How spaceships get to the moon... and students to college 😊

Key Stage 4 Programme

Pupil Name	
Handbook Designed by	Dr Evangelopoulou

Timetable and Assignment Submission

Timetable – Tutorials

1			
2			
3			
4			
5			
6 (Feedback)			

Contents

Course Rationale **P4**

Glossary of Keywords **P4**

Tutorial 1 **P5**

- Starter P5
- Objective A P5
- Practice A P5
- Assessment A P5
- Objective B P5
- Practice B P6
- Assessment B P6
- Objective C P6
- Practice C P6
- Assessment C P7
- Plenary P7

Tutorial 2 **P8**

- Starter P8
- Objective A P8
- Practice A P8
- Assessment A P8
- Objective B P8

Practice B P9
Assessment B P9
Objective C P9
Practice C P9
Assessment C P10
Plenary P10
Tutorial 3 P11
Starter P11
Objective A P11
Practice A P11
Assessment A P11
Objective B P12
Practice B P12
Assessment B P12
Objective C P13
Practice C P13
Assessment C P14
Plenary **P14**
Tutorial 4 P15
Starter P15
Objective A P15
Practice A P15
Assessment A P16
Objective B P16
Practice B P16
Assessment B P16
Objective C P17
Practice C P17
Assessment C P18
Plenary P18
Feedback session P19
Exam technique P18

Course Rationale

It is often the case that even though we study and we feel we know a topic well, we fail to get the marks we were aiming for. This is partly due to us thinking we can answer questions without fully understanding the physics behind the topic and partly due to GCSE questions being very picky with how they are answered for you to get the marks. These tutorials will focus on the following subjects: acceleration, force, Hooke's law, Moment; with the aim of helping you understand these physics topics to a deeper level, of getting rid of common misconceptions and of highlighting where points are usually lost in your answers and how to get them in your actual exams.

Glossary of Keywords

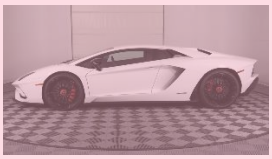
Word	Definition	In a sentence
Acceleration	Acceleration is defined as the change in velocity over time.	The sports car accelerated to overtake the bus.
velocity	Velocity is defined as the change in displacement over time.	The average velocity of an ant is smaller than that of a human.
Force	A force is any interaction that, when unopposed, will cause a change in motion on an object.	The bicycle hit the screen with enough force to break it.
Acceleration of gravity	Acceleration of gravity is the acceleration of a free-falling object due to gravity.	On earth, the acceleration of gravity is approximately 9.8m/s^2.
Moment	Moment is the turning effect of force.	The moment applied to the steering wheel was enough to turn the car the right.
Centre of mass	Centre of mass is a single point in an object where we assume all of the object's mass is concentrated.	The centre of mass of a human is usually about 10 cm below the bely button.
Base of support	The base of support refers to an area beneath an object or person, that includes every point of contact the object or person makes with the ground.	The centre of mass of the vase moved outside the base of support, and the vase fell
lever	A simple lever could be a solid beam laid across a pivot.	"Give me a lever long enough and a pivot on which to pace it and I will move the world." Archemedes
Component forces	A single force can be resolved into component forces, acting at right angles to each other.	A single force can be resolved into component forces, acting at right angles to each other.
Resultant force	When 2 or more forces are acting on an object, the resultant force can be found by adding up the individual forces.	When 2 or more forces are acting on an object, the resultant force can be found by adding up the individual forces.

1. Acceleration
Key words: acceleration, speed, time

Objectives of this tutorial:

A)Define acceleration
B) Calculate acceleration
C) Calculate changes in acceleration

Starter:
A Fiat can reach 0 to 100 Km per hour in 11 seconds
A lamborhgini can reach 0 to 100 Km per hour in 3 sec.
Which car has a greater acceleration?
What does it depend on?



Objective A: Defining acceleration

Acceleration is the rate at which an object changes its speed.
Acceleration = change in velocity / time $a = \frac{\Delta v}{t}$ and it is measure in metres per second.

Practice A: Defining acceleration

State the equation for acceleration

Explain why acceleration is measured in m/s^2.

