Physics

Key Stage 4
Tutor Guidance

Module 4 - Force

In this module you'll look at diagrams, resolving forces and understanding Hooke's law.

Tutorial	Topic
Tutorial 4.1	Forces
Tutorial 4.2	Resultant forces
Tutorial 4.3	Resolution of forces
Tutorial 4.4	Force and elasticity

Knowledge Check 1 Answers

Module 4 – Force

1. c) diagram c
2. a) diagram a
3. d) 50 N
4. d) 3 N to the left
5. a) diagram a
6. c) diagram c
7. d) diagram d
8. d) diagram d
9. c) diagram c
10. b) 15 mm
11. a) The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.
12. b) 5 cm

Tutorial 4.1 - Forces

In this tutorial you will look at:

1. Free body diagrams
2. Examples of forces
3. Weight

At the beginning of this tutorial you will guide pupils through a set of confidence and Knowledge Check questions – you'll find more details about this on the relevant tutorial slides. Answers for Knowledge Checks are found in the Appendices.

1 Free body diagrams

After ascertaining that pupils understand the keywords 'scalar quantities' and 'vector quantities', there are examples of free body diagrams on the slides to share with pupils.

The answers to their **practice** questions are:

a) 4N 270°
b) 7.4 kN 050°
c) 7.4 N 320°

The **assessment** question answer is:

2	4 N	5 N

Difficulties: Students finding this section difficult might work on squared paper or graph paper to reduce the level of challenge.

Stretch: Can the student draw a free body diagram representing themselves in their seated position? (weight and normal contact force).

2 Examples of force

Explain the keywords 'contact forces' and 'non-contact forces' and work through the examples on the slides.

Pupils may come up with a variety of answers to the first **practice** questions. Some examples answers are:

1. a) Rubbing hands together
   b) Parachute jumper
   c) Swimmer

d) Tension in a rope on a rope swing
e) Force experienced by a boat
f) The force on the wings of a plane
g) The force acting upwards on a book lying on a table
h) The force acting on a person towards earth (their weight)
i) The force keeping an electron in orbit around the nucleus of an atom
j) The force pulling the needle of a compass towards the north

For questions 2-4 you should draw the free body diagrams yourself before the tutorial.

The answer to the **assessment** question on the slides is:

3	Normal reaction force	Weight

Difficulties: Students may have very informal understandings of the forces introduced here, and may confuse terms like air resistance and friction, upthrust and lift. The first exercise in the practice section should provide an opportunity for discussion. They may also know the forces by different names e.g. reaction force for normal contact force or drag for air/water resistance. Inspect the specification of the exam board relevant to the students to ensure correct terminology.

Stretch: Students could discuss the origin of the forces listed. For example, why does friction occur?

3 Weight

Work through the explanation and example on the slides with pupils.

The answers to the **practice** questions are:

Planet	g (N/kg)	Mass (kg)	Weight (N)
Mercury	3.7	70	259
Venus	8.8	70	616
Earth	9.8	70	686
Mars	3.7	70	259
Jupiter	24.7	70	172
Saturn	10.5	70	735
Uranus	9.0	70	630
Neptune	11.7	70	819

2. a) 2×10^{-9}N = 2nN

b) 0.000029 N = 2.9×10^{-5} N = 29μN
c) 0.98N
d) 49 N
e) 9800N = 9.8kN

3. a) 10.2 kh
b) 540 kg
c) 510 kg
d) 110 kg

The **assessment** question answer is:

3. The weight of the astronaut will be more on the Earth than on the Pluto.

Difficulties: There is much confusion between mass and weight, and the terms are often used synonymously. Underlining that their weight changes depending on where they are in the solar system, but that their mass remains constant, is a helpful device for differentiating the two ideas.

Stretch: Students could explore how g varies around the Earth, and hence how their weight would vary around the planet.

