Section 1 - Signals from Space

Distances in Space

In this section you can use the following equation:

$$\bar{v} = \frac{d}{t}$$

where: $\bar{\mathbf{v}}$ = average speed in meters per second (m/s)
d = distance travelled in metres (m)
t = time taken in seconds (s).

> *Helpful Hint*
> Because distances in space are so large, astronomers use **light years** to measure distance. *One light year is the* ***distance*** *light will travel in one year. Light travels at* 3×10^8 m/s.

1. How far is a light year?

2. The star Vega is 27 light years from earth. How far away is Vega in metres?

3. The star Pollux is $3{\cdot}78 \times 10^{17}$ m from earth. How far is this in light years?

4. *The star Beta Centauri is 300 light years from earth. How long does it take light to* travel from this star to the earth?

5. An astronomer on Earth views the planet Pluto through a telescope. Pluto is $5\,763 \times 10^6$ km from earth. How long did it take for the light from Pluto to reach the telescope?

6. Our galaxy, the Milky Way, is approximately 100 000 light years in diameter. How wide is our galaxy in kilometres?

7. The nearest star to our solar system is Proxima Centuri which is $3{\cdot}99 \times 10^{16}$ m away. How far is this in light years?

8. Andromeda (M31) is the nearest galaxy to the Milky Way and can just be seen with the naked eye. Andromeda is $2{\cdot}1 \times 10^{22}$ m away from the Milky Way. How long does it take for light from Andromeda to reach our galaxy?

9. The Sun is the nearest star to the planet Earth. It takes light 8·3 minutes to reach us from the Sun. Use this information to find out the distance from the Earth to the Sun *in kilometres?*

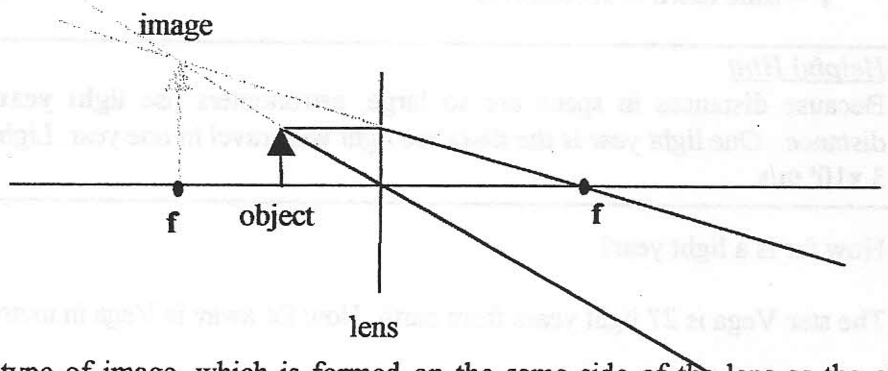
10. Sir William Herschel, an amateur astronomer, discovered the planet Uranus in March 1781. Uranus is $2\,871 \times 10^6$ km away from the sun. How long does it take for sunlight to reach Uranus?

Ray Diagrams

Helpful Hint

You may have noticed that all the images produced by convex lenses in Health Physics were on the opposite side of the lens from the object. These images are called **real images**. Sometimes, however, an image cannot be formed in this way because the rays spread out after passing through the lens. In this case we must extend the ray lines backwards until they meet.

Example

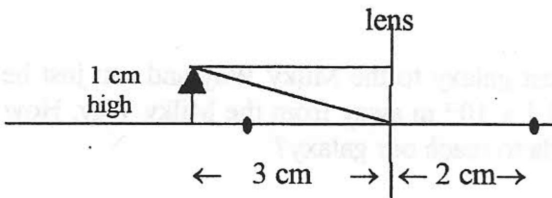


This type of image, which is formed on the same side of the lens as the object is called a **virtual image.**

Remember the rules for drawing ray diagrams:

1. a ray from the tip of the object parallel to the axis passes through the focal point of the lens.
2. a ray from the tip of the object to middle of the lens continues through the lens in the same direction.

1. An object is placed 3 cm from a lens which has a focal length of 2 cm. The object is 1 cm high.
Using a suitable scale, copy and complete the ray diagram below.
(You may find it useful to use graph paper !)



(*a*) How far from the lens is the image produced?