Write a sentence defining acceleration in words.

Which would have the greatest acceleration, a bike, Niagara Falls or a breeze?

Assessment A: Defining acceleration

Which sentence(s) are false?

2. Acceleration is equal to the change in velocity divided by the time taken.
3. If the final velocity is smaller than the initial velocity, then there is no acceleration.
4. We measure acceleration in m/s^2

Objective B: Calculate acceleration

Worked examples

1. a = (Vfinal-Vinitial)/t = (6-2)/2 = 4/2 = 2m/s^2 example 1

2. a = (Vfinal-Vinitial)/t example 2

   a*t = ((Vfinal-Vinitial)*t)/t

   a*t = Vfinal-Vinitial

   (a*t)/a = (Vfinal-Vinitial)/a

   t = (Vfinal-Vinitial)/a = (25-5)/2 = 20/2 = 10, t = 10

Practice B: Manipulate the equation for acceleration

1. Complete the following table:

Acceleration (m/s^2)	Starting speed (m/s)	Final speed (m/s)	Time taken (s)
	2	6	2
2	5	25	
10	4		2
8	5		10
4		8	2

3. Calculate the acceleration when the change in speed = 14 m/s and the time taken = 2 seconds.

Assessment B: Manipulate the equation for acceleration

A car accelerates from rest (zero speed) up to a speed of 30 m/s with an acceleration of 6m/s^2. Calculate the time taken to accelerate.

Objective C: Apply the equation to solve problems on acceleration

1. A car accelerates from rest (zero speed) up to a speed of 30 m/s in 12 seconds. Calculate the acceleration.

   a = (30-0)/12 = 30/12 = 2.5 m/s^2

2. A cyclist in the Tour de France accelerates down a hill from 22 m/s to a speed of 37 m/s. This acceleration takes him 2 seconds. Calculate the acceleration.

   a = (Vfinal - Vinitial) /2 = (37 - 22)/2 = 15/2 = 7.5 m/s^2

Practice C: Apply the equation to solve problems on acceleration

3. A rocket launching in Ukraine accelerates upwards from rest to a speed of 12 km/s in 8 seconds. Calculate the acceleration.

4. A cyclist accelerates from 0 m/s to 8 m/s in 3 seconds. What is his acceleration? Is this acceleration higher than that of a car which accelerates from 0 to 30 m/s in 8 seconds?

5. A car advertisement states that a certain car can accelerate from rest to 70 km/h in 7 seconds. Find the car's average acceleration.

6. A lizard accelerates from 2 m/s to 10 m/s in 4 seconds. What is the lizard's average acceleration?

7. If a Ferrari, with an initial velocity of 10 m/s, accelerates at a rate of 50 m/s^2 for 3 seconds, what will its final velocity be?

Assessment C: Apply the equation to solve problems on acceleration

The water in a river accelerates from 20m/s to 60m/s as it falls as a waterfall with an acceleration of 20m/s^2. How long does it take for the water to accelerate?

Plenary

A car accelerates from a speed of 14m/s to a speed of 20 m/s in 10 seconds. In the same time another car accelerates 1m/s^2.

A) Find the change in velocity of the second car. B) Which car had the greatest acceleration

2. Force

Keywords: force, mass acceleration, vector

Objectives for this tutorial:

A) Defining force
B) Calculating force
C) Adding and balancing forces

Starter: Consider a cow and an elephant. Who would push a nail into the ground with more force?
Explain your answer.

Under what circumstances could the forces be equal?

Objective A: Defining Force

According to Newton's 2nd Law the acceleration of an object depends on the mas of the object and the amount of force applied. By consequence the force is equal to the mass times the acceleration of an object.

$$F = ma$$

N kg m/s²

Note that force is a vector – it has both a magnitude and a direction.

Practice A: Defining force

State the equation for force and define the terms used.

State the units for force, weight and acceleration.

Explain what can cause a reduction in force.

A 400Kg waterfall will cause double the force on the bottom of a river compared to a 200Kg waterfall if they both move with an acceleration of 50 m/s^2 – TRUE/FALSE

Assessment A: Defining Force

Label the sentences as <u>true</u> or <u>false</u>.
The acceleration of an object is directly proportional to the force applied.

