LEARNING IN SCIENCE PROJECT

TEACHING ABOUT FORCE

University of Waikato
Hamilton, N.Z.

WORKING PAPER 34

INTRODUCTION TO THE BOOKLET

One of the central ideas in introductory science is the notion of force. Almost everyone has a meaning, and sometimes more than one meaning, for the word 'force' and has ideas about the relationship between force and motion. However these meanings and ideas are not necessarily the same as scientists.

Before teaching about force we consider it necessary for all teachers to have an appreciation of the scientists' meaning for force, the typical children's meaning for the word 'force', and an appreciation of the nature of their own meanings for this word. If you have not already done so we would strongly recommend that you read the complementary booklet to this one - "Force, Friction and Gravity" - Notes for Teachers. (Working Paper No. 33)

This Activities Booklet (Working Paper No. 34) provides suggestions for pupil activities which are appropriate for introducing ideas about forces and their relationship to motion at the Form 1-4 level. In our view almost all of the available teacher guide and textbook material make unfounded assumptions about what children already know. The ideas provided here are designed so that pupils first become aware of their own present ideas and how these differ from the basic scientific idea. If this is not done we believe many pupils simply retain their non-scientific views (See Working Paper No. 33).

We hope you find the activities set out in this booklet as useful and as enjoyable to use as we have. In our experience the activities can be used successfully with 11-14 year old children[2]. (See Working Paper No. 32 for the rationale behind these suggested teaching activities and for details of trials of the materials).

Concepts such as work, energy and power are not introduced in this booklet. We believe it is best for children to have obtained a firm grasp of the scientists' concept of force before these other concepts are introduced and developed. We have therefore limited the work here to force, including the force of friction and the force of gravity, and the effects of forces on motion.

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2 Full page worksheets have been planned for ease of copy.

THE TEACHING PROGRAMME

PART 1: DETERMINING CHILDREN'S VIEWS ABOUT FORCE

The aim of this section[3] is to make pupils and teachers aware that in the everyday use of the word force children have a range of views about what a force is.

ACTIVITIES:

(a) Survey[4]

Give out copies of the survey (Force Survey A - pages 5-7) with answer paper. Have the children answer the survey, and make a copy of their answers so they can refer to responses they made when particular sections are referred to in class. It is important that you as the teacher analyse carefully the way pupils have responded to the questions as this will help you in teaching this section of work.

Do not go over the survey with the class as this stage but keep a record of pupil results. This will be needed in Part 5.

(b) Discussion

Worksheet A is designed so that pupils can explore the range of views they and other pupils hold about the word force. Individual consideration of these situations, can be followed by small group discussion, and possibly class discussion. If consensus view is different from the scientists' view this can be returned to later in the series of lessons.[5] A low key role on the part of the teacher is vital in this discussion. Questions such as:

"Who can put that another way? Do so."

"Who disagrees with ________? Explain why to the rest of us."

"Do these forces you are talking about have directions?"

"Using arrows to show us the directions of the forces, come and show us about ________ on the blackboard."

The idea at this stage is to make pupils aware of the variety of views held about force, and that there is a need for the following series of lessons.

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[3]The Parts of this unit are not equivalent regarding the time spent on them. e.g. the two activities here can be completed within an hour.

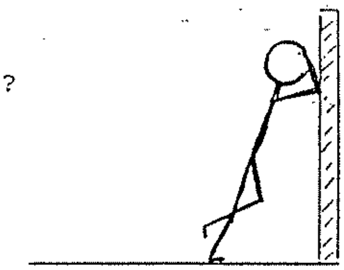
[4]The scientists' responses to the survey questions are given in Appendix A. You may wish to check these after you have first attempted the survey yourself!

[5]That is why a fourth column is there - for the scientists' view. In one trial pupils gave four different combinations of individual forces (with labels such as movement, balance, wind, drag, gravity) for the forces involved in Question 3 of Worksheet A. For an idea of the views children are likely to hold see Working Paper No. 33.

