **<u>same</u>** **<u>path</u>** but in the **<u>reverse</u>** **<u>direction</u>**.
This is the **principle of r** _ _ _ _ _ _ _ _ _ _ _ _ _ of **r** _ _ **p** _ _ _ _.

plane mirror

B

A   **C**
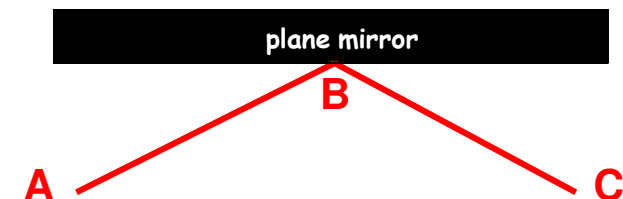
Total Internal Reflection

Fibre optics can be used as a transmission system for **c _ _ _** **light** - No **h _ _ _** **energy** passes through the system.

L _ _ _ _ _ passes along an **o _ _ _ _** **f _ _ _ _ _** by **t _ _ _ _** **i _ _ _ _ _ _ _** **r _ _ _ _ _ _ _ _ _ _**.

- What do the words "**total**" and "**internal**" tell you about the **reflection**? _____
_____
_____
_____

- Complete this diagram to show **light** passing along an **optic fibre**:
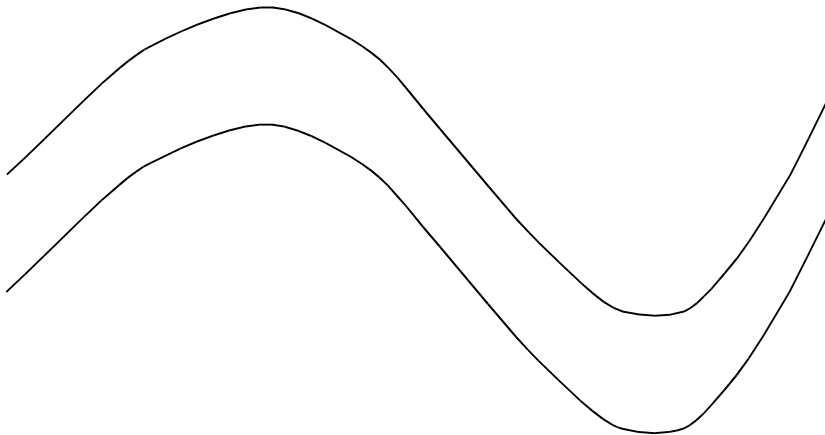
This diagram shows parts of a **f _ _ _ _ _ _ _ _ _** (**e _ _ _ _ _ _ _ _**)
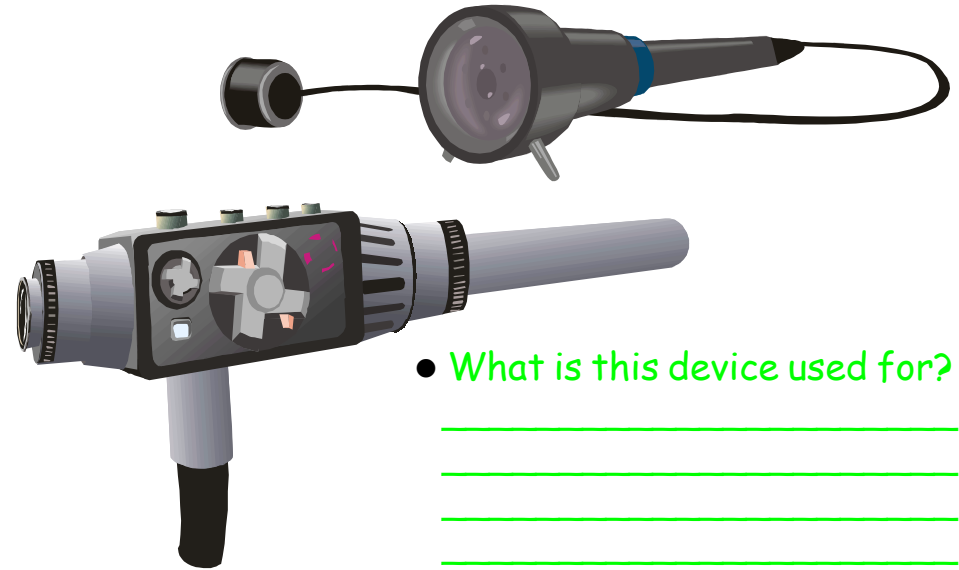
- What is this device used for?
_____
_____
_____
_____

- Describe and explain how it works: _____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Curved Reflectors

Fitting a **c _ _ _ _ _ r _ _ _ _ _ _ _ _ _ dish** to a **receiver aerial**
can make the **received signal s _ _ _ _ _ _ _ _**.

When incoming signals hit the **c _ _ _ _ _ r _ _ _ _ _ _ _ _ _ dish**,
the **dish f _ _ _ _ _ _** them all onto the **r _ _ _ _ _ _ _ a _ _ _ _ _**
- The **r _ _ _ _ _ _ _ a _ _ _ _ _** therefore receives a **s _ _ _ _ _ _ _**
signal than it would if the **dish** was not fitted to it.