Tutorial 4.2 – Resultant forces

In this tutorial you will look at:

1. Finding resultant force for forces acting along a line
2. Finding resultant force for forces acting at right angles
3. Finding resultant force for forces at an angle to each other

1 Finding resultant force for forces acting along a line

Explain the keyword 'resultant force' and work through the examples on the slide for forces acting along a line. The answers to the pupil's **practice** questions are:

1. a) 3N
   b) 1N
   c) 5N
2. b) Resultant force = 500 N
3. b) Resultant force = 0.1 kN

The answer to the **assessment** question is:

Diagram 2 has the largest resultant force.

2 Finding resultant force for forces acting at right angles

Work through the example steps for how to find the resultant force for forces acting at right angles. The answers to the **practice** questions are:

1. Force = 920 N
2. Force = 340 N
3. Force = 11 kN

The fourth diagram shows the correct resultant force for the **assessment** question.

Difficulties: Vector addition is likely to be a new and challenging concept for students. Vector addition along a line should not present too much difficulty, but use of the 'parallelogram of forces' for vectors at right angles might. The 'parallelogram of forces' is a device recommended for students to start out with vector addition. The difficulty is compounded by any existing issues that students have with drawing diagrams to scale or using protractors for bearings.

Stretch: The 'parallelogram of forces' is a device that is introduced with no explanation. For students that are comfortable with the device, you might discuss the mathematics of vector addition, and why the device works. PhET has a vector addition simulation that might be useful: https://phet.colorado.edu/en/simulation/vector-addition

3 Finding resultant force for forces at an angle to each other

Work through the example steps for how to find resultant forces for forces at an angle to each other. The answers to the **practice** questions are:

1. 9.4 kN
2. 72 kN
3. 45 N

The answer to the assessment question is diagram 2.

Difficulties: This is a very challenging skill for students. They might have difficulty identifying the parallelogram, and often draw a quadrilateral linking the vectors that is not a parallelogram. Drawing the resultant force across the diagonal, stemming from the body, also presents difficulties. These issues are compounded by any problems the students have with drawing diagrams to scale or using a protractor for bearings.

Stretch: As stated above, the 'parallelogram of forces' is a device that is introduced with no explanation. For students that are comfortable with the device, you might discuss the mathematics of vector addition, and why the device works. PhET has a vector addition simulation that might be useful: https://phet.colorado.edu/en/simulation/vector-addition

Tutorial 4.3 – Resolution of forces

In this tutorial you will look at:

1. Resolving a force into components
2. Forces on an inclined plane
3. Resolution of weight on an inclined plane

1

Resolving a force into components

Work through the steps for resolving a force into components. The answers to pupil's **practice** questions are:

1. Horizontal Component = 6N, Vertical Component = 3N
2. Horizontal Component (left) = 15N, Vertical Component (down) = 30 N
3. a) Horizontal Component = 3N, Vertical Component = 3N
   b) Resultant force = 3N
   c) You should confirm this answer yourself prior to the tutorial

The answer to the **assessment** question is:

2. The horizontal component of the force is greater in magnitude than the vertical component

Difficulties: This is an abstract idea for students, who will not be familiar with the value of handling vectors in terms of their x and y components. Perhaps highlighting the value can provide some motivation for this section. The later problems involve resolving a force so that the resultant force of a system can be determined. This requires students to combine their learning with learning from the previous lesson, is likely to be very challenging for them.

Stretch: Confident students could be given a free body diagram with three vectors to handle, and the challenge of finding the resultant force.

2

Forces on an inclined plane

There is an example to work through on slide 8. The answers to the **practice** questions are:

1. Resultant forces = 350N, 350N, 500N
2. Resultant forces = 4.2kN, 2.8kN, 1.4kN, 4kN
3. You should draw this diagram yourself prior to the tutorial

The answer to the **assessment** question is:

3. The weight of the mass is perpendicular to the plane.

Difficulties: When sketching their own diagrams, the forces are likely to wander away from their correct directions. Watch out for normal contact forces that are not normal to the plane, weight that doesn't act directly downward, and friction that doesn't act parallel to the ramp in the right direction.

Stretch: Students secure with the idea of forces on a plane could consider how the forces would change if the angle of the ramp changed.

