## Standard Grade Physics

## "SPACE PHYSICS"

## Section 1: Signals From Space



Name:
Class: $\qquad$ Teacher: $\qquad$

## Section 1: Signals from Space

## - The Solar System

The Solar System is made up of the $\mathbf{s}$ $\qquad$ the p_-_-_and all of the other objects that $\mathbf{o}_{\text {_ }}$ __ around the s_-


- The $\mathbf{S}_{-}$_ is a s___. It is a pretty ordinary S $\qquad$ and it is a very small part of our
 .
- Our g $\qquad$ is only one of millions of other g The u $\qquad$ is absolutely everything.


Complete the following descriptions:


## Galaxy:

Interesting Fact The earth has only one moon. Jupiter has 16 and Saturn has about 30. The rings of Saturn are believed by many scientists to be a moon that failed to join together into one mass and remained as millions of fragments orbiting the planet.

## - A Very Long Way

Distances in the universe are very large indeed. They are too large to be measured in kilometres. Because of this scientists have agreed another unit of distance.
A $\qquad$ $y_{---}$ is the distance travelled by light in one year.


Interesting Fact Light travels 300000000 metres every second and there are $(365 \times 24 \times 60 \times 60)=31536000$ seconds in a year so light travels:
$(300000000 \times 31536000)=9460800000000000$ metres in a year which is about $\mathbf{2 4 0}$ million times around the earth.

## Some Distances

The Sun is about $8 \mathbf{I}$ $\qquad$ m $\qquad$ away from the earth. This means that light from the sun takes approximately 8 m $\qquad$ to reach the earth.

The next nearest star in the galaxy is known as Proxima Centauri in the constellation of Centaurus. It is about 4.2 I $\qquad$ $y$ $\qquad$ away from the earth.

The earth is about $1 / 3$ of the way across our galaxy and is about 15 million light years from the edge.
The next nearest galaxy (Andromeda) is about 2.5 m $\qquad$ I_--$\mathbf{y}_{\text {_-_- }}$ away.

Interesting Fact That means if you travelled at the speed of light it would take you about 15 million years to get to the edge of our galaxy.

## - Seeing Further

Look into the clear night sky with a pair of binoculars and a whole new world opens up. You can see the craters on the moon, the six inner planets (which include planet Earth) and four of the moons of Jupiter. A small telescope will reveal even more.

## How a Telescope Works

An optical telescope is made up of three main parts:

## Objective Lens

The o $\qquad$ I $\qquad$ of a telescope is the lens nearest to the object. It gathers I $\qquad$ from the object and brings it to a f $\qquad$ inside the
t___-___. The I____-_ the d___-_-_
 will gather and the $\mathbf{b}$ $\qquad$ the final image will be.

## Eyepiece Lens

The $\mathbf{e}_{\ldots-} \mathbf{p}$ $\qquad$ I is a m $\qquad$ g $\qquad$ and makes the image appear I $\qquad$

## Light-Tight Tube

The I____-t____t__ stops unwanted light from spoiling the image.


## - The Eyepiece Lens - A Magnifying Glass

Complete this diagram to show how the eyepiece lens acts as a magnifying glass:


## More "telescope eyepiece lens" practice:



- White Light - A Mixture of Different Coloured Lights
White light is a combination of all the different coloured lights in the rainbow:


White light can be split into all of its constituent colours using a
t


Diagram representing the wavelength of the three primary colours of light - red, green and blue


## Different Colours, Different Wavelengths

Each colour of light has its own individual w $\qquad$
Which of the above primary colours of light has the longest wavelength and how many wavelengths of this light are shown on the diagram?

Which of the above primary colours of light has the shortest wavelength and how many wavelengths of this light are shown on the diagram?

List the three primary colours of light in order of increasing wavelength:

## - Line Spectra

Under certain conditions all elements emit light.
White light contains all of the colours and produces what is known as a


Individual elements emit light of only certain f_______ which means they have specific w_________ which correspond to specific $\mathbf{c}_{\text {______-_ }}$.