Show this by completing the diagram:

receiver aerial →

curved reflector dish
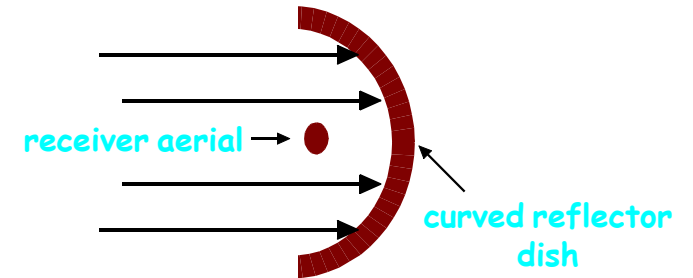
Curved Reflector Transmitter and Receiver Systems

Complete the diagram below to show **signals** being transmitted from the **transmitter aerial** to the **receiver aerial**:

curved reflector dish

curved reflector dish
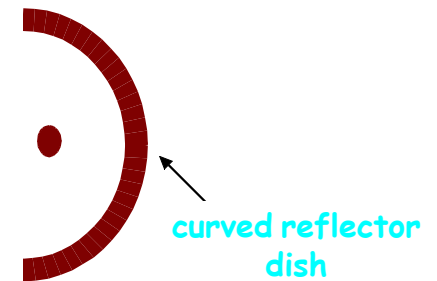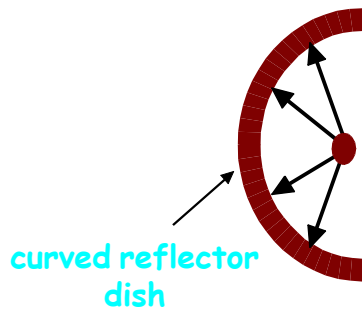
The above diagram could represent **signals** being passed from a **satellite** to the **Earth**, or a **TV link**
(e.g., television signals being sent from a sporting event to the television studio).

Sometimes, if **signals** have to travel a long distance over the Earth's surface, the **signals** get **w _ _ _ _ _**.
We make the **signals s _ _ _ _ _** again by giving them **e _ _ _ _ _** at a **b _ _ _ _ _ _ station**.

Show this on the diagram below:
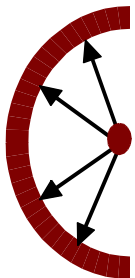
main transmitter
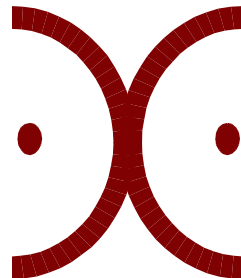
booster receiver and transmitter station

**main receiver**

15

Refraction of Light

Light travels in **straight lines** called **light r** _ _ _.

When **light** passes from one material into another of different **density**, its **s** _ _ _ _ changes and so its **d** _ _ _ _ _ _ _ _ changes (unless the light hits the material at 90° to its surface) - This is known as **r** _ _ _ _ _ _ _ _ _.

**A <u>normal</u> is a dashed line drawn at 90° to the surface of a material where a light ray hits the material.**

angle of
i _ _ _ _ _ _ _ _ _
in air

normal

When a light ray passes from air into glass/plastic/water, the ray bends **t** _ _ _ _ _ _ the normal line.

i

r

angle of
i _ _ _ _ _ _ _ _ _
in material

angle of
r _ _ _ _ _ _ _ _ _ _
in material

i

When a light ray passes from glass/plastic/water into air, the ray bends **a** _ _ _ **f** _ _ _ the normal line.