The more I increase the mass of an object the lower the force needed to accelerate it.

A car was racing at a speed of 200Km an hour and smashed into the wall with a force of 500N. Is this sentence complete?

Objective B: Calculating force:

If a ball of mass 0.5 Kg hits the wall with an acceleration of 36m/s^2 what force does it hit the wall with?

F = m*a = 0.5 *36 = 18N

Practice B: Calculating force

If a north pole of a magnet applies an attraction force of 4N to the south pole of another magnet and its acceleration is 0.3 m/^2, calculate the mass of the magnet.

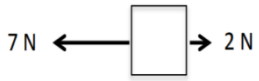
What is the force of a space ship which is accelerating at 1,000,000 m/s^2, and which has a mass of 20 tons?

On a windy day the force of the wind on a child is 80 N. If the weight of the child is 300 N, what will its acceleration due to the wind be?

Assessment B: Calculating force

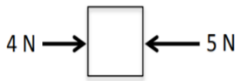
A 400Kg waterfall will cause double the force on the bottom of a river compared to a 200Kg waterfall if they both move with an acceleration of 50 m/s^2 – TRUE/FALSE

Objective C: Adding and balancing forces



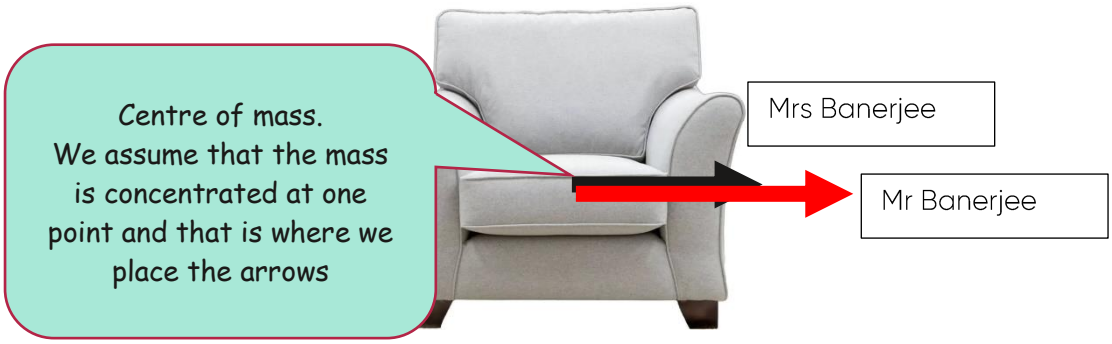
Net Force: 7N – 2N =5N and direction toward the left

Net Force: 6N + 3N =9N and direction toward the right



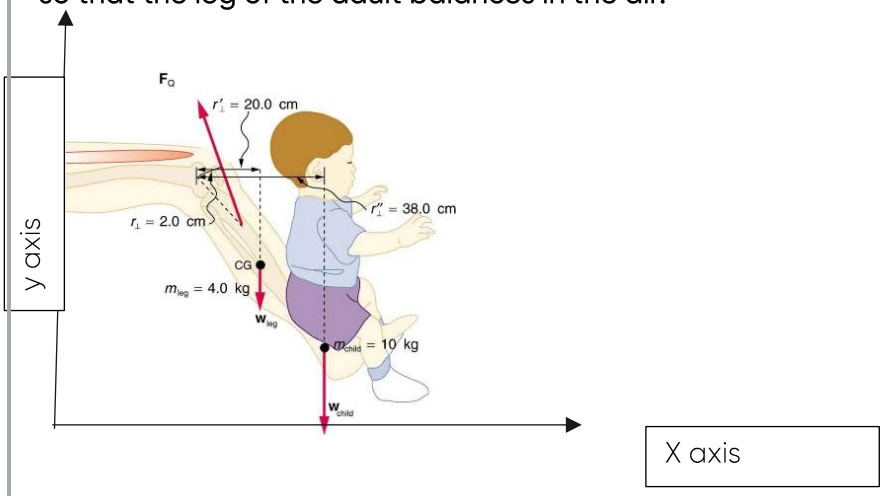
Practice C: Adding and balancing forces

Mr Banerjee and his wife are trying to move their new armchair. Mr Banerjee pulls with a force of 30N while Mrs Banerjee pushes with a force of 25N in the same direction. What is the net force?



