A Guide to Force

Teaching Approach

Force is a central concept in both physics and chemistry, and especially in mechanics. It is therefore important to help learners understand what is meant by force and how we can represent force and perform calculations with force. This will serve as a foundation for Newton's Laws. You should be aware that the word 'force' is used very loosely in everyday language and a number of other words, such as 'power' are often used to mean force. The terms 'normal' and 'acceleration' also have different meanings in everyday language compared to scientific language. You need to help learners recognise these differences and develop an ability to use these terms appropriately in scientific contexts.

Learners are first introduced to the meaning, types, effects and measurement of force, in Lesson 1. They are then taught how to draw free body diagrams in Lesson 2. Lesson 3 focuses on the normal force and Lessons 4 and 5 on friction force. The task video is provided either as additional practice for the learners, or as an assessment tool to evaluate learning of this section of work.

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. Types of Force

This lesson deals with the definition, representation, effects and measurement of force.

2. Free Body Diagrams

This lesson introduces the basic principles of drawing free body diagrams and guides learners to practise drawing such diagrams for various situations.

3. The Normal Force

This lesson focuses on the normal force: The force a surface exerts perpendicular to itself upward. Learners learn how to calculate normal force for objects of horizontal surfaces and on inclined planes.

4. Friction

This lesson defines, explains and classifies friction force. Learners are introduced to two types of friction: Static friction and kinetic friction.

5. Calculating Friction

Learners are introduced to the factors affecting, and equations for calculating, f_{smax} and f_k. They are guided to solve problems about friction on horizontal surfaces and inclined planes.

Resource Material

1. Types of Force	http://www.slideshare.net/AngelaStott/force-intro	A slide share presentation containing many of the visuals used in this movie.
	http://www.physicsclassroom.com/Class/newtlaws/u2l2a.cfm	This is the first page of Lesson 2: "Force and Its Representation' in The Physics Classroom's series on Newton's Laws. Follow the links to the other pages in the same lesson.
2. Free Body Diagrams	http://www.slideshare.net/AngelaStott/free-bodydiagrams	A slide share presentation containing many of the visuals used in this movie.
	http://phet.colorado.edu/en/simulation/forces-and-motion-basics	Explore forces in various situations.
3. Normal Force	http://www.slideshare.net/AngelaStott/normal-force	A slide share presentation containing many of the visuals used in this movie.
	http://www.youtube.com/watch?v=1WOrgrIcQZU	A teaching video from the Khan Academy: "Normal force and contact force". Following this link will also make other useful links which are relevant to learning force available to you.
4. Friction	http://www.slideshare.net/AngelaStott/friction-force	A slide share presentation containing many of the visuals used in this movie.
	https://vula.uct.ac.za/access/content/group/9eafe770-4c41-4742-a414-0df36366abe6/Chem%20Ind%20Resource%20Pack/html/polish-movies.html	A video showing how to perform an investigation into how the composition of floor polish affects amount of friction.
	http://phet.colorado.edu/en/simulation/forces-and-motion	A PhET simulation: 'Forces and Motion'. Interactively explore forces when you push a filing cabinet.
5. Calculating Friction	http://www.slideshare.net/AngelaStott/calculating-friction	A slide share presentation containing many of the visuals used in this movie.

	http://phet.colorado.edu/en/simulation/ramp-forces-and-motion	A PhET simulation: 'Ramp: Forces and Motion'. Interactively learn about forces on an inclined plane.

Task

Question 1

A man pushes a box across a horizontal table. Say whether each of the following is true or false. If false, correct the statement.

1.1 There is no friction between the box and the table:

- 1.1.1 before the man pushes the box
- 1.1.2 while the man pushes the box, but before it starts to move.

1.2 While the man pushes the box, friction is:

- 1.2.1 stronger all the time before the box moves than after it moves
- 1.2.2 equal in magnitude to his push all the time before the box moves
- 1.2.3 constant before the box moves
- 1.2.4 constant while the box moves
- 1.2.5 constant while the box moves as long as the man pushes with a constant force
- 1.2.6 equal in magnitude to his push all the time the box moves.

1.3 The man has to push harder to get the box moving if the:

- 1.3.1 table was sloped upward
- 1.3.2 box was heavier
- 1.3.3 table or box was smoother.

Question 2

A woman falls on a shop floor and blames the shop owner for having too slippery a floor. The shop owner says the floor is not too slippery. Legally, the safe cut-off for the coefficient of static friction of a floor with a rubber-soled shoe is 0,5. You are asked to find out if the shop floor meets these legal requirements.

2.1 If the coefficient of static friction between a floor and rubber is 0,6, is the floor safe, legally? (Yes/No)

2.2 Explain your answer to 2.1.

You are given a tile from the shop floor and a comparison tile which is known to have exactly the minimum legal requirement for static friction. You are also given a protractor and a shoe with a rubber sole.

2.3 Explain how you will determine whether the tile from the shop is legally safe or not. Use this guide:

- 2.3.1 What will you do with the apparatus (shoe, protractor, comparison tile, shop tile), and what will you measure?
- 2.3.2 How will your measurements tell you whether or not the shop tile is legally safe? (“If _____ [I measure this], then I know the shop tile is legally safe. Otherwise I know the shop tile is legally unsafe.”)

  Even if you find that the shop tile is legally safe, it is possible that the woman might have slipped. Refer to the equation $f_{s\,max} = \mu_s N$.

2.4 Complete this table for another three kinds of conditions which would have increased the likelihood of the woman slipping, even if the shop tile is legally safe. One of these conditions has been completed as an example.

