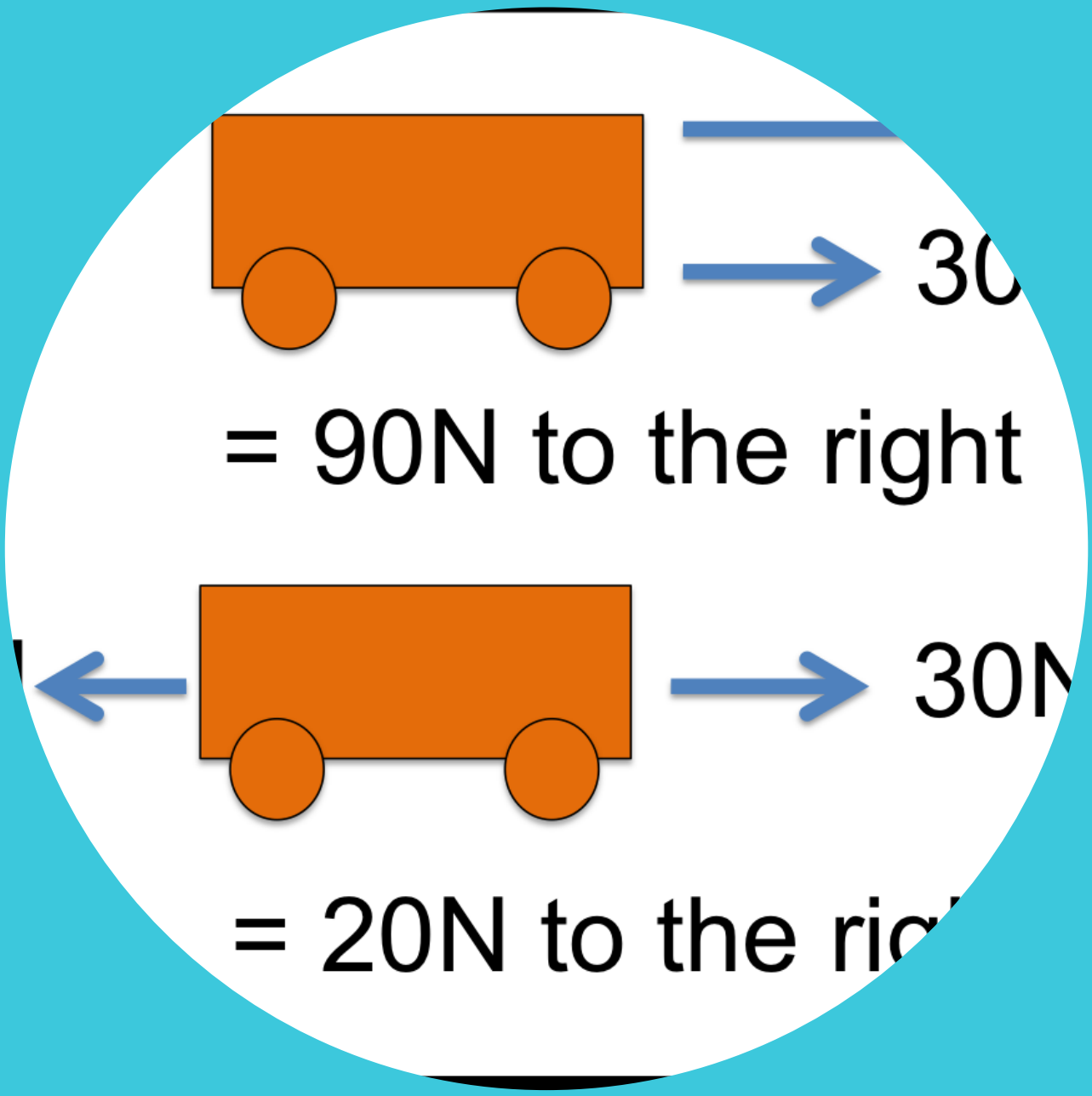

Forces

Key Stage 4 Revision Programme

Pupil Name	
Handbook Designed by	Taiwo Alaje

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1 (Baseline assessment)			
2			
3			
4			
5			
6 (Final assessment)			
7 (Feedback)			

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Course Rationale

The knowledge of forces is central to many key concepts in science and technology. From washing machines to fans, cars to aircrafts, pulleys to cranes, the understanding of what a force is, how it can be calculated and manipulated has become indispensable for scientific and technological advancement. Yet, this unit is one of the least understood in physics. One that many students will try to avoid if they have the opportunity.