The classes are playing tug of war. Mrs Larson's homeroom pulls with a force of 50N. Mr Badis homeroom pulls with a force of 45N in the opposite direction. What is the net force and who won?

Based on the image and information below, find the force that the muscle must pull with on the y axis, so that the leg of the adult balances in the air.



Assessment C: Adding and balancing forces

What force must I apply to a mass of 3 Kg to accelerate it at 4.0 m/s^2 on a horizontal surface if:

1. There is no friction
2. There is a friction force of 4.0 N

Plenary:

According to an odd myth, there was an intelligent horse that knew Newton's laws. When asked to pull a cart, the horse sneakily replied: according to Newton's 3rd law, if I apply a force on the cart, it will apply an equal and opposite force toward me. Consequently, the total force applied will be equal to zero and according to Newton's 1st law the cart will not move. What would you reply to this odd horse?

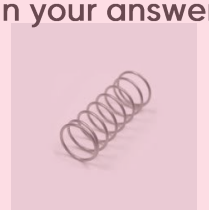
3. Hooke's Law

Keywords: force, spring, extension vector

Objectives for this tutorial:

A) Defining Hooke's law
B) Calculating the extension of a spring
C) Interpreting and drawing graphs

Starter: You first try to stretch the spring in your ball point pen and then a spring in your bike. In which case will you need more force? Explain your answer.



Objective A: Defining Hooke's Law

Hooke's Law

When an elastic object - such as a spring - is stretched, the increased length is called its extension. The extension of an elastic object is directly proportional to the force applied to it:

$$F = k \times e$$

- **F** is the force in newtons, N
- **k** is the 'spring constant' in newtons per metre, N/m
- **e** is the extension in metres, m

Practice A: Defining Hook's Law

State the equation for force of a spring and define the terms used.

State the units for force, weight and extension of a spring.

Explain what can cause a reduction in the force of a spring.

Assessment A: Defining Hooke's Law

Choose the correct answer:

We measure the spring constant in N/m

We measure the spring constant in m/s^2

We measure the spring constant in m/N

The spring constant is unitless

Objective B: Calculating the extension of a spring

Worked examples:

What is the magnitude of the force required to stretch a 20 cm-long spring, with a spring constant of 100 N/m, to a length of 21 cm?

Solution

The spring changes from a length of 20 cm to 21 cm, hence it stretches by 1 cm or e = 1 cm = 0.01 m.

F = k e= 100 N / m × 0.01 m = 1 N

If a spring is stretched by a force of 5N and the spring constant is 0.4, calculate the extension of a spring.

Solution

F = k*e → e = F/e = 5/0.4 = 12.5 m

What force was applied if two identical springs of spring constant 10N/m each were placed in parallel and an extension of 30cm for each was accomplished?

Solution

F = ke = 10 (30 + 30) = 10 * 60 = 600 N

Practice B: Calculating the extension of a spring

A force of 20N stretches a spring by 0.5m. The spring obeys Hooke's law.

a. Calculate the spring constant including a suitable unit.

b. How much force must a someone use to stretch it by 1.5m?

A car has a weight of 24000N which is distributed equally over all four wheels. Each wheel has a spring of spring constant 400N/cm.

a. Determine the force through the spring on each wheel.

b. Calculate the compression of each spring when the car rests on the ground.

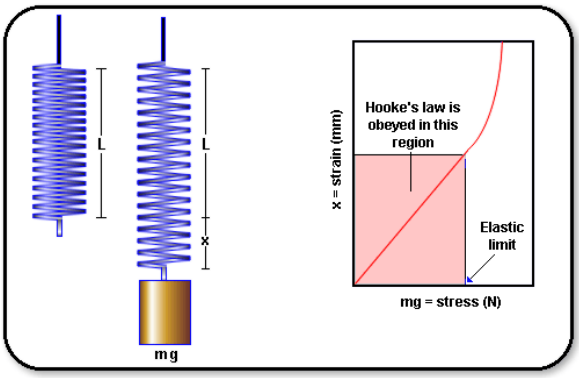
Assessment B: Calculating the extension of a spring

Under a 3N force, two identical springs in parallel stretch 12.5cm. What is the spring constant for one of these springs?

