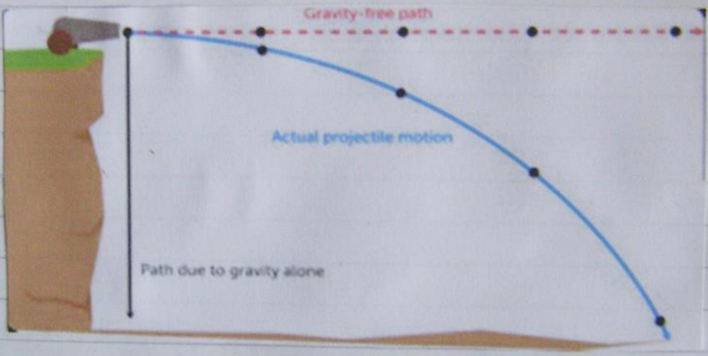
BMcMULLEN ①

CfE Projectile motion and Satellites -

• Projectile motion

This involves the motion of an object moving freely through the air.



Projectile motion consists of two components:

- Horizontal motion
- Vertical motion

When these two components of motion combine the path that the object is travelling in is called a trajectory.

Framework for projectiles questions

V	H
$u_V =$	$u_H =$
$v_V =$	$v_H =$
$a_V = 9.8 ms^{-2}$	$a_H = 0$
$t =$	$t =$

V → Vertical
H → Horizontal

uvat

- The horizontal speed during projectile motion is constant $\therefore a_H = 0$.
- The vertical speed during projectile motion continually changes due to the force of gravity acting vertically down.

Guide to solving projectile problems.

- Look closely at the information given in the question and then fit it into the framework given above
- Then apply the equation $a = \frac{v-u}{t}$ or in the form $v = u + at$.
- Then if you are asked to calculate a distance travelled then use

$$d = \bar{v} \times t \quad \text{where } \bar{v} = \text{average speed.}$$

Horizontally $d_H = \bar{v}_H \times t$

Where $\bar{v}_H$ is the horizontal speed as this is a constant that never changes.

Vertically $d_v = \bar{V}_v \times t$

Where $\bar{V}_v$ is the average of the initial vertical speed and the final vertical speed.

$$\bar{V}_v = \frac{u_v + V_v}{2}$$

($a_v = 9.8ms^{-2}$ which is a constant and never changes during the motion)

ie To find the average of two numbers you would add them up and then divide by 2!!

Ex 1

A person drops a coin vertically down a water well from his hand from rest.
If the coin hits the water surface 2·6 seconds later then calculate or find:

Q
a) The vertical speed of the coin as it hits the water surface.

b) The vertical distance travelled by the coin from the persons hand to the water surface.

A
It is important at this stage to write down the framework to put the information into.

V	H
$u_v = 0ms^{-1}$	NOT
$v_v = ?$	NEEDED IN
$a_v = 9.8ms^{-2}$	QUESTION
$t = 2.6s.$	

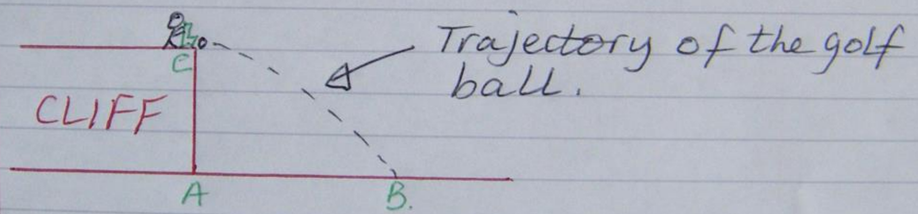
a) $v_v = u_v + a_v t \Rightarrow v_v = 0 + 9.8 \times 2.6 = \underline{\underline{25.5ms^{-1}}}$

b) $d_v = \bar{v}_v \times t$ $\qquad \bar{v}_v = \frac{u_v + v_v}{2}$

$\Rightarrow d_v = 12.8 \times 2.6$ $\qquad \bar{v}_v = \frac{0 + 25.5}{2} = \underline{\underline{12.8ms^{-1}}}$

$\Rightarrow \underline{\underline{d_v = 33.3m}}$

Ex2



A person stands at the edge of a cliff with a golf ball and a putter.