This tutorial is designed to help lay a good foundation for understanding the unit on forces. The approach adapted is called deliberate practice.

In deliberate practice, the teacher works with the student to identify areas where they need improvement. He then gets them to engage rigorously with tasks in which these areas of difficulty are embedded. By repeatedly practising these tasks, the student can master the skills he needs to become confident in this hitherto challenging aspect.

Tutorial 1 – Scalars and Vectors

Objectives of this tutorial

1. Definition of scalar and vector quantities
2. Representing vector quantities

Objective One - Definition of scalar and vector quantities

Scalar quantity: A physical quantity that can be completely described without reference to distance. Examples are time, mass, energy, speed and power.

Vector quantity: A physical quantity that can be completely described only with reference to distance. Examples include gravitational field strength, momentum, weight and acceleration.

a. A baker only needs to state the **mass** of flour needed in a recipe to give a complete description of the amount required.
b. A controller directing the sailor of a ship must give the **distance and direction** to **completely describe** where the sailor needs to go.
c. Imagine a Satnav that gives only distance. Would the driver be able to follow?

Displacement: Distance in a specific direction. Where an object is relative to a specific position

	Vector or Scalar quantity	Why?
Mass		
Speed		

Practise

	Vector or Scalar quantity	Why?
Time		
Displacement		
Speed		
Velocity		
Distance		
Weight		
Acceleration		

Complete the sentences.

Choose answers from the box.

controlled	**dependent**	**scalar**	**valid**	**vector**

Force has both magnitude and direction, so it is a _____ quantity.

A quantity with magnitude only is a _____ quantity.

Identify which of the following quantities can be described fully by its magnitude.

a. force
b. displacement
c. energy
d. velocity
e. acceleration

Identify which of the following quantities requires magnitude and direction for a complete description.

a. mass
b. time
c. speed
d. kinetic energy
e. acceleration

Can you explain the choices you made above?

(a) Explain the difference between speed and acceleration

_____

_____

_____

_____

Assessment

Mass and weight are measurable quantities. Choose which of the following is correct (can be more than one)

a. Mass can only be completely defined when we have magnitude and direction

b. Weight can only be completely defined when we have magnitude and direction

c. Mass and weight are essentially the same

d. It is okay to simply define weight using its magnitude

What does 'magnitude' mean?

a. A measurement with no units

b. Something that can be measured

c. The size of a numerical value

Which row correctly states whether momentum, mass and velocity are scalar or vector quantities?

	Momentum	**Mass**	**Velocity**	
A	scalar	scalar	vector	⬭
B	vector	scalar	scalar	⬭
C	scalar	vector	scalar	⬭
D	vector	scalar	vector	⬭

Objective Two - Representing vector quantities

- ✓ When drawing a vector on paper, you need its magnitude and direction.
- ✓ Convert the magnitude (in Newtons) to an equivalent length (in cm or mm) using a convenient scale that fits onto your paper.
- ✓ Draw this as a line which points in the direction of the vector

Example
To represent a force of 400 N acting northwards (assuming the top of your notebook is north).

- ✓ You have the magnitude and direction
- ✓ You convert the magnitude of 400 N into an equivalent length using a scale of 100 N ≡ 1 cm
  The 400 N force is represented by a line of 4 cm.
- ✓ The line is drawn to point northwards

Practise Two

Represent the following forces in your book

a. 500 N acting westwards
b. 10 kN acting southwards

Represent the following vectors in your book

a. An aircraft flying at 1000 km/hour on a bearing of 45°
b. A ship moving at 623 km/minute on a bearing of 120°

Represent the following vectors in your book

a. A displacement of 500 μm eastward.
b. A cyclist travelling 750 km

Assessment

On a vector diagram, which two things does the arrow show?