Objective C: Interpreting and drawing graphs

Steel wires or steel springs behave similarly:

- They behave elastically up to the *'elastic limit'* (also called the **limit of proportionality**).
- If they are stretched beyond the 'elastic limit' they will exhibit *'plastic'* behaviour and will have *permanent deformation.*
- If they are stretched too much they will eventually break!



Practice C: Interpreting and drawing graphs

1. In a spring experiment the results were as follows:

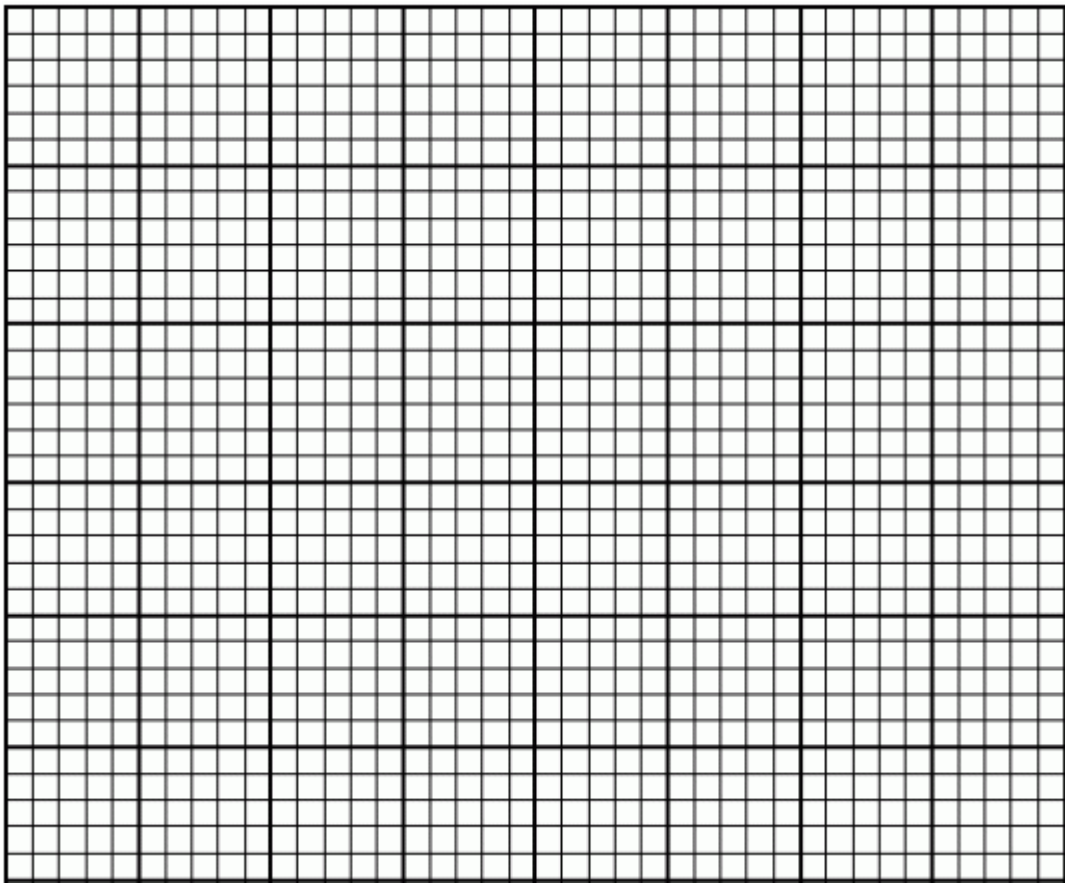
Force (N)	0	1	2	3	4	5	6	7
Length (mm)	50	58	70	74	82	90	102	125
Extension (mm)								

a. What is the length of the spring when unstretched?