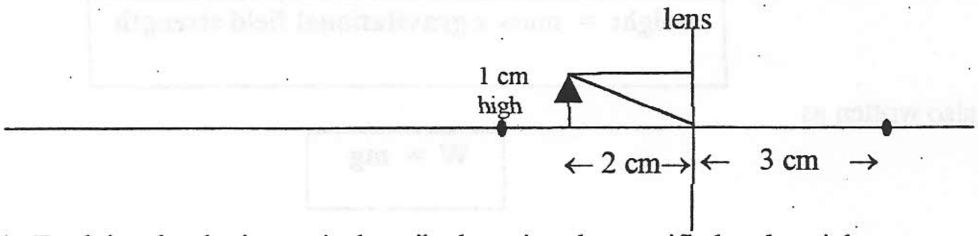
(*b*) Is the image inverted or upright?

(*c*) Is the image real or virtual?

2. A magnifying glass produces an image which is described as virtual, magnified and upright.

A 1 cm high object is placed 2 cm from a magnifying lens whose focal length is 3 cm.

(*a*) Copy and complete the ray diagram below to show how the image is formed.



(*b*) Explain why the image is described as virtual, magnified and upright.

3. A 1 cm high object is placed 5 cm from a lens which has a focal length of 2 cm.

(*a*) Use a ray diagram to find out what kind of image is formed (i.e. real or virtual? magnified , diminished or same size? inverted or upright?)

(*b*) The same object is moved to a distance of 4 cm from the lens. Describe the image which is now formed.
(You will need to draw a new ray diagram !)

(*c*) The object is again moved - this time to a distance of 1·5 cm from the lens. Describe what happens to the image now.

4. A magnifying glass, which has a focal length of 1 cm, is used to examine some small objects. Each object is placed 0·5 cm from the lens. By drawing ray diagrams, to an appropriate scale, find out the size of the image produced by each of the following objects.

(*a*) A printed letter which is 4 mm high.

(*b*) A 2 mm grain of rice.

(*c*) A 5 mm pearl.

5. A man creates an image of a fuse using an 8 cm lens. The fuse is 2 cm high and is positioned at a distance of 4·8 cm from the lens.

(*a*) Draw a ray diagram in order to find out the height of the image produced.

(*b*) How far was this image from the lens?

Section 2 - Space Travel

Weight

In this section you can use the equation:

weight = mass x gravitational field strength

also written as

W = mg

where **W** = weight in Newtons (N)
m = mass in kilograms (kg)
g = gravitational field strength in Newtons per kilogram (N/kg)

Helpful Hint
On Earth **'g' = 10 N/kg** but it varies from planet to planet. In questions about weight on other planets you must use these values by referring to the **data sheet** on page 24

1. Find the missing values in the following table.

	Mass (kg)	*Gravitational field strength* (N/kg)	*Weight* (N)
(*a*)	12	10	
(*b*)	279	4	
(*c*)	0·56		5·6
(*d*)	7·89		78·9
(*e*)		12	700
(*f*)		10	58

2. Calculate the weight of a 70 kg man on Earth.

3. If a moon rock has a weight of 4·6 N, what is its mass?

4. An objects weight depends on the strength of the gravitational field around it. A scientist records the weight of a 3 kg rock on each planet and records the information in the table overleaf.

Planet	Weight(N)
Earth	30
Jupiter	78
Mars	12
Mercury	12
Neptune	36
Saturn	33
Venus	27
Uranus	*35·1*
Pluto	12·6

Use the results from the table to work out the value of the gravitational field strength on each planet (you can check your answers against the data sheet on page 24).

5. Using your results to question 4, state which planet(s) have:

   (*a*) the strongest gravitational field strength

   (*b*) *the weakest gravitational field strength*

   (*c*) a gravitational field strength nearest to that on Earth

   (*d*) a gravitational field strength three times as strong as that on Mercury.

6. Which is heavier, a 2 kg stone on Neptune or a 0·9 kg rock on Jupiter?

7. How much lighter does a 65 kg woman seem on the moon, where 'g' = 1·6 N/kg, than on Earth?

8. Find the weight of a satellite booster on Mars if it weighs 24 N on the moon.

9. What is the difference in **mass** between a 40 N weight on Venus and a 104 N weight on Jupiter?

10. A rock weighs approximately two and a half times its weight on Earth somewhere in our solar system. Where is it likely to be?