a. Actual size of vector and its direction
b. A line drawn to scale
c. Direction of vector and relative size
d. An arrow pointing in the direction of the vector

Tutorial 2 – Resultant Forces

Objectives of this tutorial

1. Define a resultant force.
2. Free Body Diagrams
3. Calculate Resultant Forces
4. Explain whether forces on an object are balanced or unbalanced

Objective One - Define a resultant force

When two or more forces act on an object, **the resultant force** can be found by adding up the individual forces. This is a **single force** that has the same effect as all the forces acting on the object. If the resultant forcer is zero, we say that the forces acting on the object are balanced.

Practise 1

A resultant force is the ……. of two or more forces

a. Subtraction
b. highest
c. lowest
d. sum

Assessment 1
Two 30 N forces act on an object in opposite directions. Which statement is correct?

a. The resultant force is: 30 + 30 = 60 N

b. The resultant force is: 30 - 30 = 0 N

c. The resultant force is: 2 × 30 = 60 N

Objective Two: Force (Free Body) Diagrams

A force diagram models the forces acting on an object. The object or 'body' is usually shown as a box or a dot. **The forces are shown as thin arrows pointing away from the centre of the box or dot. The size of the force is represented by the arrow.**

Practise Two

1. The arrow on the right represents a force.

Draw another arrow underneath it that represents a larger force acting in the opposite direction

2. The arrows represent forces on a car.

Draw an arrow underneath that represents the resultant force on the car (not to scale)

3. The drawing shows a sailing boat.
   Answer the questions on the same diagram
   a The weight and upthrust forces are the same size as each other. Draw labelled force arrows on the diagram to show these two forces.
   b There is a forwards force from the sails acting on the boat. Draw a labelled force arrow to show this force.
   c There is also a drag force on the boat. This force is smaller than the force from the sails. Draw a labelled force arrow to show this force.

Assessment Two

1. In which way does a force arrow point?
   a. Towards the object
   b. Away from the object
   c. In the direction of movement

Objective Three: Calculate Resultant forces

To find the resultant of two or more forces acting in the same direction we add them, when the forces are acting in opposite directions, we subtract one from the other**. If the resultant of all the forces is zero, the forces are said to be balanced. If the resultant is not zero, the forces are said to be unbalanced.**

Practice Three

1. Three people are pushing a car. Each person pushes with a force of 200 N. Friction forces cause a force of 50 N. What is the resultant force on the car?
   Hint: start by working out the force in the forwards direction by adding up the forces from three people pushing the car. Then subtract the friction force.

2. An Ariane 5 rocket has a main engine and two booster engines. The main engine produces a thrust of 960 kN and each of the boosters produces a thrust of 7080 kN. The weight of the rocket and boosters at take-off is 7700 kN.
    a. Calculate the resultant force on the rocket as it is taking off.
    b. Explain why the resultant force on the rocket will be greater 10 seconds after take-off.

   Hint: Question 2a: Remember that the upwards force comes from the main engine and two booster engines. Add up the upwards forces first, then subtract the downwards force. As all the forces given are in kilonewtons, you do not need to convert them to newtons before carrying out the calculations.
   Question 2b: Part of the weight of the rocket is the fuel for the engines. What happens to the weight of fuel in the rocket as the engines burn?

3. A diver is using a 'diver propulsion vehicle' that is producing a forwards force of 100 N, and she is also producing a forwards force of 30 N from her flippers. Other forces on her are 85 N upthrust, 900 N weight and 50 N drag. Calculate the resultant force on the diver in the vertical direction and in the horizontal direction.

a. Draw a diagram of the diver and add force arrows to show the two resultant forces. Remember that force arrows show the direction and relative sizes of forces, so the two arrows you draw should be of different lengths
b. What is the resultant forwards force?
c. What is the overall resultant force in the horizontal direction?
d. What is the resultant force in the vertical direction?