normal

r

angle of
r _ _ _ _ _ _ _ _ _
in air

16
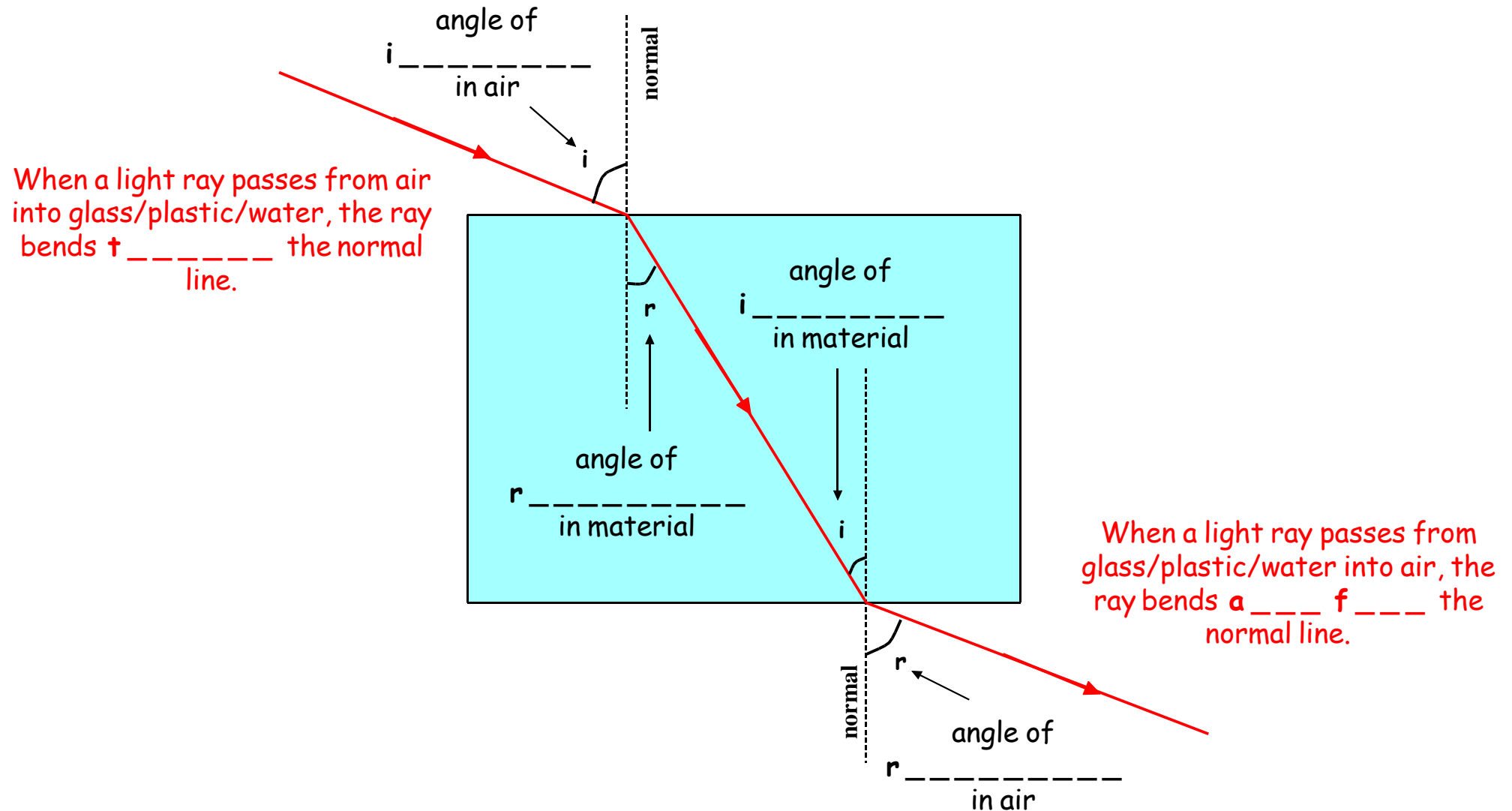
- Using a **ruler** and **protractor**, complete each diagram below to show what happens to the **rays of light** as they pass through the glass blocks. (Remember to draw **normal** **lines**).
TAKE YOUR TIME AND WORK VERY CAREFULLY.
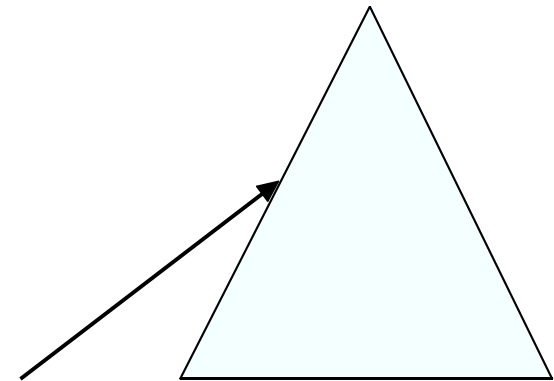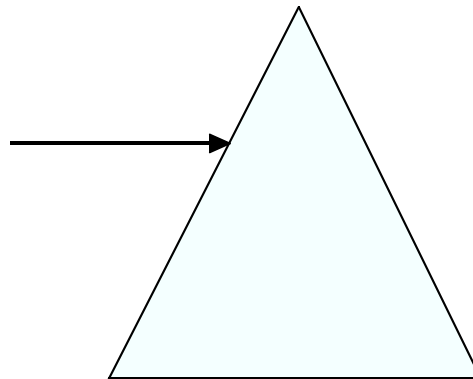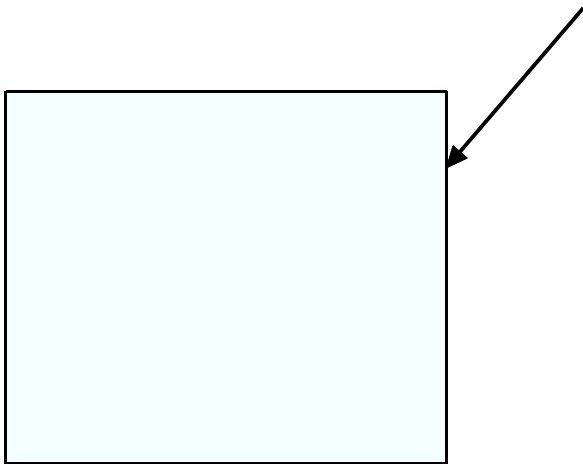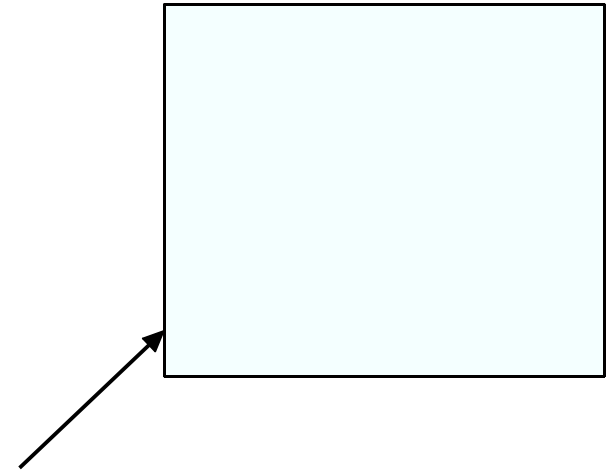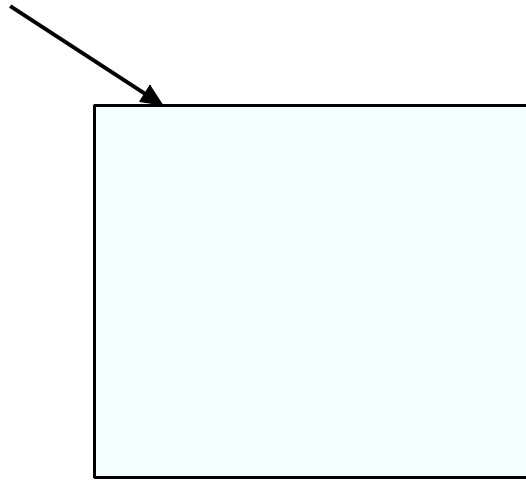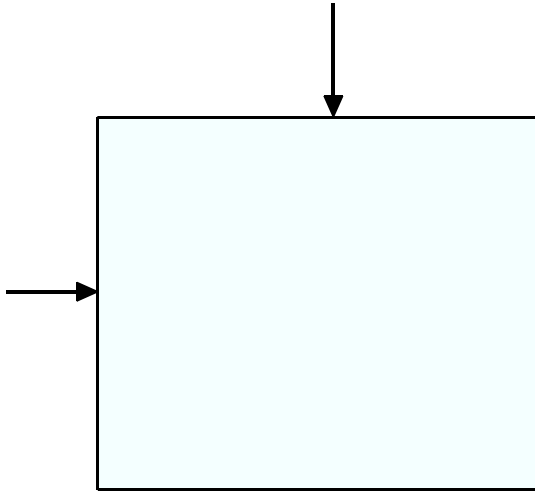
Lenses

