A Guide to Newton's 1st 2nd and 3rd Laws

Teaching Approach

The concept of force and its effects on interacting bodies is further developed in this series by investigating Newton's Laws of Motion. Newton's Laws of Motion are introduced and applied in everyday contexts as the concepts of inertia and momentum are discussed. The series includes practical investigations in which learners are given results and required to analyse these results, draw graphs and to report on their findings. The last lesson of the series focuses specifically on how to apply Newton's second law to various contexts. This series is linked to the core knowledge area of Mechanics.

The series addresses all the specific aims in Physical Sciences which promotes knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge; an understanding of the nature of science and its relationships to technology and society.

In the past, this topic was generally taught by defining the terms, stating the laws of motion and by practising problem solving using Newton's Second Law of Motion. While it is important that learners are able to do all these things, the new approach to science encourages the learners to build their knowledge sequentially through an experimental approach. In this series of lessons we emphasise an investigative approach and we deal with examples of force in contexts that should be familiar to many young people. For example: soccer players kick a ball to make it move; and in terms of fuel efficiency, modern cars have many plastic components to decrease the mass of the car to improve performance. These examples should help to make the topic relevant and should also enable learners to analyse subsequent situations on their own.

Learners often find it difficult to distinguish between inertia and momentum so it will be a good idea to spend time in class to discuss the definitions of these terms and to highlight their differences. Although momentum is covered in Grade 12, this will lay a good foundation for understanding change in momentum and impulse when this is covered.

Learners hold many alternative conceptions when it comes to force and Newton's Laws of motion. For example, it is a common misconception that larger objects exert a larger force on smaller objects and vice versa. Another commonly held misconception is that a constant applied force is required to move an object. In the first three videos questions are posed where there is an opportunity to pause and allow learners to discuss their ideas and make predictions. Encourage learners to share their ideas and then as they progress through the video the correct concepts can be developed. In addition the series starts with Newton's third law of motion, which deals with pairs of forces between interacting bodies, and then moves on to Newton's first and second laws which looks at forces acting on one body.

Many pause opportunities come up in each of the videos in the series. Use these opportunities to discuss learners' understanding. This approach will help highlight any misconceptions, and through discussion learners can work towards conceptual change.

Look for the following pause opportunities in the first video on Newton's Third Law:

- The pause to allow learners to discuss the magnitude of the force exerted by two bodies to determine any alternative conceptions.
- The pause is inserted during the discussion on a pair of forces – the table on the book and the book on the table. What can be said about the magnitude and direction of these two forces?

In the second video on Newton's First Law there are three opportunities:

- The first pause follows a diagnostic question in which learners are asked about the forces acting on a stationary object and an object moving at a constant speed. Allow learners to discuss these questions.
- The second pause follows the scene of an ice skater continuing to move at the same speed on ice, and a car slowing down. The presenter asks in which of these situations no resultant force is acting on the body.
- The third pause follows an amusing animation of an ice skater. The following statement is written on a slate: When a body moves with constant velocity in a straight line there is no resultant force acting on it. The presenter then asks learners to recap the effects of a non-zero resultant force acting on a body.

Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

1. Newton's Third Law

In this lesson learners are introduced to Newton's third law of motion. In order to grasp Newton's third law learners are required to identify action-reaction pairs of forces and list the properties of these forces.

2. Newton's First Law

The lesson starts with the question: Which is harder to stop – a large truck or a small car, both travelling at the same speed? These questions are used to describe the properties of inertia and momentum as properties of objects and introduce Newton's First Law of motion.

3. Newton's Second Law

This lesson looks at Newton's second law, which explains what happens to the motion of an object. The relationship between the resultant force and acceleration are investigated

4. Applying Newton's Second Law

This lesson introduces learners to how to apply Newton's Second law of motion to solve problems.