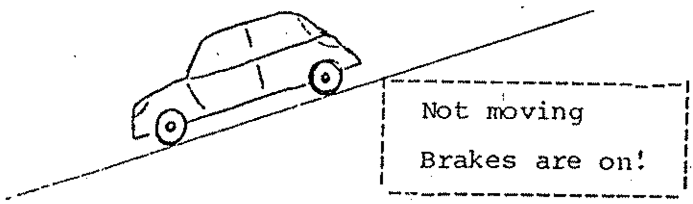
5. A person in leaning against a brick wall.
   Is the person putting a force on the wall?

   (a) No

   (b) Yes



6. A car is parked on a hill. It is not moving.



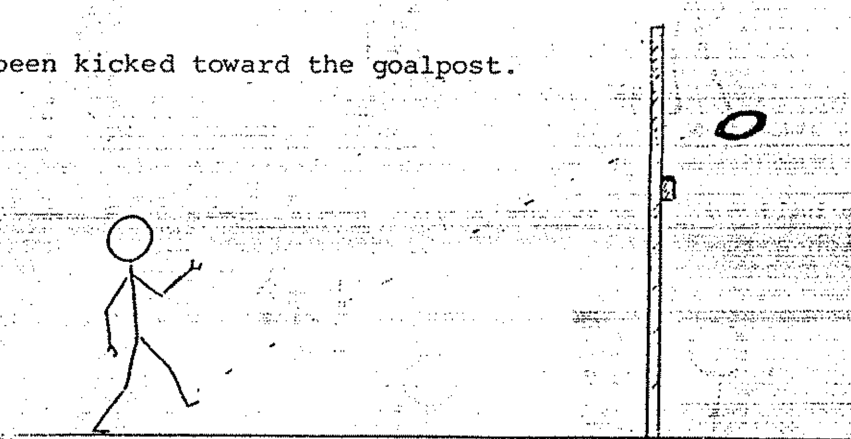
   Which of the following is correct?

   (a) There are many forces on the car but the total force is zero

   (b) There are many forces on the car and the total force is downwards

   (c) There are no forces on the car at all

7. A football has been kicked toward the goalpost.

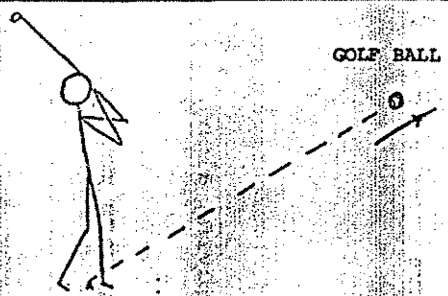
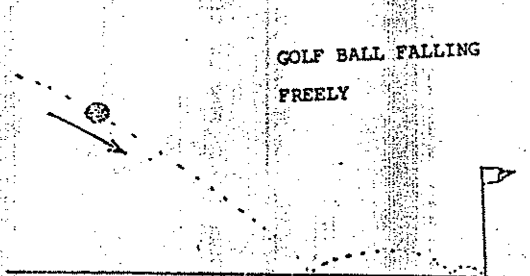
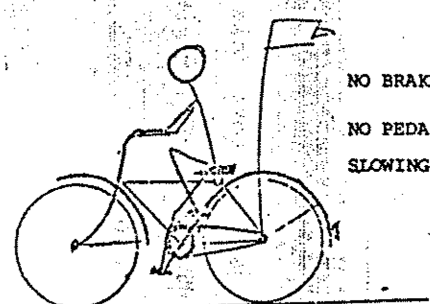
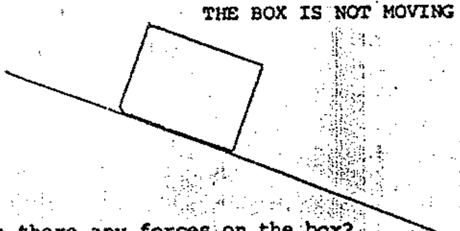


   As it moves through the goalpost what are the forces on it?
   (you can choose more than one)