Assessment Three

For the boat in question 3 under objective two, the force from the sails is larger than the drag forces on the boat. Circle the words or phrases that describe the horizontal forces on the boat.

a. balanced
b. unbalanced
c. non-zero resultant
d. zero resultant
e. resultant acts forwards
f. resultant acts backwards

Tutorial 3 – Newton's First Law

Objectives of this tutorial

1. Use Newton's first law to predict what happens to the motion of an object when the forces are balanced
2. Use Newton's first law to predict what happens to the motion of an object when the resultant force is non-zero
3. Explain that an object moving in a circular orbit at constant speed has a changing velocity (qualitative only).

Objective One - What happens to the motion of an object when the forces are balanced

According to Newton's first law of motion, an object remains in the same state of motion unless a resultant force acts on it. If the resultant force on an object is zero, this means:

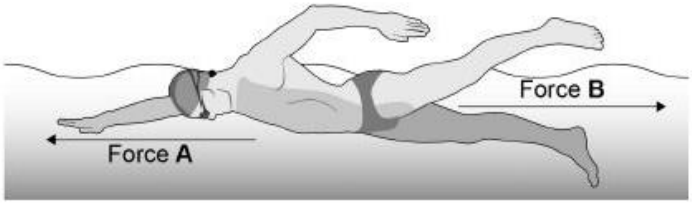
- ✓ a stationary object stays stationary
- ✓ a moving object continues to move at the same velocity (at the same speed and in the same direction)

If two forces act on an object with zero resultant force, the forces must be equal to each other and act in opposite directions.

Practice One

Fig 1 shows the horizontal forces acting on a man swimming in the sea.

Figure 1



Describe the movement of the man when the resultant horizontal force is 0 N

……
……

Which word describes the forces on an object moving at a constant speed?

a. Resultant

b. Balanced

c. Unbalanced

You are cycling along a flat road.

a Are you moving up or down?

b What is the force that is pulling you downwards?

c There is a force from the road acting on the bike. Is this force acting upwards or downwards?

d Are the forces in b and c balanced or unbalanced?

e What is the size of the resultant force on you in the vertical direction?

Assessment One

If an object is moving continuously at the same speed in the same direction, what can you say about the resultant force on it?

a. The resultant force is zero.

b. The resultant force is in the direction of movement.

c. The weight is the only force acting so it must be the resultant.

d. The resultant force acts in the opposite direction to the movement.

Objective Two - What happens to the motion of an object when the resultant force is not zero

When the resultant force acting on an object is not zero, the forces acting on it are not balanced. **The size and direction of** the resultant will determine the movement and direction of the object. Movement will be in the direction of the larger force.

Practise Two

1. As you cycle along the flat road your speed is increasing.

a What are the forces acting in a horizontal direction?

……..

b Are the forwards and backwards forces balanced? How did you arrive at your answer?

……
……

c Circle the two words that describe the resultant force on you in a horizontal direction.

backwards	forwards	non-zero	zero

2. Complete these sentences using words from the box below. You can use each word once, more than once or not at all.

i. If the forces are ……, there is a …… resultant force on the object. A resultant force can make a …… object start to move. If the object is moving, the force …… change the speed or direction of movement.

balanced	can	direction	large	non-zero	small	stationary	unbalanced	zero

3. A jet plane lands on the runway. State the direction of the resultant force on the plane (vertical and horizontal) as it lands.
   Vertical
   .....

   .....

   Horizontal
   .....

   .....

Assessment Two
If a resultant force acts on an object, what happens to its motion?

a. There is no change in speed
b. The object accelerates in opposite direction to resultant force
c. The object accelerates in same direction as resultant force

Objective Three : Explain that an object moving in a circular orbit at constant speed has a changing velocity (qualitative only).

Velocity is defined as speed in a specific direction. Acceleration is defined as the rate of change of velocity with time. When an object is moving in circular motion, the direction is continually changing hence the velocity is also changing though it has a constant speed.

An object will only accelerate if there is a resultant force acting on it. Centripetal force is the resultant force that causes acceleration in circular motion.