.....

b. Complete the 'Extension' row of the table

c. Plot a graph of extension against force. Circle the anomalous point.



d. Mark the limit of proportionality on your graph (elastic limit).

e. What load would give an extension of 30mm?

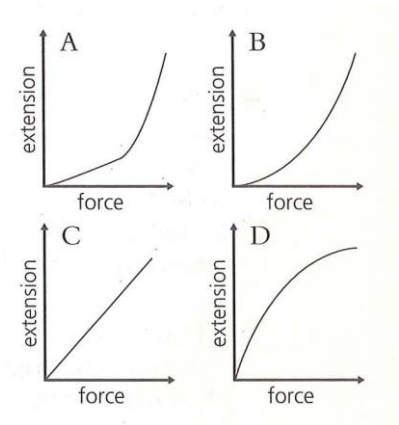
Assessment C: Interpreting and drawing graphs

The graphs show how the extension changes with stretching force for four different materials.

Which two graphs show materials that follow Hooke's law?

Which two graphs show materials that become less stiff as they are stretched?

Which graph shows a material that maintains the same stiffness throughout?



Plenary:

A hair bobble is stretched but does not spring back. Explain what has happened using the objectives of today's lesson.

4. Moment
Key words: moment, force, mass, direction, vector

Objectives for this tutorial

A) Defining moment

B) Calculating moments

C) Adding, subtracting and balancing moments

Starter:
In the circumstances above, who do you think will open the door more easily? Explain your answer.

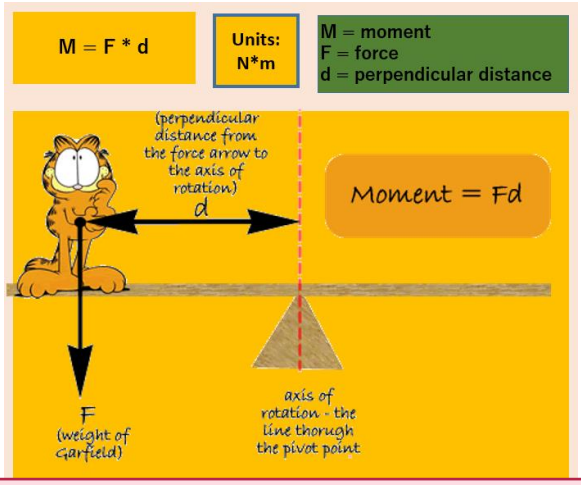
Scenarion1:.....

.....

Scenario 2:.....

.....

Objective A: Defining moment



Practice A: Defining moment

State the equation for moment and define the terms used.

Explain why the units for moment are Nm.

Explain what can cause an increase in moment.

Assessment A: Defining moment

For a see-saw to balance, the anti-clockwise moment must be equal to the _____
a) Clockwise moment, b) weight, c) mass