   (a) The force of gravity

   (b) The force of friction

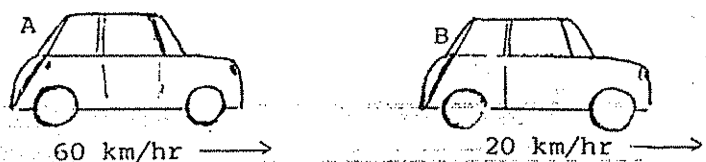
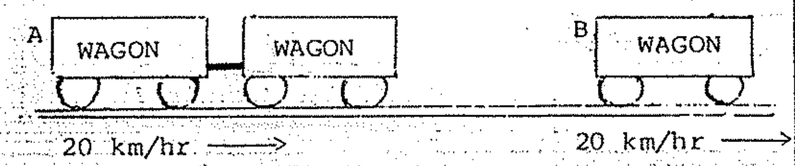
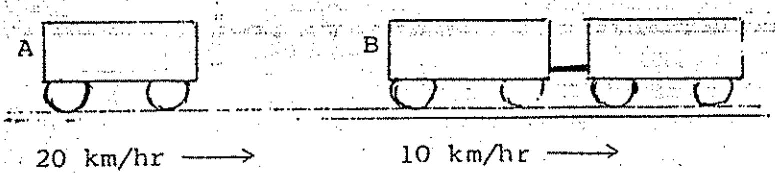
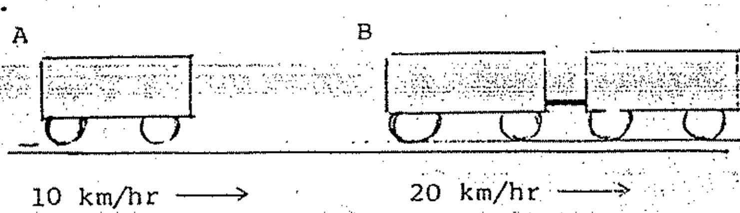
   (c) The force of the kick

		YES/ NO	WHY YOU THINK THAT WAY — YOU	WHY YOU THINK THAT WAY — GROUP	
I	 Are there any forces on the golf ball?				
2	 Are there any forces on the golf ball?				
3	 Are there any forces on the bicycle?				
4	 Are there any forces on the box?				

2.2 Teacher-led Discussion and Worksheet (Can be omitted for F1/2)

Copy and allow children to complete (answers to these and other worksheets are given in Appendix C).

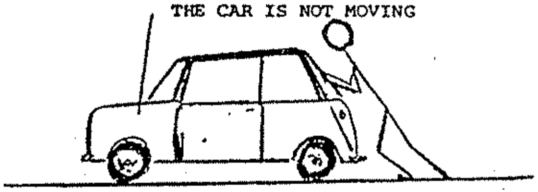
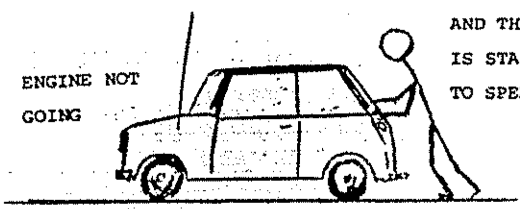
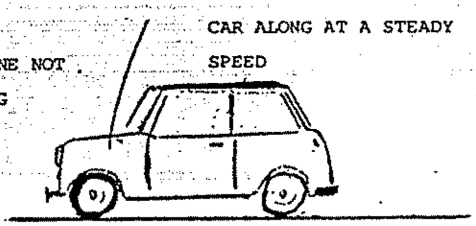
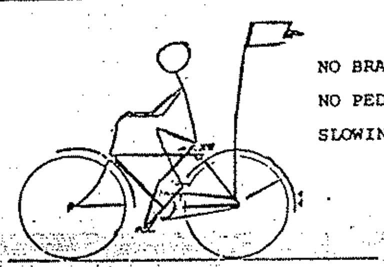
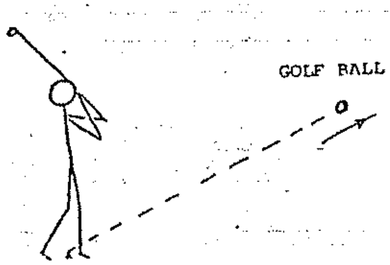
MOMENTUM

	Does A or B have more momentum?	How much more momentum?
1.  Car A and Car B are the same type of cars - (Minis)		
2. 		
3. 		
4. 		