Condition which increases likelihood of woman slipping	**Relevant variable**	**Reason why this increases likelihood of woman slipping**
A slippery substance is spilt on, or applied to, the shop tile.	μ_s	Even though the tile's μ_s is safe, the slippery substance on top of the tile does not have a safe μ_s.
(a)	μ_s	(b)
(c)	N	(d)
(e)	N	(f)

Question 3

A car has a mass of 1 392 kg. The force of friction on each wheel is 700 N when the car drives on a tar road and the normal reaction force on each wheel is 3 480 N. The car moves to the left at constant velocity.

3.1 Draw a free body diagram (not to scale) of all the forces on the right front wheel.

3.2 Calculate the co-efficient of kinetic friction for this situation.

The car now drives down a slope inclined at an angle of 15°.

3.3 Draw a diagram (not to scale) showing the resolution of the car's weight, W into components into the slope (W_y) and down the slope (W_x). Label relevant angles and vectors clearly.

3.4 If we take the car's weight to be 13 950 N, what is the magnitude of the normal force on the entire car while it is on the slope?

3.5 Does friction force act up or down the slope in this situation?

3.6 Calculate the magnitude of kinetic friction on the entire car (not only on one wheel).

Task Answers

Question 1

1.1.1 True.

1.1.2 False. Static frictional force acts while the man pushes the box, but before it starts to move.

1.2.1 False. It is stronger some of the time before the box moves than after it moves, but not all the time. This is because the magnitude of static friction increases from zero to $f_{s\,max}$ before the box starts to move. Although $f_{s\,max}$ is greater than f_k, the box does not experience $f_{s\,max}$ for the entire time before the box starts to move (it only experiences $f_{s\,max}$ just before the box moves).

1.2.2 True.

1.2.3 False. Static friction increases from zero to $f_{s\,max}$ before the box starts to move.

1.2.4 True.

1.2.5 False. Amount of friction (kinetic friction) is constant regardless of how hard the man pushes for all the time while the box is moving.

1.2.6 False. Amount of friction (kinetic friction) is constant regardless of how hard the man pushes for all the time while the box is moving.

1.2.7 True.

1.2.8 True.

1.2.9 False. The man would not have to push as hard to get the box moving if the table or box were smoother.

Question 2

2.1 Yes

2.2 This would offer more friction than the safe limit, and so would resist slipping more, and therefore be safer than the minimum safety limit.

2.2.1 Suggested method (Note: There are other valid methods possible, so discretion should be used when marking the answers which follow):

- Place the shoe on the test tile.
- Tilt the comparison tile until the shoe just starts to slide. Hold the comparison tile still at this angle.
- Use the protractor to measure the angle the comparison tile now makes to the horizontal. This is called the minimum sliding angle for the comparison tile and shoe.
- Repeat this procedure for the shoe on the shop tile.

2.2.2 If the minimum sliding angle for the COMPARISON tile and shoe is LESS than or EQUAL to the minimum sliding angle for the SHOP tile and shoe, then I know the shop tile is legally safe. Otherwise I know the shop tile is legally unsafe.
Another way to say this correctly:
If the minimum sliding angle for the SHOP tile and shoe is EQUAL to or MORE than the minimum sliding angle for the COMPARISON tile and shoe, then I know the shop tile is legally safe. Otherwise I know the shop tile is legally unsafe.

2.3

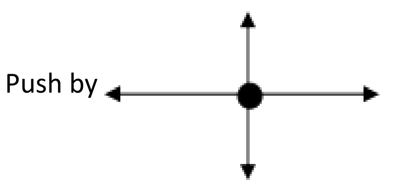
Condition which increases likelihood of woman slipping	Relevant variable	Reason why this increases likelihood of woman slipping
A slippery substance is spilt on, or applied to, the shop tile.	μ_s	Even though the tile's μ_s is safe, the slippery substance on top of the tile does not have a safe μ_s.
(a) The sole of the woman's shoe is smoother than rubber.	μ_s	(b) The μ_s for the woman's shoe and the shop floor may be less than a safe 0,5.
(c) The woman's mass is low (she is light).	N	(d) Normal force acting upward on the woman is low, and so she experiences less maximum static friction than a heavier person would, and so is more likely to slip.

(e) The floor was sloped (inclined).	N	(f) Normal force is weaker on a body when the body is on a slope than on a horizontal surface. Therefore, maximum static friction is also weaker, making it easier to slip.

Question 3

A car has a mass of 1 392 kg. The force of friction on each wheel is 700 N when the car is driving on a tar road and the normal reaction force on each wheel is 3 480 N. The car is moving to the left at constant velocity.

3.1

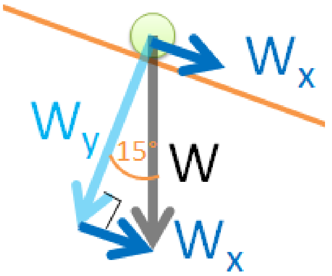


3.2 $f_k = \mu_k N$

$\mu_k = \frac{f_k}{N}$

$\mu_k = \frac{700\ N}{3\ 480\ N}$

$\mu_k = 0{,}20$



3.3

3.4 $N = W_y$

$W_y = W \cos 15°$

$W_y = 13\ 950\ N \cdot \cos 15°$

$W_y = 13\ 475\ N$

$N = 13\ 475\ N$

3.5 *Up the slope (since the car is moving down the slope and friction always acts opposes motion).*

3.6 $f_k = \mu_k N$

$f_k = 0{,}20 \cdot 13\ 475\ N$

$f_k = 2\ 695\ N$

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