Resource Material

1. Newton's Third Law	http://www.youtube.com/watch?v=Yf0BN0kq7OU	The most common misconceptions about Newton's three laws of motion are described.
	http://www.physicsclassroom.com/class/newtlaws/Lesson-4/Newton-s-Third-Law	Newton's Third Law is described in terms of 'For every action there is an equal but opposite reaction' and learners can identify action-reaction forces.
	http://www.neok12.com/video/Laws-of-Motion/zX5b70020d7b510f41440767.htm	Newton's three laws are described and illustrated with 3D animations.
	http://www.youtube.com/watch?v=QP5H5uECFnY	A demonstration of Newton's Third Law
2. Newtons First Law of Motion	http://www.physicsclassroom.com/class/newtlaws/Lesson-1/Newton-s-First-Law	Newton's First Law is described in terms of objects at rest and objects in motion with animations of applications of Newton's First Law.
	http://www.nextvista.org/demonstrations-of-newtons-first-law-of-motion/	A series of demonstrations of Newton's First Law in action.
	http://www.youtube.com/watch?v=MAm6LOUnJ80	Newton's Laws of Motion are demonstrated in sports
3. Newtons Second Law of Motion	http://www.physicsclassroom.com/class/newtlaws/Lesson-3/Newton-s-Second-Law	Newton's Second Law is described in terms of anunbalanced force acting on an object resulting in acceleration.
	http://en.wikipedia.org/wiki/File:Electromagneticwave3D.gif	Is the animation you saw in the video lesson. You can open it and let it play for as long as you wish.
4. Applying Newtons Second Law	http://www.youtube.com/watch?v=iwP4heWDhvw	A demonstration of Newton's Second Law using high powered air canons.
	https://d3jc3ahdjad7x7.cloudfront.net/znhVNmBOirAd3Bjuoi27oQ6C0iuc8IEBrpVWua55YBo2rSxy.pdf	Ten simple problems using Newton's Second Law to calculate the net force, mass or acceleration of an object.

Task

Question 1

A girl sends a radio signal to a model motor boat to speed up the boat. Apply Newton's Third Law to this scenario by drawing a free body diagram. Label the forces between the boat and the water.

Question 2

In the demonstration a thin piece of cardboard can stop a slow moving ball but not a faster moving ball. A thicker piece of cardboard is required to stop the faster moving ball.

Slow moving ball stopped by thin sheet of cardboard

Faster moving ball is not stopped by thin piece of cardboard

Faster moving ball is stoped by a thicker piece of cardbaod

2.1 Analyse this experiment. What conclusions can you make about the relationship between momentum and velocity from the results of the experiment?

2.2 Based on your conclusions use Newton's First Law to explain the slogan 'Speed Kills'.

2.3 Apply Newton's First Law of Motion to explain how seat belts can save lives in a motor car accident.

Question 3

The table of results below are from the experiment with different mass pieces on the trolley and the acceleration of the trolley.

Mass (kg)	1/mass (kg^{-1})	Acceleration ($m.s^{-2}$)
0,5		0,73
0,45		0,81
0,4		0,91
0,35		1,05
0,3		1,23

3.1 Complete the column where you calculate the value for the inverse of mass, one over the mass.
3.2 Plot a graph of acceleration versus the inverse of mass
3.3 What conclusions can you make from your graph about the relationship between mass and acceleration?

Question 4

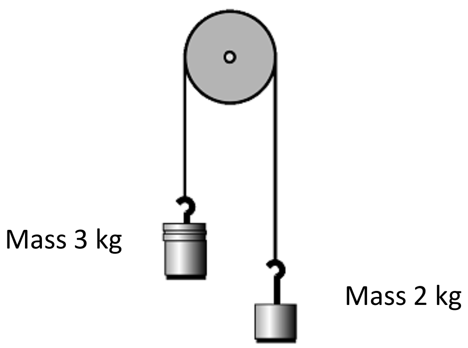
A one kilogram box is pushed up an inclined plane with an angle of inclination of twenty degrees. The applied force is 6 N. There is a constant frictional force of 2 N between the box and surface of the inclined plane.
4.1 Draw of free-body diagram of all the forces acting on the one kilogram box.
4.2 Calculate the acceleration of the box.

Question 5

A 1 kg box is released from the top of the inclined plane. It accelerates down the slope. There is a constant frictional force of 2 N between the box and the inclined plane.
5.1 Draw of free-body diagram of all the forces acting on the one kilogram box.
5.2 Calculate the acceleration of the box.

Question 6

Look at the following pulley system.
One mass piece has a mass of 2 kg and the other mass piece has a mass of 3 kg. The mass of the string is negligible and the pulley system is frictionless.