N.B. : You may like to use P.S.S.C. trolleys to demonstrate the points made above

: For the more able F3 and F4 pupils, the ideas of momentum might be quantified by using Part 1 of Extension 1 in Appendix B.

2.4 Worksheet C

<table>
<tr><th></th><th>Does the _____ have momentum? Yes/No</th><th>Is the momentum changing? Yes/No</th><th>If the momentum is changing describe how it is changing</th></tr>
<tr><td>1
THE MAN IS TRYING TO MOVE THE CAR BUT THE CAR IS NOT MOVING
</td><td></td><td></td><td></td></tr>
<tr><td>2
THE MAN IS TRYING TO MOVE THE CAR AND THE CAR IS STARTING TO SPEED UP
ENGINE NOT GOING
</td><td></td><td></td><td></td></tr>
<tr><td>3
THE MAN IS MOVING THE CAR ALONG AT A STEADY SPEED
ENGINE NOT GOING
</td><td></td><td></td><td></td></tr>
<tr><td>4

NO BRAKES
NO PEDALLING
SLOWING DOWN</td><td></td><td></td><td></td></tr>
<tr><td>5

GOLF BALL</td><td></td><td></td><td></td></tr>
</table>

3.2 FORCE as an Alternative Name for Pushes and Pulls

The word force may have been used in the discussion as an alternative to the words push or pull. This is fine as long as it is realised force has other meanings as well, in a non-scientific sense but these other meanings are not appropriate in this study of force.

Discuss with Class:

Force is a familiar word to us all.
We talk of the police force.
We talk about "we had to force him to do it".
We talk about the force being with you. (Star Wars)
We talk about the force in a jet of water.

These ways of using the word force are quite different to the way a scientists uses the word force.

Copy into Books

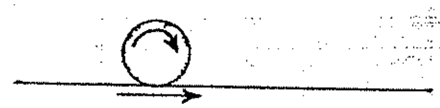
> Just those things we have been calling pushes or pulls scientists call forces. Forces can change momentum but scientists do not think of momentum as a force.

3.3 Momentum not Changing

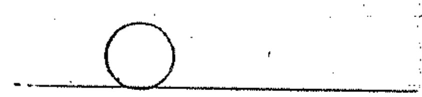
What's happening if the momentum is not changing? [This Section (3.3) involves situations where the effects of friction are minimal or there is no friction.]

Instructions:

1. Roll a ball along a smooth horizontal surface (a marble is best).



2. Place a ball on a horizontal surface.



3. Allow a glider to move steadily along an air track (if available).

Questions for Discussion:

1. What happens to the object in each case? (They hardly change speed at all)
2. What is happening to its momentum? (It is not changing)
3. If momentum doesn't change what can we say about the force on the object? (It is zero. Momentum is not a force)

These lead to the important idea:

> If there are no pushes or pulls acting the momentum is not changing.

If some pupils point out that sometimes when pushes and pulls act there is no momentum change (e.g. immovable objects) it might be hinted that may be there is other pushes and pulls also

3.6 Frictional Forces

The idea of frictional forces is clarified in the following section. Situations involving momentum changes caused by friction only are used. Focus on what happens after the contact push has ceased.[8]

Activities:

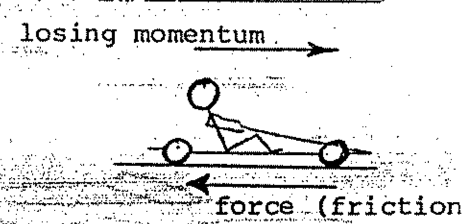
Worksheet

Questions \ Instructions	What happens after you have finished pushing?	Has momentum increased/ decreased/stayed the same (for the underlined object)
1. Push a trolley.		
2. Slide a block of wood along the floor.		
3. Riding along on a bicycle on a flat road.		
4. Riding along on a skateboard.		
5. Push a small boat across the water in a swimming pool.		