The trajectory of the golf ball is shown above after impact with the putter.

The ball lands on the ground at B, 1.8 seconds after leaving point C.

If the ball is hit with a horizontal component of velocity $8ms^{-1}$ then Calculate or find:

Q a) Horizontal velocity when the ball hits the ground at B.

b) Vertical velocity when the ball hits the ground at B.

c) Horizontal distance travelled. (AB)

d) Vertical distance travelled. (CA)

FRAMEWORK

V	H
$u_V = 0ms^{-1}$	$u_H = 8ms^{-1}$
$V_V = ?$	$V_H = ?$
$a_V = 9{\cdot}8ms^{-2}$	$a_H = 0ms^{-2}$
$t = 1{\cdot}8s$	$t = 1{\cdot}8s.$

$u_V = 0$ as the ball is projected with an initial horizontal component of velocity only.

A a) $u_H = V_H = 8ms^{-1}$ (Hor. comp of velocity is constant)

b) $V_V = u_V + a_V t = 0 + 9{\cdot}8 \times 1{\cdot}8 = 17{\cdot}6ms^{-1}$

c) $d_H = \bar{V}_H \times t = 8 \times 1{\cdot}8 = 14{\cdot}4m$

d) $d_V = \bar{V}_V \times t$

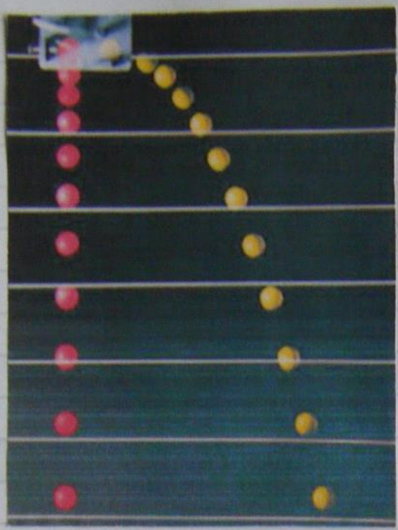
$\Rightarrow d_V = 8{\cdot}8 \times 1{\cdot}8$

$\Rightarrow d_V = 15{\cdot}8m$

$\bar{V}_V = \frac{u_V + V_V}{2}$

$\bar{V}_V = \frac{0 + 17{\cdot}6}{2} = \frac{17{\cdot}6}{2}$

$\bar{V}_V = 8{\cdot}8ms^{-1}$

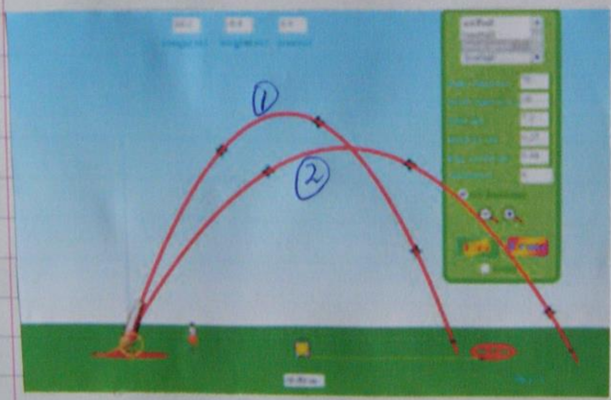


① ②

The strobe photograph shows that the vertical distance travelled by the balls each second is the same.

In ① the ball is dropped with a vertical component of velocity only.

In ② the ball is dropped with a horizontal and vertical component of velocity.



In ① greatest height.

In ② greatest horizontal range.

In ① the projectile is fired at a higher angle than ②.

In ① the maximum height reached by the projectile is greater than ②, but the horizontal range in ② is greater than in ①.

• Satellites

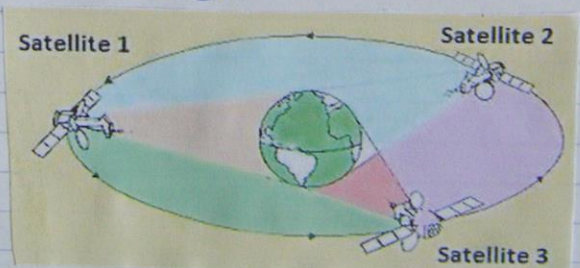
Satellites transmit signals around the World. One complete path around the Earth is called an orbit.