● Name each shape of **lens** shown below.

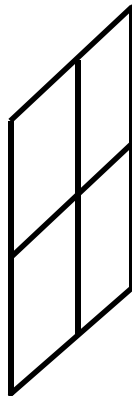● Using a **ruler**, complete both diagrams to show what happens to the **light** **rays**.
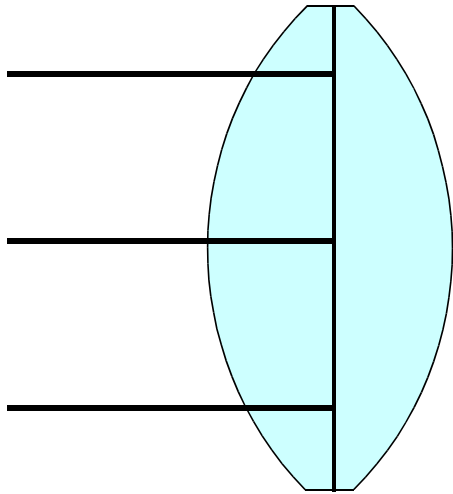
_____ **lens**
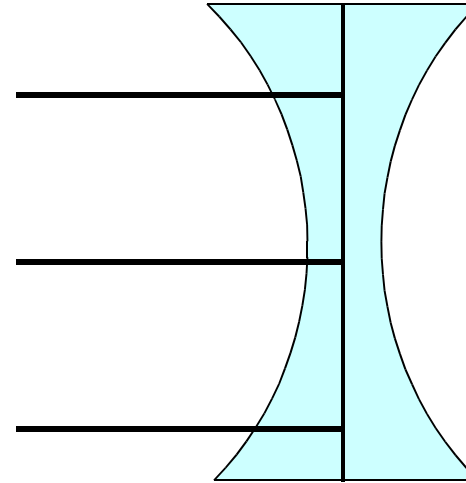
_____ **lens**

● On each diagram, show the **focal** **length** of the lens.

● Describe a simple experiment you could perform to find the **focal** **length** of a **convex** **lens**.

far away window

screen

convex lens

ruler

18

Focal Length and Power of Lenses

T _ _ _ _ lenses refract (**b** _ _ _) light more than **t** _ _ _ lenses - so **t** _ _ _ _ lenses are more **p** _ _ _ _ _ _ _ _.

A **powerful** lens has a **s** _ _ _ _ _ _ focal length.

Convex lenses have a **p** _ _ _ _ _ _ _ _ (_ _) power.   Concave lenses have a **n** _ _ _ _ _ _ _ (_ _) power.

$$\text{power (P)} = \frac{1}{\text{focal length in metres (f)}}$$

$$\frac{1}{P \mid f}$$
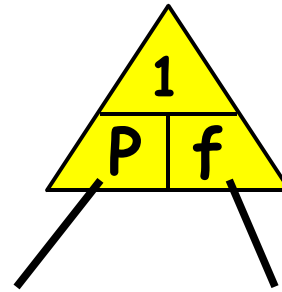
$$\text{focal length in metres (f)} = \frac{1}{\text{power (P)}}$$

dioptres (D)   **metres (m)**

Convex Lenses

A convex lens has a power of + 5 D. Calculate its focal length in metres.

A convex lens has a focal length of 0.5 m. Calculate its power.

Calculate the focal length of a lens with power + 40 D.

Calculate the power of a convex lens of focal length 0.25 m.

## Concave Lenses

A concave lens has a power of –4 D. Calculate its focal length in metres.

A concave lens has a focal length of 1.25 m. Calculate its power.

Calculate the focal length of a lens with power –8 D.

Calculate the power of a concave lens of focal length 0.6 m.