Questions:

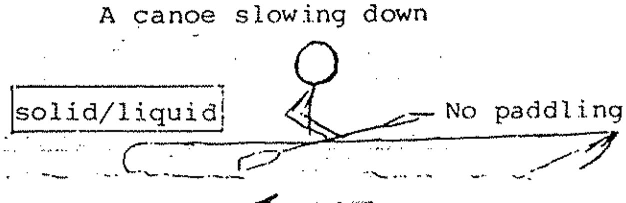
(a) What has caused the momentum to change?

(b) What is the direction of this force (push, pull)?

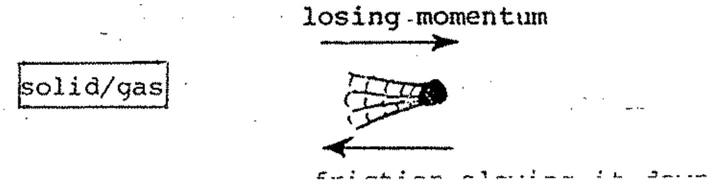


[8] In all these cases the momentum has decreased because of the force of friction in the opposite direction. The most common instances of where friction acts are when two solid surfaces tend to slide, or are sliding, over each other. However, friction can also act when other combinations of surfaces are in contact.

A canoe slowing down



shuttlecock slowing down
losing momentum



3.8 Reaction Forces (could be omitted with F1/2 pupils at this stage)

Many children have a great deal of difficulty appreciating that a solid non-moving object like a wall or a concrete path; can push on an object. This activity attempts to introduce this idea, by following through the idea that there must be a force to produce a momentum change.

	Is the momentum changing?	Is there a force on the object?
1. A car collides with a solid wall.		
2. A ball hits the ground.		

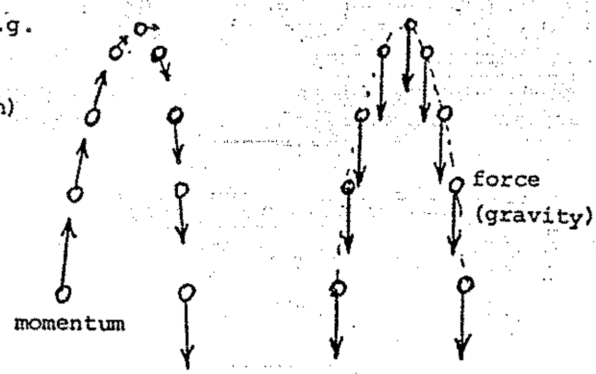
We call the force provided by the wall, and the ground, in the above cases a reaction force.

3.9 Summary: The Differences Between Force and Momentum

(a) Pupils need plenty of opportunity to draw diagrams to show the similarity and differences between these terms for many situations, e.g.

i) Ball thrown upwards (ignoring friction)

(length of arrows shows size of the momentum and force)



ii) A trolley slowing down

(b) It may be useful to return to 2.4 Worksheet C and get pupils to draw in all the individual forces (for example see Appendix B of Notes for Teachers, Working Paper 33)

Summary

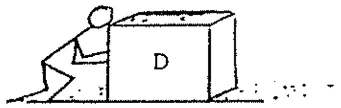
> If a body is changing its momentum then there must be a force on the body.
>
> Momentum is not a force, but forces can produce changes of momentum.

Extension: For more able F3 and F4 pupils the above ideas could possibly be quantified. See Appendix B, Extension 1(ii).

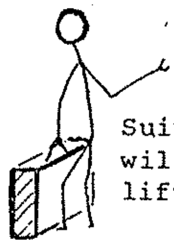
Practical Activities: Various practical activities for F3 and F4 pupils could be introduced here. See Appendix B, Extension 2

(b) <u>Invisible Pushes and Pulls</u>

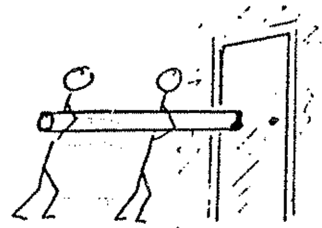
Sometimes the total push is zero even though it doesn't look like it.