Microwaves, which are very short wavelength radio waves are often used to transmit the signals. Microwaves travel at a speed of $3 \times 10^8 ms^{-1}$ through air and space.

Geostationary Satellites

They are put into orbit at a height of almost 36,000km above the surface of the Earth. These satellites are very expensive to put into orbit at this height.

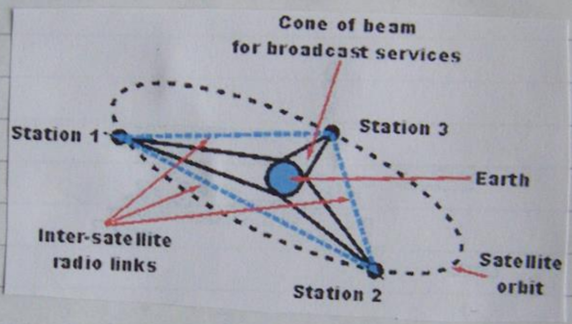
A minimum of 3 geostationary Satellites are required to allow signals to be sent anywhere on Earth.



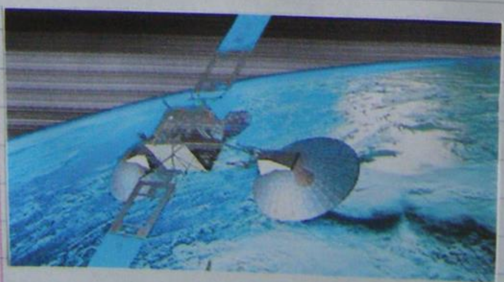
Geostationary satellites stay above the same point above the Earth's surface 24/7 and so it takes 24 hours to complete one orbit. (Just like the Earth!)

Satellites in space act as repeater stations and amplifiers. They get energy from the sun, using solar panels to increase the strength of the signals.

Satellites transmit and receive signals with different frequencies so that signals do not get mixed up and interfere with each other.



It is much cheaper to put satellites into lower orbits, but they move much faster and are not always above the same point above the Earth's surface, unlike geostationary satellites.



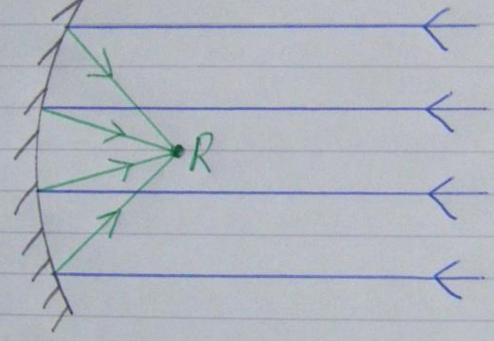
This means that non-geostationary satellites might not be in the right place to send or receive signals when they are needed.

Curved Reflectors

• As Receivers

Curved reflectors collect a lot of signals from a large area and direct them to one point, called the focus.

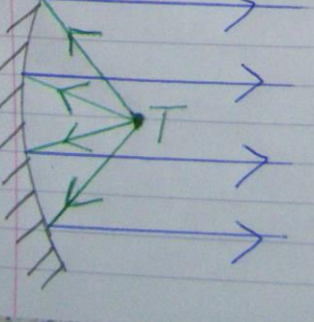
The signal received at the focus is much stronger than without using the reflector.
ie Wave energy at the focus is at a maximum.



The receiver is placed at the focus.
A satellite dish at the side of your house acts as a receiver in this way.

• As Transmitters

Curved reflectors can also act as a transmitter, with the transmitter placed at the focus of the curved reflector.



The strong signal at the focus can produce a wide parallel beam.

This is the idea behind a car headlight, where the silvered curved reflector is used to throw the beam of light forward.

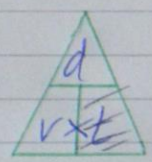
Ex3

Q a) What is meant by a geostationary satellite?

b) Calculate the time taken for a signal to be sent from Earth to a geostationary satellite directly 36,000Km overhead.