19

Long Sight

Can focus on
a far object

Near object

Image focused
behind retina
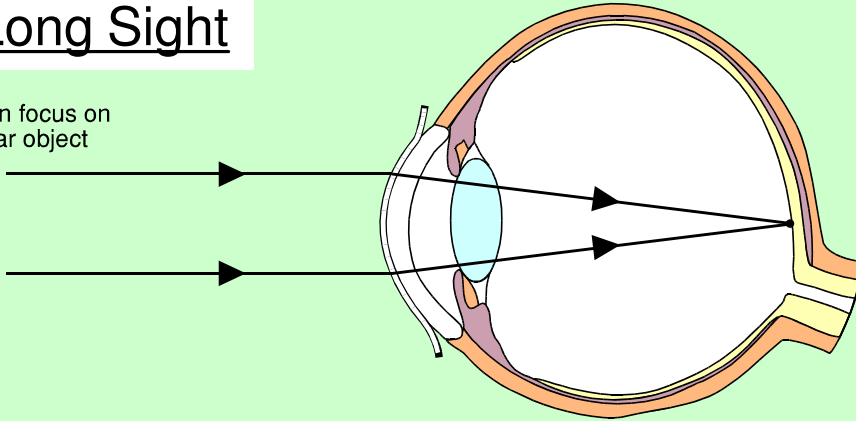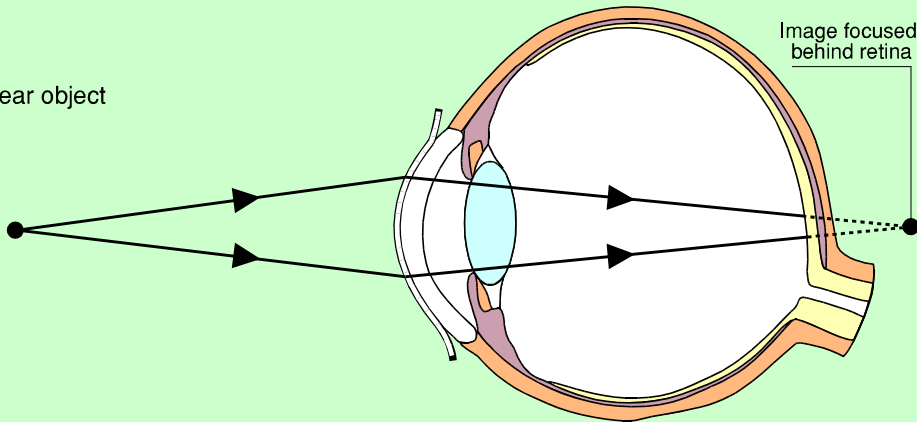
A convex lens will bend
the light rays inwards

Image focussed
on retina
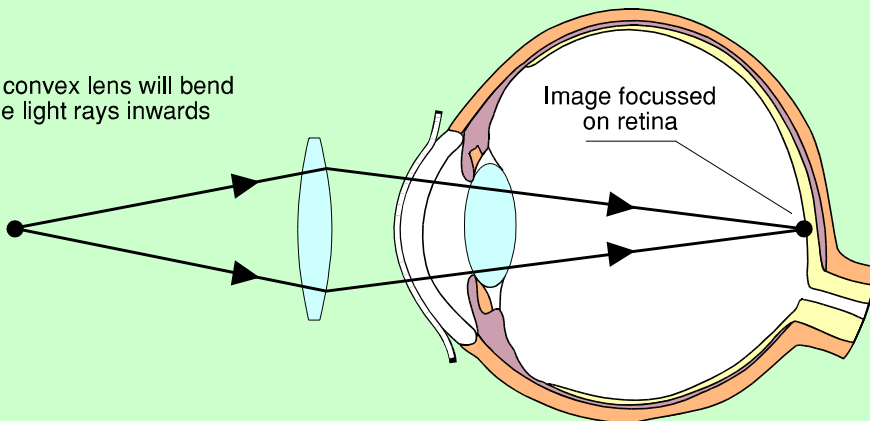
A person who is l _ _ _ s _ _ _ _ _ _ _ can see c _ _ _ _ _ _ objects which are f _ _ a _ _ _ _ - This is because the eye c _ _ focus the p _ _ _ _ _ _ _ _ light rays coming from the object on the r _ _ _ _ _.

However, the person cannot see c _ _ _ _ _ _ _ objects which are c _ _ _ _ _ to them - This is because the eye c _ _ _ _ _ focus the n _ _ - p _ _ _ _ _ _ _ _ light rays coming from the object on the r _ _ _ _ _.