3

Resolution of weight on an inclined plane

Work through the steps for resolving weight on an inclined plane. The answers to **practice** questions are:

1. a) Parallel to slope = 14N, Perpendicular to slope = 14N
   b) Parallel to slope = 11N, Perpendicular to slope = 17N
   c) Parallel to slope = 9N, Perpendicular to slope = 18N
2. The box will slide down the ramp.

The answer to the **assessment** question is:

4. 60N

Difficulties: The example is for a ramp at 45°. Students might find resolving the weight on ramps at different angles (as in the first question) very challenging. Using a set-square ruler could be very helpful here.

Stretch: Finding the resultant force for inclined plane problems is beyond the scope here, but confident students might attempt to determine resultant force after resolving weight.

Tutorial 4.4 – Force and elasticity

In this tutorial you will look at:

1. Elasticity
2. Hooke's Law
3. Equation for Hooke's Law

1

Elasticity

After talking through elastic and inelastic objects, the answers to the pupil **practice** questions are:

1. a) A spring is elastic. Play doh is inelastic
   b) To test if an object is elastic you could deform it to test whether it returns to its original shape.
2. a) 5N down, 5N up.
   b) 7N down 7N up.
3. a) 7.8cm
   b) 1.5cm
   c) 9.3cm
4.

Spring	Natural length (m)	Extension (m)	New length (m)
A	0.10	0.01	1.1
B	0.10	0.05	0.15
C	0.1	0.02	0.12

The answer to the **assessment** question is:

4. new length = natural length + extension

Difficulties: The wording of questions can sometimes trip students up here – they should be clear on what they need to calculate: natural length, extension or new length. Students also have trouble identifying extension in diagrams. For example, they might measure extension from the tip of the spring at natural length to the bottom of the mass on the extended spring. They should be reminded to measure from 'tip to tip'.

Stretch: Students might explore the applications of springs in science and technology, and why an understanding of their behaviour is useful.

2 Hooke's Law

Pupils have Hooke's Law in their handbooks. Ensure they understand it before setting the **practice** questions.

1. (a) 0-7N. The graph is a straight line through the origin for this range.
   b) Extension = 0.035m
   c) After the limit of proportionality is reached the extension increases more quickly with force.
2. a) 0.015m
   b) 0.17m
   c) 6N
3. Spring B is the stiffest.

The answer to the **assessment** question is:

4. Between 0 and 5 N, Y is stiffer than X.

Difficulties: Students not comfortable with the idea of direct proportionality will not be able to appreciate Hooke's law fully. Referring to Chapter 1 may be helpful in this instance.

Stretch: Students might discuss the behaviour of a spring beyond the limit of proportionality. The elastic limit is not introduced until A-level, but might be introduced here as long as it is clearly distinguished from the limit of proportionality.

3 Equation for Hooke's Law

Run through the example for F = ke. The **practice** question answers are:

1. a) 37.5N
   b) 0.07m
   c) k = 1000 N/m
2. 200 N/m
3. Y: k = 200 N/m. X k = 100 N/m

The answer to the assessment question is:

4. 100 N/m

Difficulties: Discriminating between e vs F graphs and F vs e graphs, and then interpreting the physical meaning of the gradient, is a sticking point.

Stretch: Students could discuss applications of springs in relation to stiffness. They could try to estimate the spring constant for a spring in the suspension of a car, a watch, a pen, a mattress…

At the end of this tutorial you will guide pupils through a set of confidence and Knowledge Check questions. You will also complete a reflection exercise so that pupils can take time to think about what they found challenging and where they did well – you'll find more details about this on the relevant tutorial slides. Answers for Knowledge Checks are found in the Appendices.

Knowledge Check 2 Answers

Module 4 – Force

13. c) diagram c
14. a) diagram a
15. d) 50 N
16. d) 3 N to the left
17. a) diagram a
18. c) diagram c
19. d) diagram d
20. d) diagram d
21. c) diagram c
22. b) 15 mm
23. a) The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.
24. b) 5 cm

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