## Hydrogen



## Lithium

## Interesting Fact

Each band of colour corresponds to electrons moving between precise energy levels within the atom. It provides a sort of fingerprint for each element.

## Carbon



Each element can be identified by its unique pattern of $\mathbf{c}$ $\qquad$ I _-_-.
Astronomers analyse the light they collect from a star (using an optical t $\qquad$ ) by passing the light through a $\mathbf{t}$ -_-_-_-_-_ glass p $\qquad$ This produces a series of $\mathbf{c}_{\ldots}$ I_-_ on a b $\qquad$ background.
The position of the $\mathbf{c}$ _______I $\qquad$ tells the astronomers what $\mathbf{e}$ are present on
 the star.

- Electromagnetic Spectrum

Write down a detector for each of the types of radiation
Gamma:
X-rays:

| Ultra violet: |
| :--- |

Visible light:

| Infra-red: |
| :--- |
| Microwaves: |
| TV: |

Radio:

The members of the electromagnetic spectrum have different wavelengths and frequencies. They carry different amounts of energy but all travel through space (and air) at the same speed: $\qquad$ $\mathrm{m} / \mathrm{s} \quad\left(\_\times 10-\mathrm{m} / \mathrm{s}\right)$.

large radio telescope

- Radio Telescopes

Complete the diagram to show how a radio telescope collects radio signals from outer space:


Explain why the dish of a radio telescope has an extremely large diameter:

sэIsイчd əрел๖ pлериеłS

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## - Mass, Weight and Gravitational Field Strength

## Mass

The mass of an object is the amount of material in the object. The unit of mass is the $\mathbf{k}$ $\qquad$ (__).

PROVIDED NO MATERIAL IS ADDED TO OR REMOVED FROM AN OBJECT, ITS MASS WILL NOT CHANGE NO

## MATTER WHERE THE OBJECT IS MOVED TO IN THE UNIVERSE.

On Earth, a large book book has a mass of 1.25 kg .
What would the mass of the book be if it were:
(a) On the moon? $\qquad$

(b) On Mars?
(c) At the edge of the Milky Way galaxy?
(d) On the star Proxima Centauri?

## Inertia

The inertia of a moving object is a measure of how difficult it is to change the motion of an object ..... The greater the mass of the object, the greater is its inertia.
(a) Which moving shopping trolley is more difficult to stop? - An empty one or a full one:
(b) Explain why: $\qquad$

## Weight and Gravitational Field Strength

All objects attract (pull one another together) - This attraction (pull) is known as the force of g $\qquad$
Weight is a force. It is the gravitational pull of the Earth (or another planet or moon or star) on an object.

The unit of weight is the $\mathbf{n}$ $\qquad$ (_


The force of gravity pulls every object near or on the Earth's surface down towards the centre of the Earth with a force of 10 newtons for every kilogram of mass.
This downwards force (weight) per kilogram of mass is called the $\mathrm{g}_{-}$
 Near the Earth's surface,
$\mathrm{g}=$ $\qquad$ newtons per kilogram ( $\mathrm{N} / \mathrm{kg}$ ).

[^0]- Mass and Weight Calculations

For any object, anywhere in the universe:


```
w}=m
```


gravitational field strength newtons per kilogram (N/kg)

Some examples of gravitational field strength:

| PLACE IN <br> UNIVERSE | gravitational <br> field strength <br> $(\mathrm{N} / \mathrm{kg})$ |
| :---: | :---: |
| Near surface of earth | 10 |
| Near surface of the moon | 1.6 |
| Near surface of mars | 4 |
| In deep outer space | 0 |

Calculate the weight of a 2.5 kg metal block when it is:
(a) Near the surface of earth.
(b) Near the surface of the moon.
(c) Near the surface of mars.
(d) In deep outer space.

## Gravitational Field Strength and Distance From a Planet/Moon/Star

As you move further away from the surface of a planet/moon/star, the value for the gravitational field strength decreases.
This means that the weight of an object decreases as its distance from a planet/moon/star increases.