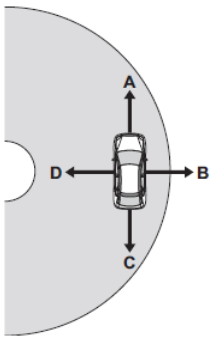
Practice Three

1. Write a definition for 'centripetal force', including all the words in the box.

centripetal	centre	circle	change	direction	force	velocity

2. Figure 1 shows a car travelling around a bend in the road. The car is travelling at a constant speed.

Figure 1



In which direction, A, B, C or D, does the centripetal force act on the car?

Tick (✓) **one** box.

A ☐ **B** ☐ **C** ☐ **D** ☐

(1)

(ii) State the name of the force that provides the centripetal force.

.....

3. Describe three different kinds of force that can act as centripetal forces. (Hint: think about the following situations.):

- a car driving around a roundabout

- someone whirling a stone around their head on a string

- a satellite orbiting the Earth.

Assessment Three

An object moving at constant speed in a circle experiences a force that is

A in the direction of motion.

B outwards and at right angles to the direction of motion.

C inwards and at right angles to the direction of motion.

D opposite to the direction of motion.

Tutorial 4 – Mass and weight

Objectives of this tutorial

1. Define weight, recall and use the equation : weight (newton, N) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg), W = m × g.

2. Describe the relationship between the weight of a body and the gravitational field strength.

Objective 1 Define weight, recall and use the equation : weight (newton, N) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg),

W = m × g.

The quantity of matter in an object is called its mass. The pull of gravity on an object is called its weight. The weight of an object is determined by its mass and the strength of the pull of gravity. Weight is a force, hence is measured in Newtons (N).

On earth, the gravitational filed strength acting on objects is approximately 10 N/kg.

The formula for calculating weight is,

Weight (N) = Mass (kg) x Gravitational field strength (N/kg)

Practise One

1. Calculate the weights of the following objects. Use a value of 10 N/kg for the gravitational field strength.

a. a 5 kg bag of bird seed

b. a car with a mass of 1200 kg

c. a suitcase with a mass of 15 kg

d. a 200 g piece of meat

e. an apple with a mass of 100 g

f. a tablet with a mass of 50 mg

2. Calculate the masses of the following objects. Use a value of 10 N/kg for the gravitational field strength.

a. a girl with a weight of 400 N

b. a man with a weight of 850 N

c. a biscuit with a weight of 0.2 N

d. a fully loaded truck with a weight of 125 000 N

e. a rocket with a weight of 8000 kN

f. a car with a weight of 1.5 × 104 N

3. From the table below, match two boxes and write them out. There should be four pairs.

kilograms	newtons
mass is measured in	of gravity pulling on an object
mass is the amount of	weight is measured in
matter in an object	weight is the force

Assessment One
What is the correct equation for calculating weight?

a. W = m ÷ g

b. W = g ÷ m

c. W = m g

Objective Two : Describe the relationship between the weight of a body and the gravitational field strength.

Gravitational field strength differs from one planet to the other. Hence, the weight of an object on earth will be different from its weight on the moon due to the differences in the pull of gravity.

Practise Two
A space probe on Titan has a weight of 280 N. Calculate its mass and its weight on Earth.
The gravitational field strength on Titan is 1.4 N/kg and on earth is 10 N/kg.
Hint: First calculate the mass of the probe using the gravitational filed strength of Titan.

In 2005 the Huygens space probe descended through Titan's atmosphere under a parachute, gathering data as it fell. The mass of the probe was 319 kg.
Calculate the weight of the probe on Titan and on Earth.

A Mars rover has a mass of 275 kg, its weight is 1017.5 N. What is the gravitational field strength on Mars.

Assessment Two

What is the relationship between the weight of a body and the gravitational field strength?

a. Weight is directly proportional to gravitational field strength

b. Weight is inversely proportional to gravitational field strength

c. Weight is not proportional to gravitational field strength

Tutorial 5 – Final Assessment

What is the Purpose of Tutorial 5?

- A final assessment to understand how much the students have learnt.

Tutorial 6 - Feedback

What is the Purpose of Tutorial 7?

- To receive feedback on final assessments.
- 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 assessment feedback

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

My target for future work is…

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
• • •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

Notes

Notes

Notes

Forces

Key Stage 4 Programme

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