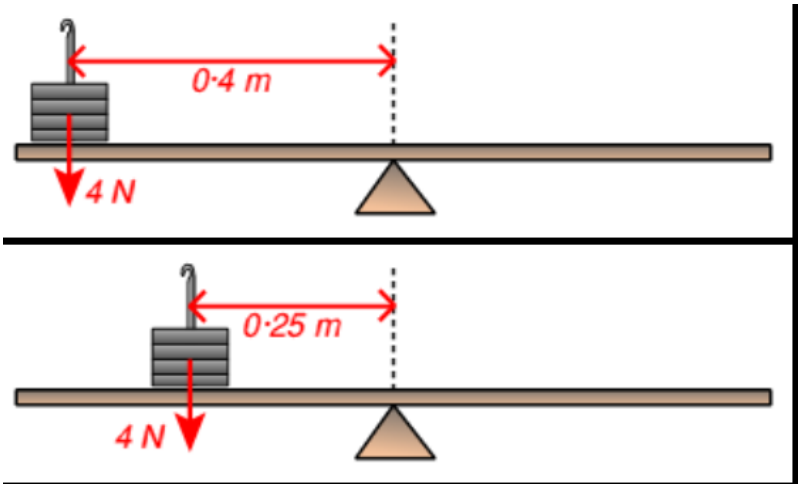
d = F/m TRUE/FALSE

Moment can only be positive TRUE/FALSE
We measure distance in cm TRUE/FALSE

1 m = _____cm, 1 cm_____ m

Objective B: Calculating moment

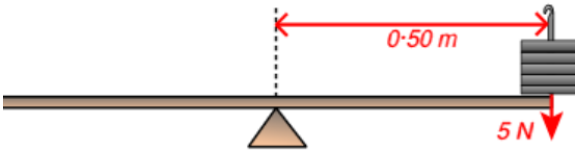
Worked Examples



Moment = 4 N × 0·4 m
Moment = 1·6 Nm
anticlockwise

Moment = 4 N × 0·25 m
Moment = 1·0 Nm
anticlockwise

Practice B: Calculating moment



Find the acceleration caused by the force.

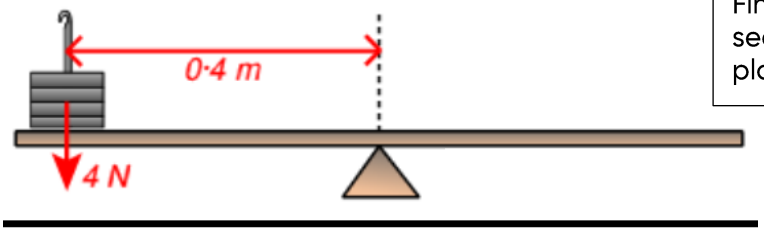
The water in a watermill causes a clockwise force on the mill of 35N at a distance of 2m away from its centre. What is the moment of the watermill?

What is the force of a wind, if it turns an ornament with a moment of 10N and it is acting at a distance of 0.3 m from the point of rotation?

Assessment B: Calculating moment

Calculate the distance wonder woman pushes with 100N from the centre of the vault door for the door to turn under a 60Nm moment.

Objective C: Adding, subtracting and balancing moments



Find the moment on the left-hand side of the seesaw. At what distance should an 8 N force be place to balance the original force?

Solution

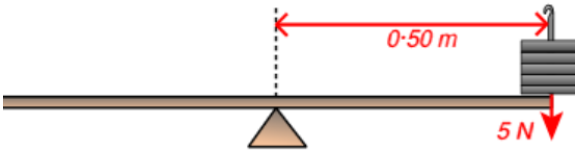
M = F* d = 4 * 0.4 = 1.6Nm

In order to balance this moment, an equal and opposite moment must be applied in the clockwise direction.

M = F* d If F= 8N then d = M/F = 1.6/8 = 0.2 m

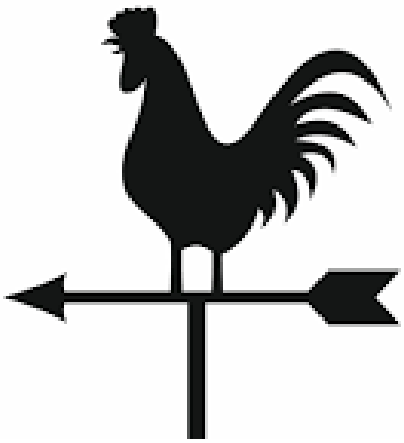
Practice C: Adding, subtracting and balancing moments

Where would we need to place a 12.5N weight for the seesaw to balance?



A 0.5 N weight is stuck to the 20cm mark of a uniform metre stick, which weighed 0.5 N before the weight was added. You can balance the metre stick horizontally on your finger, if you put your finger in the right place. How far from the 0.0 cm end do you need to put your finger in order to get it to balance. (HINT: draw & label the diagram first)

The air is hitting the back of the weather vane with a force of 20 N and at an angle of 60 ° to the arrow. The distance between the vane and the point of rotation is 40 cm. A cat bumps into the same side of the vane with a perpendicular force of 5N. Draw on the graph to show the direction of the resultant force.



Assessment C: Balancing moments

Fig. 2.1 shows a computer resting on a tabletop that is hunged at A.