Complete this diagram to show how a "long-sighted eye" focuses light rays from a **close** object.
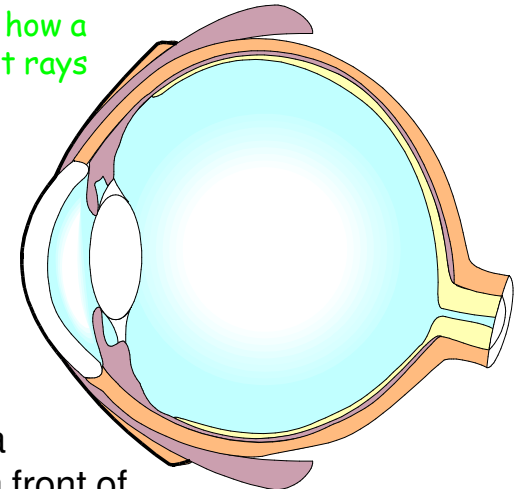
To correct long sight, a c _ _ _ _ _ _ l _ _ _ is placed in front of the eye. Complete this diagram to show the affect the lens has on light rays from a **close** object.
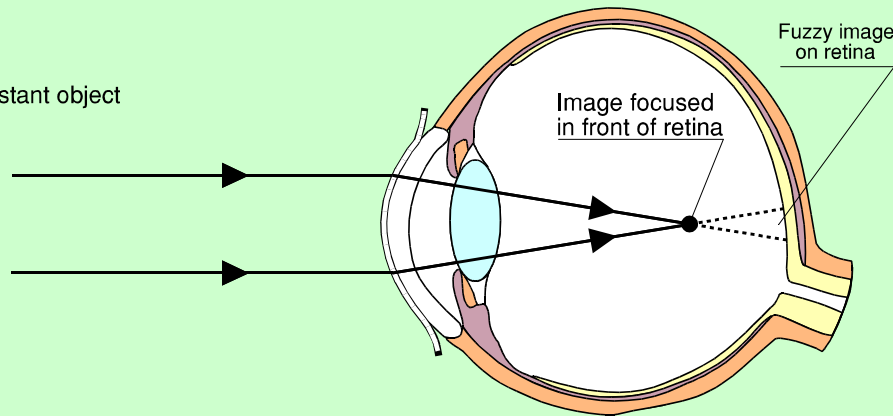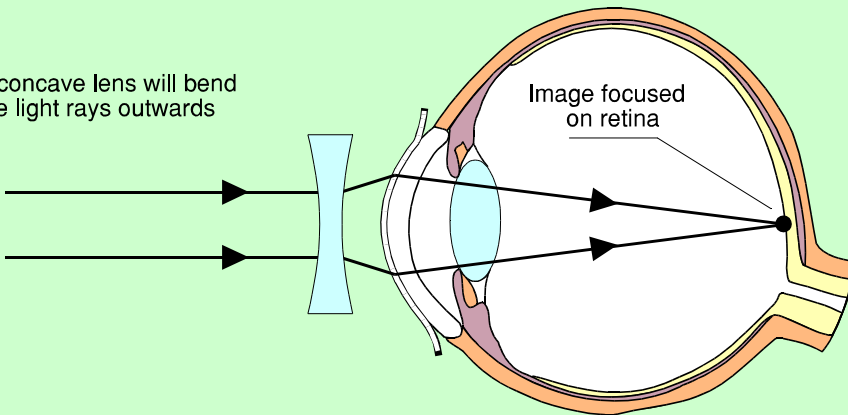
20
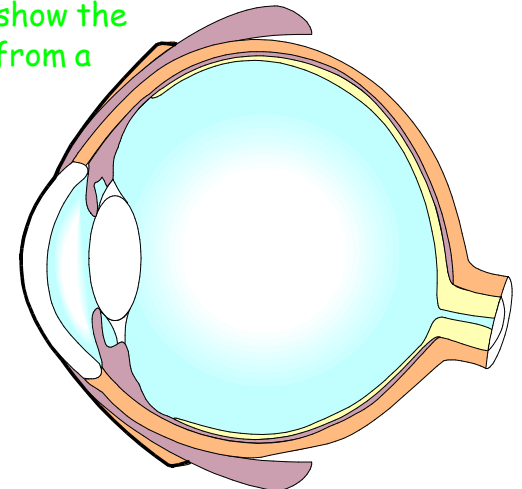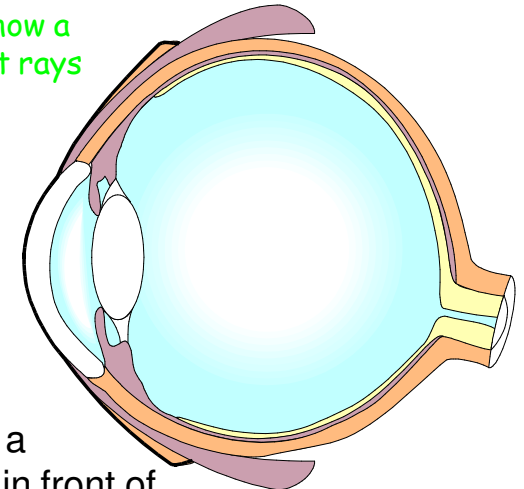
Short Sight

Can focus on
a near object

Distant object

Fuzzy image
on retina

Image focused
in front of retina
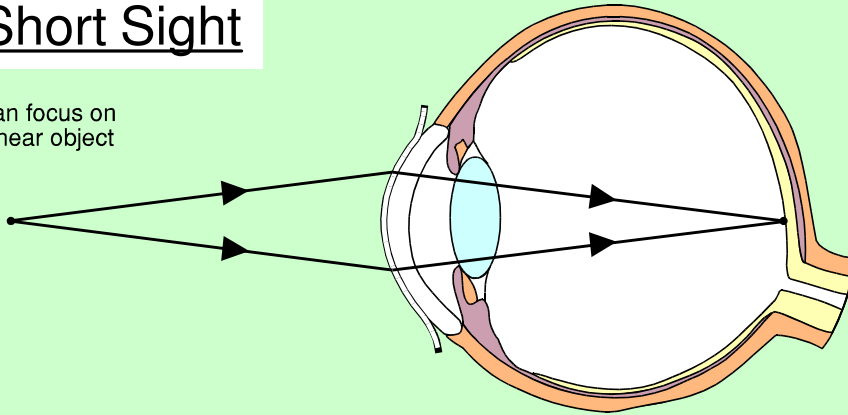
A concave lens will bend
the light rays outwards

Image focused
on retina

A person who is **s** _ _ _ _ **s** _ _ _ _ _ _ _ can see **c** _ _ _ _ _ _ _
objects which are **c** _ _ _ _ - This is because the eye
c _ _ focus the **n** _ _ - **p** _ _ _ _ _ _ _ light rays coming from
the object on the **r** _ _ _ _ _.

However, the person cannot see **c** _ _ _ _ _ _ _ objects which
are **d** _ _ _ _ _ _ _ (**f** _ _ **a** _ _ _) - This is because the eye
c _ _ _ _ _ focus the **p** _ _ _ _ _ _ _ light rays coming from the
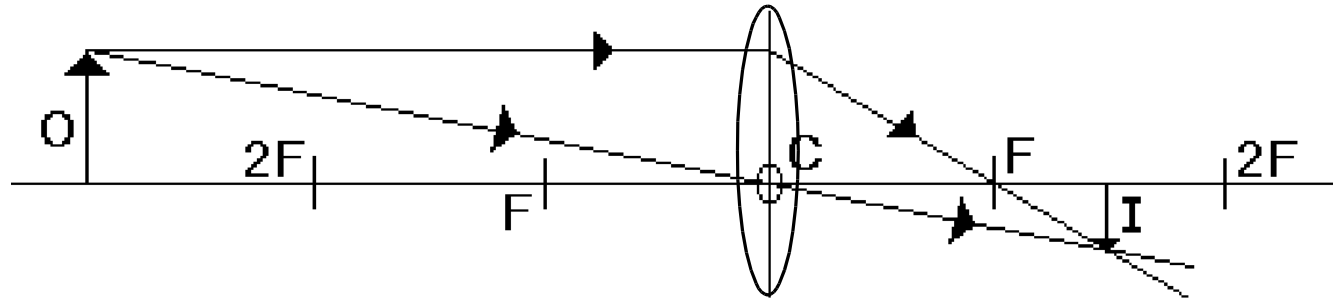object on the **r** _ _ _ _ _.