The graph below shows how the gravitational field strength of the earth decreases as you move further away from its surface:


Use the graph to help you calculate the weight of a 15 kg object when it is at each of the following heights above the earth's surface.
(a) 200 km
(b) 1400 km
(c) 2200 km

## - Balanced and Unbalanced Forces

We can show the direction of a force using an arrow.

## Balanced Forces

If the forces acting on an object are equal in size but act in opposite directions, the forces are said to be b $\qquad$
For
example: 5 newtons


The forces cancel out. They are equivalent to no force at all.

We say: "The resultant force is zero".

## Unbalanced Forces

If the forces acting on an object are not equal in size, the forces are said to be u $\qquad$ -.

For
example:


The forces do not cancel out.
We could replace the forces with one force (called a resultant force) which would have exactly the same affect on the object.

For the forces shown in the diagram above, we can say:
"The resultant force is $\qquad$ newtons to the $\qquad$ ".

- Newton's First Law of Motion


If the forces acting on an object are balanced (or no forces act), the object's speed remains the same.

The object:

- remains s
s ---------or
- continues to move at c
 s $\qquad$ in a s $\qquad$ 1 _ .

Sir Isaac Newton

- a famous 17th and 18th century physicist

If the forces acting on an object are unbalanced, the object:
in the direction of the

- a $\qquad$ u _-_-_-_-_-f_---
For example:
The diagram shows the forces which act on a car in the horizontal direction:

- The car is stationary at a set of traffic lights.

The horizontal forces acting on it are $\qquad$ size.

- As the traffic lights change to green, the car accelerates forwards.

The horizontal forces acting on it are now $\qquad$ The engine force is $\qquad$ than the friction forces.

- After a few seconds, the car reaches a constant speed (known as its $\mathbf{t}$ $\qquad$ speed).
The horizontal forces acting on it are now $\qquad$ again. (During these few seconds, the size of the friction forces until they are the $\qquad$ size as the engine force).


## Forces in Outer Space and Motion

Large parts of outer space are a vacuum - There are no air (or other) particles present.
Therefore, when a spacecraft travels through outer space, there is no air friction acting on it ..... If its engine is switched off, no forces will be acting on it.
This means the spacecraft will travel at $\qquad$ speed in a $\qquad$ line.

If the spacecraft engine is switched on, this will create an u _ - - - - - - - force, so the spacecraft will a in the direction of the $\mathbf{u}$ force.

A spacecraft is travelling through outer space. Its engine is switched off.
(a) Describe and explain the motion of the spacecraft:
(b) The spacecraft's engine is now switched on.

Describe and explain the spacecraft's motion:

An astronaut is travelling at constant speed through outer space towards her space capsule.
(a) Describe the forces acting on her:
(b) The space capsule is accelerating towards the astronaut.
Describe the forces acting on it: $\qquad$

A rocket is launched vertically upwards from the earth's surface. During launch, three forces act on the rocket: its weight, the thrust force from its engine and air friction.
(a) Show the direction of each of these forces on the diagram, using arrows.

Label each force.
(b) At the instant the rocket is launched, it accelerates upwards.
Explain why, in terms of the forces acting on the rocket.
$\qquad$
$\qquad$
(c) As the rocket travels into outer space,

its acceleration increases.
Suggest one reason why:
$\qquad$
$\qquad$
(d) Once the rocket reaches outer space, its engine is switched off.
(i) The forces acting on the rocket become balanced. Explain why:
(ii) Describe the motion of the rocket in outer space:

## - Newton's Second Law of Motion

An object accelerates (or decelerates) when an unbalanced force acts on it.
The acceleration of the object depend on the mass of the object and the size of the unbalanced force acting on it.

- If you increase the mass of the object, the acceleration $\qquad$ .
- If you increase the size of the unbalanced force, the acceleration $\qquad$ .