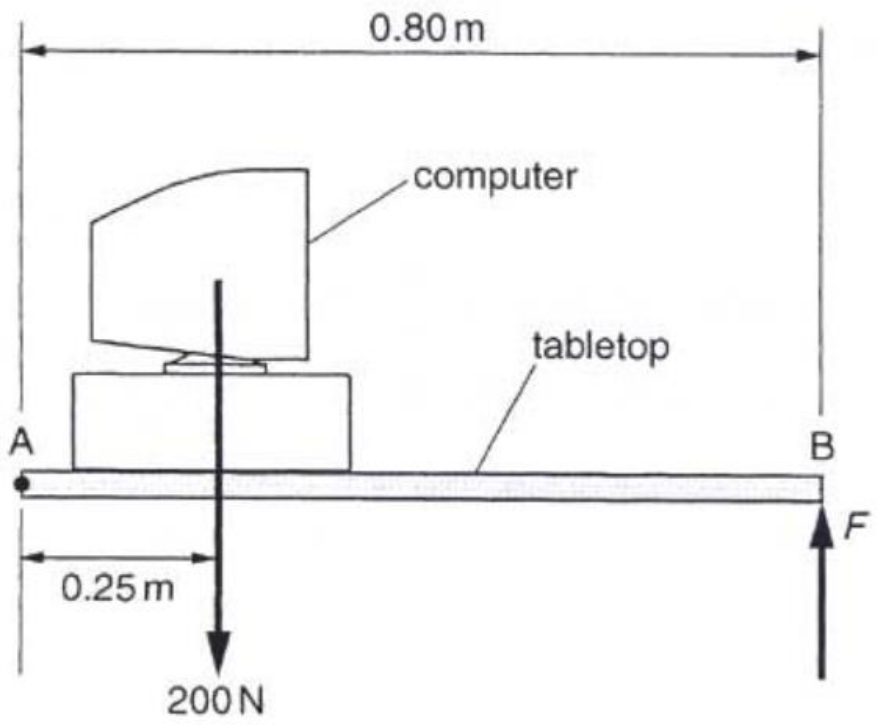


Fig. 2.1

The tabletop has a mass of 5.0kg and its centre of gravity is 0.40 m from the axis of the hinge at A. The computer has a weight of 200 N acting through a point 0.25m from the hinge at A. The tabletop is supported to maintain it in a horizontal position by a force of F acting vertically at B. The distance AB is 0.80 m.

a) Calculate the weight if the tabletop.

Plenary:

Using what you have learnt today, create a question for your classmates to answer. It should be a 3-mark question or higher.

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well…	What I could have improved on…
•	•
•	•
•	•

My target for future work is…

Exam technique:

A) Know what a resultant force is and what component forces are by definition.

B) You should be able to state that the centre of mass is a single point in an object where we assume all of the object's mass is concentrated.

C) You will need to be able to state when two quantities are directly proportional (**they go up by the same amount; when you double one you double the other)** and that this means that **when graphed against one another you would get a straight line passing through 0.**

D) Never talk about moments to the right and left. They are always clockwise and anticlockwise moments and you should state the forces that cause them.

E) If forces are not balanced and this could lead to an object toppling over you must talk about **the line of action of the weight moving outside the object's base of support.**

F) When asked to show your work ALWAYS show all your calculations clearly and in steps.

G) Underline what the questions is giving you and what it is asking you. Does it say **describe** or **explain?** Does it ask you to discuss a topic regarding, **forces or motion?** Motion usually means you will need to talk about velocity, acceleration and deceleration.

H) Read the units in questions carefully! They may need converting to SI units.

I) Question 3cii is still question 3. Just because you are answering a specific sub question does not mean that you won't need information from the previous parts of the question. Read carefully and go back to the main question, or sub-questions, or the answers to those questions if needed.

If a question is presented in an unfamiliar setting do not freak out. That is probably the main point of the question: to scare you/ to check you really understand the physics. These are often fairly straight forward questions masked to look difficult. Underline the familiar quantities it is giving you, and what it is actually asking you to do with them.

How spaceships get to the moon... and students to college

Key Stage 4 Programme

researchersinschools.org