Complete this diagram to show how a
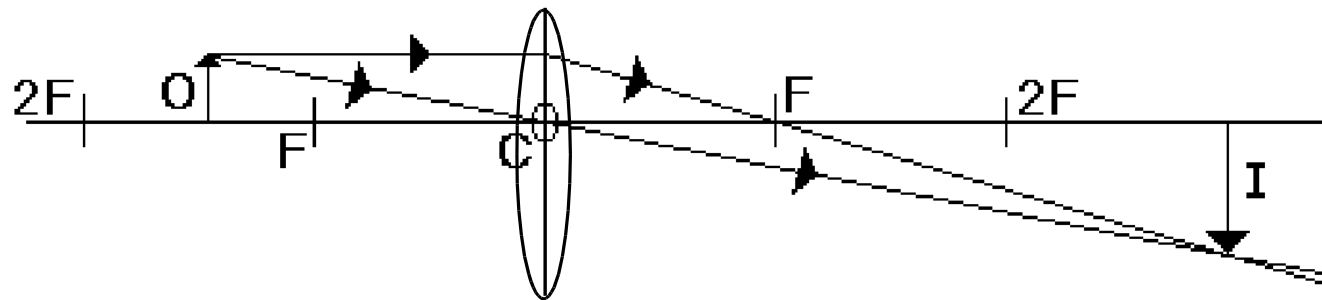"short-sighted eye" focuses light rays
from a **_distant_** object.

To correct short sight, a
c _ _ _ _ _ _ _ **l** _ _ _ is placed in front of
the eye. Complete this diagram to show the
affect the lens has on light rays from a
distant object.

21
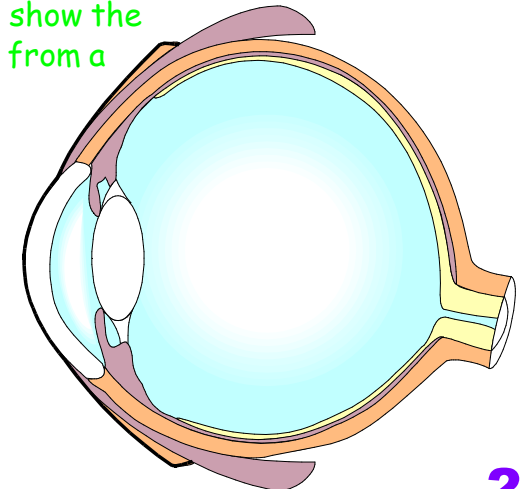
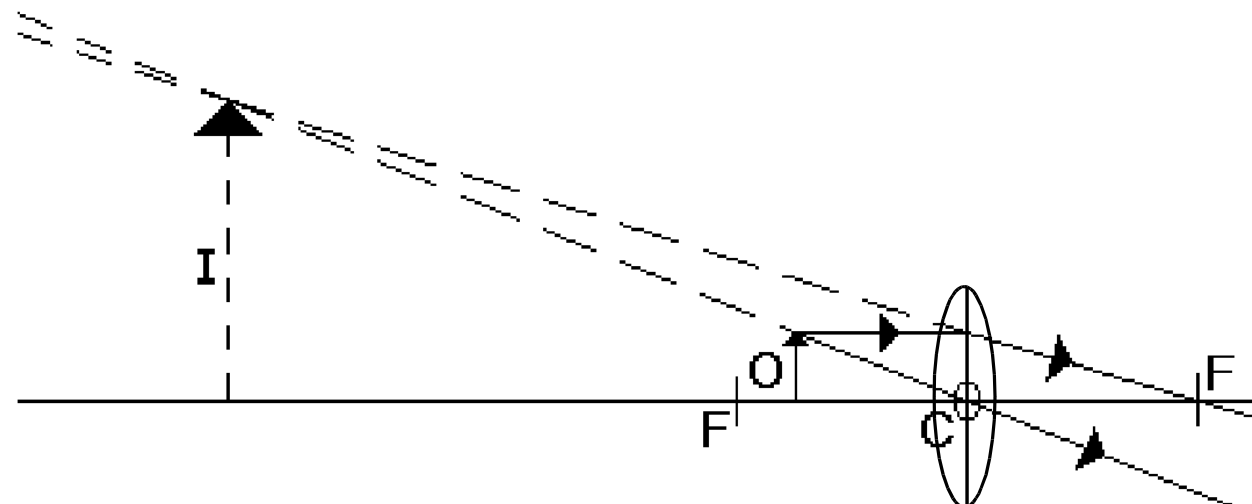# Images Formed by Convex Lenses

Object beyond 2F, image is inverted, real and diminished

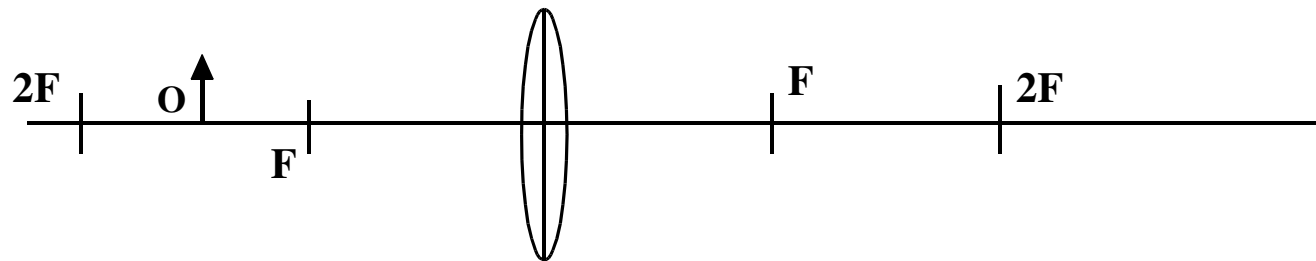Object between2F and F, image is inverted, real and magnified.