Acceleration, unbalanced force and mass are related by the formula:
unbalanced force $=$ mass $\times$ acceleration


## - F = ma Calculations

Thrust force (from engine) $=250000 \mathrm{~N}$

Example: The diagram shows the vertical forces acting on a rocket of mass 10000 kg which is being launched from the earth's surface, where $g=10 \mathrm{~N} / \mathrm{kg}$
(Air friction has been ignored).
Determine:
(a) The weight of the rocket.
(b) The size and direction of the unbalanced force acting on the rocket.
(c) The size and direction of the rocket's acceleration.
(a) $\mathrm{W}=\mathrm{mg}$
$=10000 \times 10$
$=100000 \mathrm{~N}$
(b) Unbalanced force $=250000 \mathrm{~N}-100000 \mathrm{~N}$
$=150000 \mathrm{~N}$ upwards
(c) $a=\frac{F}{m}$
$=\frac{150000}{10000}$
$=15 \mathrm{~m} / \mathrm{s}^{2}$ upwards

The diagram shows the vertical forces acting on a rocket of mass 12000 kg which is being launched from the earth's surface, where $g=10 \mathrm{~N} / \mathrm{kg}$ (Air friction has been ignored).


Determine:
(a) The weight of the rocket.
(b) The size and direction of the unbalanced force acting on the rocket as it is launched.
(c) The size and direction of the rocket's acceleration as it is launched.

A spacecraft of mass 1500 kg "blasts off" from the surface of the moon where $\mathrm{g}=1.6 \mathrm{~N} / \mathrm{kg}$. The forces acting on the spacecraft at the instant it
"blasts off" are shown on the diagram.

Calculate:
(a) The weight of the spacecraft on the moon's surface.
(b) The size and direction of the unbalanced force acting on the spacecraft as it "blasts off".
(c) The size and direction of the spacecraft's acceleration as it "blasts


Increased Acceleration of a Rocket After Launch From the Earth's Surface

Once a rocket has been launched from the earth's surface, its acceleration will increase, because:

- As you travel further from the earth's surface, there is less air So $\mathbf{a}_{\text {__ }} \mathbf{f}$ $\qquad$ will
d_______ and therefore the
u $\qquad$ f $\qquad$ acting
on the rocket will $\mathbf{i}$
_-------
- As you travel further from the earth's surface, the
 f g will d
 of the rocket will d _____-_ and therefore the
$\mathbf{u}_{\text {on }}$ the rocket will $\mathbf{i}_{\text {_-_-_-_-_-_ }}$.
- The rocket will have burned up d $\qquad$ , so its m $\qquad$ will have
$\qquad$
u
_-_--_---_and therefore the
on the rocket will i
$\qquad$ acting
$\qquad$
- Newton's Third Law (Newton Pairs)

Forces occur in pairs - Newton pairs - The "action" and the "reaction". If object $A$ exerts a force on object $B$, then object $B$ exerts an equal but opposite force on object A.

## PUPILS OFTEN CONFUSE BALANCED/UNBALANCED FORCES WITH NEWTON PAIRS.

YOU MUST LEARN THAT:

- BALANCED/UNBALANCED FORCES ACT ON THE

S $\qquad$ OBJECT.

- NEWTON PAIRS ACT ON D $\qquad$ OBJECTS.

Four NEWTON PAIRS are shown in the diagrams below.
Complete each diagram to identify the "action" and "reaction" forces:


Rocket propulsion can be explained in terms of "Newton pairs":

The rocket engine produces exhaust gases.

- The rocket engine pushes the exhaust gases (the "propellant") b__ _ _ _ _ _ - This is the a $\qquad$ force.
- At the same time, the exhaust gases push the rocket engine (and therefore the rocket) f $\qquad$ - This is the $r$ $\qquad$ force.

Complete the diagram below to show the "action" and "reaction"


Complete the diagram to show the "action" and "reaction" forces which cause the rocket to be propelled forward:

## ACTION



On his back, an astronaut wears a 'jet pack'. This contains a small rocket engine which, when fired, emits exhaust gases away from the astronaut's back.
Label the diagram with "arrows" and "words" to explain how the 'jet pack' can propel the astronaut forwards through space.