Box will not slide



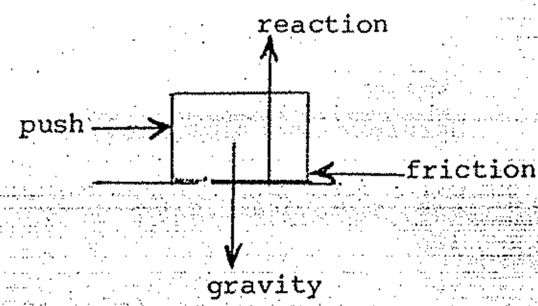
Suitcase will not lift up



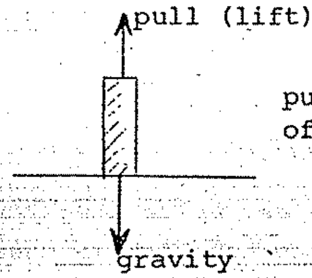
Ram will not go through door!

In these cases there are invisible pushes and pulls (friction on Box D, gravity on suitcase E and a reaction force on Wall E), so that the total push (or pull), i.e. the total force is zero. Of course there are vertical gravity and reaction forces as well.

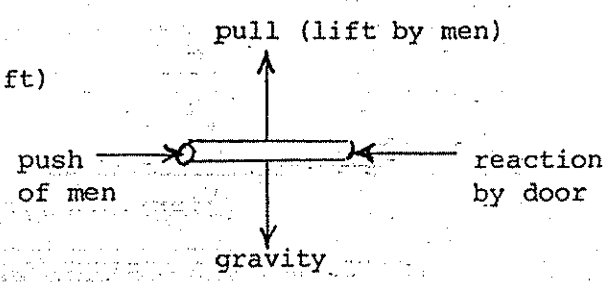
These situations can be represented symbolically:



forces on the box



forces on the suitcase



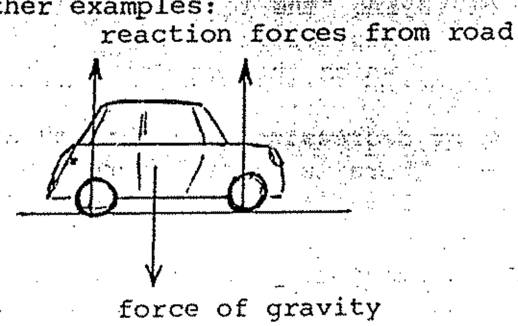
forces on the ram

However note:

1. The friction force (under any set of conditions) has a maximum value and if the push is bigger than this, then a momentum change will occur. Therefore the total force would not be zero.

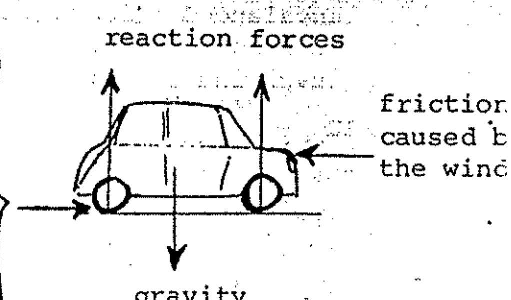
2. You can think of the reaction force generally as a supporting force to stop things (and people) falling through the floor, through tables, through the ground, or through walls.

Other examples:



parked on the road

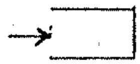
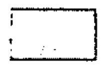
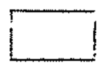
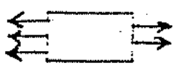
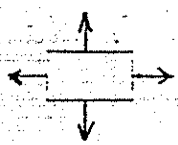
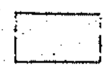
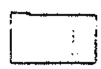
motor causes wheels to try to spin, friction of road stops spinning and puts a force on the car.