Weight, Thrust and Acceleration

In this section you can use the equation:

unbalanced force = mass x acceleration

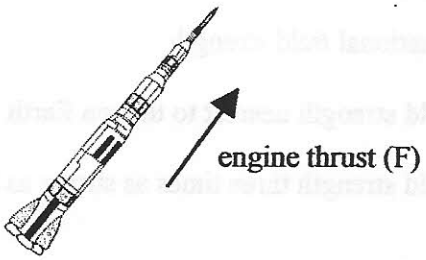
also written as

F = ma

where **F** = unbalanced force in newtons (N)
m = mass in kilograms (kg)
a = acceleration in metres per second per second (m/s^2).

Helpful Hint

When a spacecraft is in space the only force acting on it is its **engine thrust.**



1. Find the missing values in the table.

	Force (N)	*Mass* (kg)	*Acceleration* (m/s^2)
(*a*)		700 000	2·0
(*b*)		45 000	0·9
(*c*)	1 000		0·05
(*d*)	3 600 000		0·01
(*e*)	10 000	80 000	
(*f*)	2 600 000	2 000 000	

2. The engine of a space shuttle can produce a thrust of 600 000 N. The mass of the shuttle is 8×10^5 kg. Calculate the acceleration of the shuttle in space.

3. What engine thrust must be produced by a rocket of mass 3×10^6 kg in order to produce an acceleration of 1·4 m/s² in space?

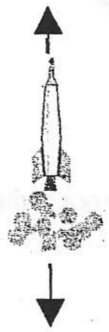
4. The maximum engine thrust of a spacecraft is $2{\cdot}4 \times 10^7$ N and this produces an acceleration of 12 m/s² in space. What is the mass of the spacecraft?

5. An engine force of 160 kN is used to slow down a shuttle in space. If the mass of the shuttle is 120 000 kg what is its rate of deceleration?

Helpful Hint

To find the **acceleration, a,** of an object during a vertical take-off you will need to calculate the unbalanced force acting on the object first.

Example



1st. Unbalanced force = thrust - weight

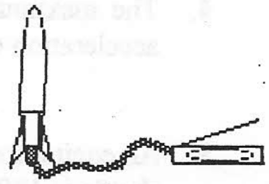
2nd. $\mathbf{a} = \frac{\mathbf{F}}{\mathbf{m}}$

(where F = unbalanced force)

6. Use the three stages outlined in the example above to find the missing values in the following table. Assume that each mass is in the Earth's gravitational field.

	Mass (kg)	*Weight* (N)	*Thrust* (N)	*Unbalanced force* (N)	*Acceleration* (m/s²)
(*a*)	3	30	60		
(*b*)	2 000	2 000	21 000		
(*c*)	1 500		20 000		
(*d*)	50 000		550 000		
(*e*)	70 000		840 000		
(*f*)	76 000		896 800		

7. A water rocket has a mass of 0·8 kg and is launched in a school playground with an initial upwards thrust of 12 N.

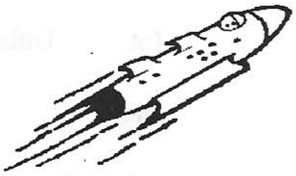


(*a*) What is the weight of the water rocket in the playground?

(*b*) What is the initial acceleration of the rocket in the playground?

(*c*) If this water rocket were launched from the moon, what would be its initial acceleration?
(Remember to find the new weight first !)

8. A rocket is launched from Earth with an initial acceleration of 2·5 m/s^2. The mass of the rocket is 1 600 000 kg.



(*a*) Calculate the unbalanced force acting on the rocket during its launch.

(*b*) What is the weight of the rocket?

(*c*) Calculate the engine thrust of the rocket.

(*d*) What engine thrust would be required to launch this rocket from the moon with the same acceleration?

9. Calculate the acceleration of the following objects.

(*a*) A model rocket of mass 30 kg being launched from Earth with an engine thrust of 800 N.

(*b*) A satellite in space whose mass is 1 800 kg and whose engine force is 4·68 kN.

(*c*) A 100 000 kg shuttle travelling at 50 m/s in space.

(*d*) A toy rocket of mass 1·5 kg whose engine stopped while the rocket was in mid air.

(*e*) A spaceship of mass 4×10^7 kg lifting off from Saturn with an engine thrust of 9×10^8 N.

(*f*) A rocket of mass $2{\cdot}2 \times 10^6$ kg being launched from Neptune with an engine thrust of $4{\cdot}4 \times 10^7$ N.