- Gravitational Field Strength and Acceleration Due to Gravity

The force of gravity pulls every object near or on the Earth's surface down towards the centre of the Earth with a force of
10 newtons for every kilogram of mass.
This downwards force (weight) per kilogram
Gravitational field strength of $10 \mathrm{~N} / \mathrm{kg}$ acts on an object, causing it to accelerate downwards towards the Earth's surface at $10 \mathrm{~m} / \mathrm{s}^{2}$. of mass is called the g $\qquad$ - (Symbol $\qquad$ ).
$\mathrm{f}_{\text {_ }}$ _ s $\qquad$ .
$\mathrm{g}=$ $\qquad$ newtons per kilogram ( $\mathrm{N} / \mathrm{kg}$ ).

The force of gravity acting on all objects with mass which are close to the Earth's surface, causes the objects to accelerate towards the Earth's surface - The objects have "acceleration due to gravity".

The objects all have the same value of acceleration (if the effects of air resistance are negligible (very small):
acceleration due to gravity $(\mathrm{g})=10 \mathrm{~m} / \mathrm{s}^{2}$.

GRAVITATIONAL FIELD STRENGTH and ACCELERATION DUE TO GRAVITY
are "EQUIVALENT TERMS".

## - Free Fall and Weightlessness

Any object which is falling "freely" towards the Earth's surface is said to be in "free fall".
Objects in free fall appear to be weightless.

For example:


Kerry is standing still on a diving board.
In her right hand, she is holding a force meter with a 3 kg mass hanging from it.
Due to its weight, the mass exerts a downward force on the force meter.

Calculate the size of the downward force the mass exerts on the force meter:

Both the force meter and the 3 kg mass are now in f $\qquad$ f f_-_ - They are both accelerating downwards towards the Earth at the same rate of

$$
\ldots \mathbf{m} / \mathbf{s}^{2} .
$$

Because the force meter and the 3 kg mass are falling at the same rate, the mass does not exert a
d $\qquad$ f $\qquad$ on the force
meter - So the reading on the force meter is $\qquad$ N. (The $\mathbf{3} \mathbf{~ k g}$ mass appears
to be w as it falls f


## - Projectile Motion

Any object which is projected (fired) through the air is known as a projectile.

An object which is originally projected (fired) in a horizontal direction, follows a c $\qquad$ $\mathbf{p}_{\text {_-_ }}$ known as a t $\qquad$
The $\mathbf{c}$ $\qquad$ p_-_ is due to a combination of 2 separate motions in the
h $\qquad$ and $\mathbf{v}$ $\qquad$ directions:


$$
a=\frac{v-u}{t}
$$

The diagram below shows the position of a ball projected horizontally at three different speeds. In each case, the ball takes exactly 3 seconds to reach the ground.


We can use this acceleration equation to calculate the downward vertical speed of the ball in the above diagram as it lands:

$$
a=\frac{v-u}{t} \quad \therefore 10=\frac{v-0}{3} \quad \therefore 10=\frac{v}{3} \quad \therefore v=10 \times 3
$$

$\begin{array}{ll}\begin{array}{l}\text { downward acceleration (a) } \\ \text { due to gravity }=10 \mathrm{~m} / \mathrm{s}^{2}\end{array} & \begin{array}{l}\text { initial downward } \\ \text { speed }(\mathrm{u})=0 \mathrm{~m} / \mathrm{s}\end{array}\end{array} \quad=\mathbf{3 0 \mathrm { m } / \mathrm { s }}$

Jordan the goalkeeper punches a football which has been crossed across his goal mouth. The football leaves his glove with a horizontal speed of $11.5 \mathrm{~m} / \mathrm{s}$ and takes 0.80 s to land on the pitch.


(a) Describe the horizontal speed of the football from the instant it is punched to the instant it lands.
(b) Show, by calculation involving horizontal motion, that the horizontal distance travelled by the football during the 0.8 s is 9.2 m .
(c) At the instant the football leaves Jordan's hand, the downward vertical speed of the football is $0 \mathrm{~m} / \mathrm{s}$.
Calculate the downward vertical speed of the football as it lands.