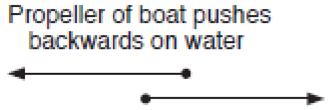


6.1 Draw of free-body diagram of all the forces acting on each mass piece.
6.2 Calculate the acceleration of the system.

Task Answers

Question 1

Free-body diagram of the forces acting on the boat and on the water



Question 2

2.1 a. *Results*

Velocity of ball	Thickness of cardboard	Effect on ball's motion	Momentum of ball
Slow	Thin	Ball stops	Low
Fast	Thin	Ball does not stop	High
Fast	Thick	Balls stops	High

Conclusions

- The slower the velocity of the ball, the less its momentum is. When the velocity of the ball is high, the momentum is high.
- The thicker the cardboard, the greater the force exerted by it.
  The experiment shows that there is some link between the force acting on the ball and its change in momentum. When the force is small (thin cardboard) it can only stops the ball with a low momentum. When the force is greater (thick cardboard) the ball with the greater velocity can also be stopped.

b. The momentum of the ball increases as the ball travels faster. For a ball of constant mass we can say that the velocity of the ball is directly proportional to its momentum. We can represent this mathematically as $p \propto v$ and so it follows that $p = mv$

2.2 The greater the velocity the larger the force required to bring a motor car to a stop, Travelling at high speeds therefore will result in a greater change of momentum and the driver accelerates at a faster rate and will experience a greater force which could be fatal.

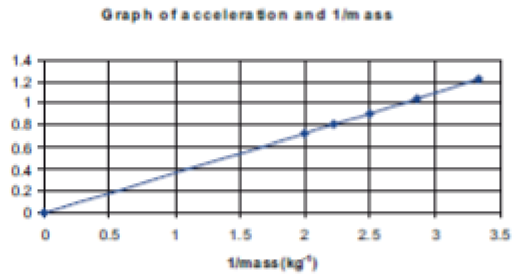
2.3 The driver continues to move forward according to Newton's First law, so the seatbelt provides the unbalanced force to prevent the driver moving forward.

Question 3

3.1 Results

Mass (kg)	$\frac{1}{\text{Mass}}$ (kg^{-1})	Acceleration ($m.s^{-2}$)
0,5	2,0	0,73
0,45	2,2	0,81
0,4	2,5	0,91
0,35	2,9	1,05
0,3	3,3	1,23

3.2

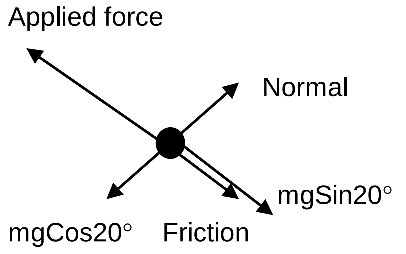


3.3 Conclusion

The graph of acceleration against one over mass is a straight linegraph. This shows us that the acceleration of the trolley is directly proportional to one over mass, when the force applied remains constant.

Question 4

4.1 Free body diagram



4.2 $F_{net} = ma$

Applied force + friction + mgSinθ = ma

+ (-2) + (-1x9,8xSin20°) = 1a

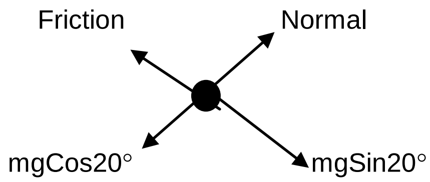
6 – 2 – 3,35 = a

0,65 = a

a = 0,65 $m \cdot s^{-2}$ up the slope

Question 5

5.1 Free body diagram



5.2 $F_{net} = ma$

mgSinθ + Friction = ma

(-1 x 9,8 x Sin20°) + (-2) = 1a

3,35 – 2 = a

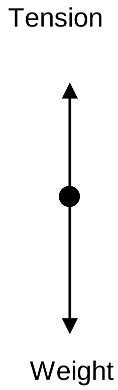
1,35 = a

a = 1,35 $m \cdot s^{-2}$ down the slope

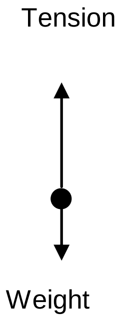
Question 6

6.1 Free body diagrams

3 kg mass piece



2 kg mass piece



6.2 $F_{net} = ma$

Weight – Tension = m_1a

$m_1g - T = m_1a$

$3 \times 9{,}8 - T = 3a$

$29{,}4 - T = 3a$ – (1)

$F_{net} = ma$

Tension – weight = m_2a

$T - m_2g = m_2a$

$T - (2 \times 9{,}8) = 2a$

$T - 19{,}6 = 2a$

$T = 2a + 19{,}6$ – (2)

Substituting (2) into (1)

$29{,}4 - (2a + 19{,}6) = 3a$

$29{,}4 - 2a - 19{,}6 = 3a$

$9{,}8 = 3a + 2a$

$5a = 9{,}8$

$a = 1{,}96\ m{\cdot}s^{-2}$ in direction of motion.

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