Object inside F, image is upright, virtual and magnified.

22

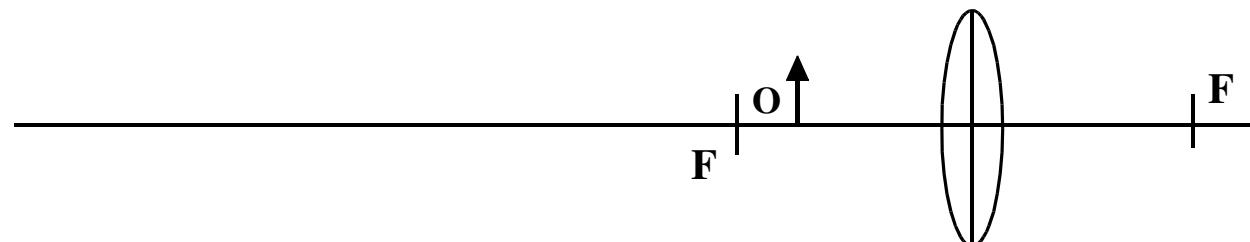- Complete each diagram, to show the **image** formed by the convex lens.

   USE A PENCIL AND RULER.   BE CAREFUL.   TAKE YOUR TIME.

O
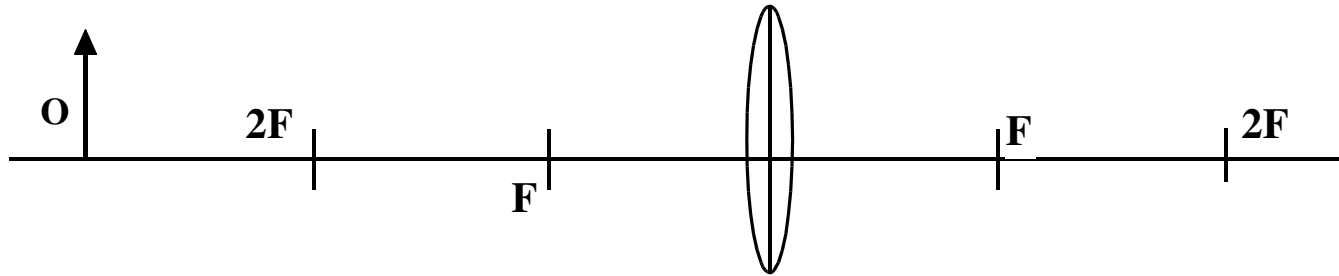
2F

F

F

2F

Object beyond 2F: Image is i _ _ _ _ _ _ _ _ , r _ _ _ and d _ _ _ _ _ _ _ _ _ .

2F

O

F

F

2F

Object between 2F and F: Image is i _ _ _ _ _ _ _ _ , r _ _ _ and m _ _ _ _ _ _ _ _ .

O

F

F

Object inside F: Image is u _ _ _ _ _ _ _ , v _ _ _ _ _ _ and m _ _ _ _ _ _ _ _ .

23
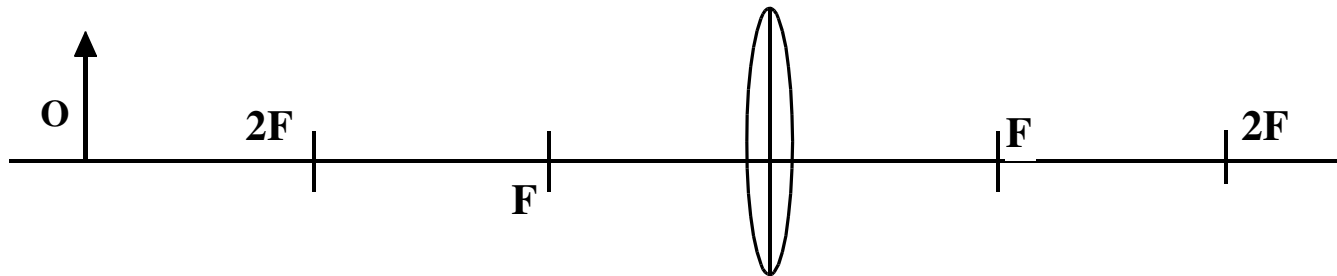
- *ONCE AGAIN*, complete each diagram, to show the **image** formed by the convex lens.

USE A PENCIL AND RULER.   BE CAREFUL.   TAKE YOUR TIME.

O

2F

F

F

2F

Object beyond 2F: Image is i _ _ _ _ _ _ _ _ , r _ _ _ and d _ _ _ _ _ _ _ _ _ _.

2F

O

F

F

2F

Object between 2F and F: Image is i _ _ _ _ _ _ _ _ , r _ _ _ and m _ _ _ _ _ _ _ _ _.

O

F

F

Object inside F: Image is u _ _ _ _ _ _ _ , v _ _ _ _ _ _ and m _ _ _ _ _ _ _ _ _.