The Physics Department's pet cat jumps horizontally from a window ledge. The cat lands on the floor 0.36 s later, having travelled a horizontal distance of 1.8 m .

(a) During the jump, does the horizontal speed of the cat increase, decrease or remain constant?
(b) Show, by calculation involving horizontal motion, that the horizontal speed of the cat just before landing is $5 \mathrm{~m} / \mathrm{s}$.
(c) At the instant the cat jumps from the window ledge, its downward vertical speed is $0 \mathrm{~m} / \mathrm{s}$.
Calculate the downward vertical speed of the cat as it lands.

Ellen's hand hits a volleyball from a point directly above the central net. The volleyball leaves Ellen's hand with a horizontal speed of $8.4 \mathrm{~m} / \mathrm{s}$. On leaving the hand, the volleyball follows a curved path, hitting the floor after travelling a horizontal distance of 6.3 m .

(a) Show, by calculation involving horizontal motion, that the time taken for the volleyball to travel from Ellen's hand to the floor is 0.75 s .
(b) At the instant the volleyball leaves Ellen's hand, the downward vertical speed of the volleyball is $0 \mathrm{~m} / \mathrm{s}$.
Calculate the downward vertical speed of the volleyball as it reaches the floor.

- Satellite Motion - An Extension of Projectile Motion

Satellite motion is an extension of $\mathbf{p}$ $\qquad$ motion.


The motion of a satellite around the Earth is a combination of two separate motions:
$\bullet$ C $\qquad$ h $\qquad$ s $\qquad$ (which is not large enough for the satellite to move away from the Earth).

- C $\qquad$ d $\qquad$ a $\qquad$ towards the Earth's surface due to the attractive force of the Earth's g $\qquad$ -.

The combination of these two separate motions is a c $\qquad$ p $\qquad$ which exactly matches the $\mathbf{c}$ $\qquad$ of the Earth.
As the satellite accelerates down towards the Earth, the Earth's surface c $\qquad$ away from it at the same rate - So the satellite does not get any closer to the Earth's surface. The satellite remains in o $\qquad$ around the Earth.

## - Entry (or Re-Entry) of Objects into the Earth's Atmosphere

When a moving object enters (or re-enters) the Earth's atmosphere from outer space, an air friction force acts on the object, causing the object to decelerate.
The air friction force does work on the object, changing some of the object's $\mathbf{k}$ $\qquad$ energy to $h$ $\qquad$ energy - The t $\qquad$ of the object increases. Often the $\mathbf{t}$ $\qquad$ increase is so large that the object $\qquad$ Not all of the heat energy causes an increase in temperature - Some e $\qquad$ to the surroundings and some causes part of the object to $\mathbf{m}$ $\qquad$ When the object is $\mathbf{m}$ $\qquad$ , its $t$ $\qquad$ does not c $\qquad$


- Entry (or Re-Entry) Calculations


## Example:

(a) A meteorite of mass 120 kg enters the Earth's atmosphere with a speed of $15000 \mathrm{~m} / \mathrm{s}$.
Calculate the kinetic energy of the meteorite.

$$
\begin{aligned}
E_{k} & =1 / 2 m v^{2} \\
& =0.5 \times 120 \times 15000^{2} \\
& =1.35 \times 10^{10} \mathrm{~J}
\end{aligned}
$$

(b) The force of air friction acting on the meteorite changes $1.5 \times 10^{9} \mathrm{~J}$ of the meteorite's kinetic energy to heat energy as the meteorite travels a distance of 25000 m through the Earth's atmosphere.
Calculate the average force of the air friction acting on the meteorite.

$$
\begin{aligned}
E_{w} & =F d \\
\therefore F & =\frac{E_{w}}{d} \\
& =\frac{1.5 \times 10^{9}}{25000}=60000 \mathrm{~N}
\end{aligned}
$$