A a) • Geostationary satellites are in an orbit at the same point above the Earth's surface at all times.
• They have an orbit of 24hours.
• They orbit at a height of almost 36,000km above the Earth's surface.

b) $d = 36{,}000km = 36{,}000 \times 10^3 m$
$v = 3 \times 10^8 ms^{-1}$
$t = ?$



$$t = \frac{d}{v} = \frac{36{,}000 \times 10^3}{3 \times 10^8} = 0.12s$$

Ex4

A satellite receives information from a ground station at 5·2GHz and transmits information to Earth at 5·6GHz.

Q a) Why are two frequencies used?

b) Calculate the two wavelengths used?

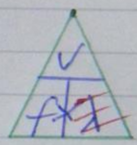
A satellite ground station.

A a) This is to make sure that the transmitted and received signals do not interfere with one another.

b) Received Signals

GHz = $\times 10^9$ Hz

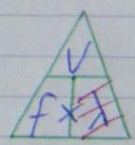
$v = 3 \times 10^8 ms^{-1}$
$f = 5.2 GHz = 5.2 \times 10^9 Hz$
$\lambda = ?$



$\lambda = \frac{v}{f} = \frac{3 \times 10^8}{5.2 \times 10^9} = 5.8 \times 10^{-2} m$

Transmitted Signals.

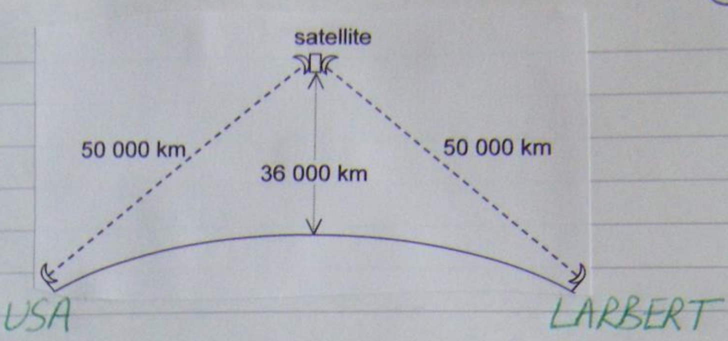
$v = 3 \times 10^8 ms^{-1}$
$f = 5.6 GHz = 5.6 \times 10^9 Hz$
$\lambda = ?$



$\lambda = \frac{v}{f} = \frac{3 \times 10^8}{5.6 \times 10^9} = 5.4 \times 10^{-2} m$

** frequency ↑ ∴ Wavelength ↓ **

Ex5



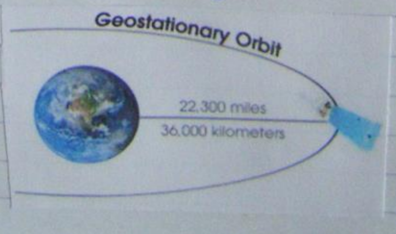
TV signals from the USA are sent to Larbert via space satellites.

Q a) Why can the signals not be transmitted directly from the USA to Larbert?

b) Calculate the time taken for a signal to be sent from Larbert to the USA with an immediate reply being received back in Larbert.

c) Explain how the geostationary satellite receives the signal from Larbert and then re-transmits it to the USA.

d) How can you tell from the diagram above that the satellite is geostationary?

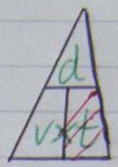


A a) The signals cannot be sent directly from the USA to Larbert due to the curvature of the Earth.

b) $d = 50{,}000\text{km} \times 4 = 200{,}000\text{km} = 200{,}000 \times 10^3\text{m}$

$v = 3 \times 10^8 \text{ms}^{-1}$

$t = ?$



$$t = \frac{d}{v} = \frac{200{,}000 \times 10^3}{3 \times 10^8}$$

$\Rightarrow$ $t = 0.67\text{s}$

c) When the geostationary satellite receives the signal from Larbert it will be extremely weak due to the distance that it has travelled. The geostationary satellite will then boost the signal before it is re-transmitted back down to the USA.

(Writing that the signal is reflected off the geostationary satellite in space and then it goes back down to Earth is totally wrong!!!)

d) You can tell that the satellite in the diagram is geostationary as it sits in orbit 36,000km above the Earth's surface.