(c) $1.5 \times 10^{9} \mathrm{~J}$ of the meteorite's kinetic energy is changed to heat energy as the 120 kg meteorite travels through the Earth's atmosphere. The material from which the meteorite is made has a specific heat capacity of $1500 \mathrm{~J} / \mathrm{kg}{ }^{\circ} \mathrm{C}$.
Calculate the rise in temperature of the meteorite. (Assume no other energy changes take place and that no heat energy is lost to the surroundings).

$$
\begin{aligned}
E_{h} & =c m \Delta T \\
\therefore \Delta T & =\frac{E_{h}}{c m} \\
& =\frac{1.5 \times 10^{9}}{1500 \times 120}=8333^{\circ} \mathrm{C}
\end{aligned}
$$

(a) A meteorite, mass 250 kg , is travelling at a speed of $12000 \mathrm{~m} / \mathrm{s}$ when it enters the Earth's atmosphere.

Calculate the kinetic energy of the meteorite at this instant.
(b) As the meteorite travels 30000 m through the Earth's atmosphere, the force of air friction changes $1.8 \times 10^{10} \mathrm{~J}$ of the meteorite's kinetic energy to heat energy.
Calculate the average force of the air friction acting on the meteorite.
(c) $1.8 \times 10^{10} \mathrm{~J}$ of the meteorite's kinetic energy is changed to heat energy as the 250 kg meteorite travels through the Earth's atmosphere. The material from which the meteorite is made has a specific heat capacity of $1600 \mathrm{~J} / \mathrm{kg}{ }^{\circ} \mathrm{C}$.
Calculate the rise in temperature of the meteorite. (Assume no other energy changes take place and that no heat energy is lost to the surroundings).

(a) An 800 kg mass of space debris is travelling at a speed of $15000 \mathrm{~m} / \mathrm{s}$ when it enters the

## Earth's atmosphere.

Calculate the kinetic energy of the space debris as it enters the Earth's atmosphere.
(b) As the space debris travels 170000 m through the Earth's atmosphere, the force of air friction changes $8.5 \times 10^{10} \mathrm{~J}$ of the kinetic energy of the space debris to heat energy.
Calculate the average force of the air friction acting on the space debris as the debris travels through the Earth's atmosphere.
(c) $8.5 \times 10^{10} \mathrm{~J}$ of the kinetic energy of the 800 kg space debris is changed to heat energy as the debris travels through the Earth's atmosphere. The space debris has a specific heat capacity of

$$
2500 \mathrm{~J} / \mathrm{kg}^{\circ} \mathrm{C} \text {. }
$$

Calculate the rise in temperature of the debris. (Assume no other energy changes take place and that no heat energy is lost to the surroundings).
(a) At the instant a space capsule of mass 1200 kg enters the Earth's atmosphere, the capsule has
$7.26 \times 10^{10} \mathrm{~J}$ of kinetic energy.
Calculate the speed of the space capsule at this instant.
(b) As the space capsule travels 3000 m through the Earth's atmosphere, the average force of air friction acting on the capsule is

$$
2 \times 10^{7} \mathrm{~N}
$$

Calculate the work done by the atmosphere on the capsule as the capsule travels this distance.
(c) A 'heat shield' on the space capsule has a mass of 5000 kg . The heat shield absorbs $5 \times 10^{10} \mathrm{~J}$ of heat energy as the space capsule travels through the Earth's atmosphere, causing the temperature of the heat shield to increase by $15000^{\circ} \mathrm{C}$.
Calculate the specific heat capacity of the material from which the heat shield is made. (Assume no other energy changes take place and that no heat energy is lost to the surroundings).


[^0]:    ON DIFFERENT PLANETS (OR MOONS OR STARS), THE FORCE OF GRAVITY PULLING DOWN ON EVERY
    KILOGRAM OF AN OBJECT WHICH IS NEAR ITS SURFACE IS DIFFERENT ..... SO THE GRAVITATIONAL FIELD STRENGTH NEAR THE SURFACE OF DIFFERENT PLANETS (OR MOONS OR STARS) IS DIFFERENT.