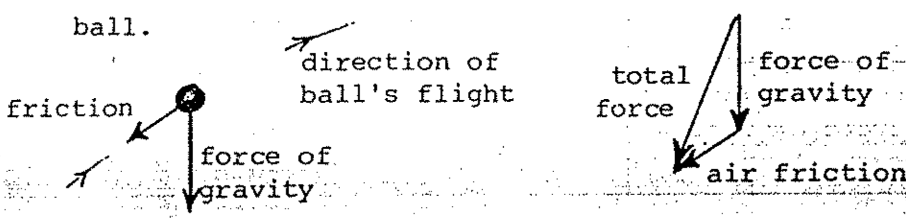
Car speeding up

4.2 Worksheet

The diagrams below show equal sized forces (pushes/pulls) acting on objects. Work out which forces total to zero and mark what is left on the diagram opposite. An example has been done to show you what to do. Copy and complete:

	Separate forces	Total force	Would there be a momentum change?
	e.g.		
(a)		same as 	Yes
Now try these:			
(b)		same as 	
(c)		same as 	
(d)		same as 	
(e)		same as 	
(f)		same as 	

Extension: Some pupils may wish to know how to find the total force when individual forces are in different direction, e.g. golf ball.



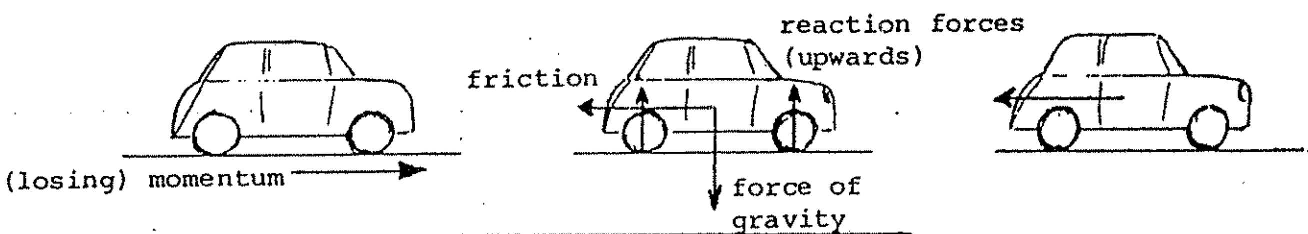
In these cases, we add the arrows together (head to tail)

4.4 Grand Summary: Momentum, Individual Forces, Total Force

Again, pupils should have plenty of opportunity to draw diagrams to show clearly that they understand the terms momentum, individual forces, and total force and appreciate the differences between them.

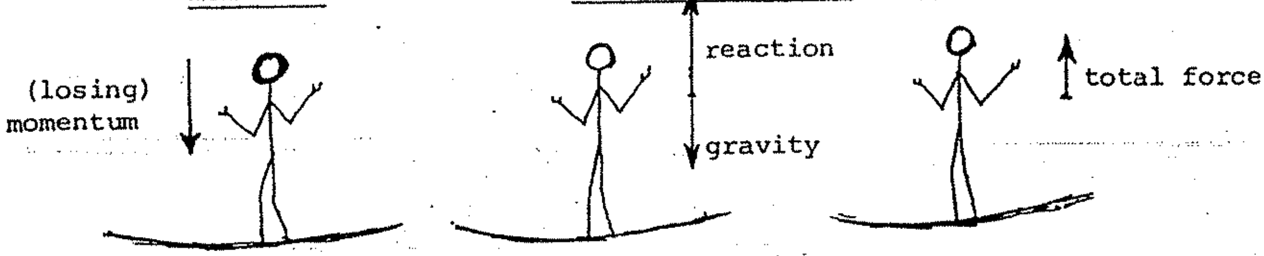
Example: Car slowing down (motor not going)

momentum | individual forces | total force



Stopping on a trampoline (still going down!)

momentum | individual forces | total force



Individual forces add together to give the total force.

The total force causes the momentum to change.

NOTE: zero total force means the momentum will not change

total force in the direction of motion means momentum will increase

total force in the opposite direction to the direction of motion means momentum will decrease

PART 5: INVESTIGATING HOW CHILDREN'S VIEWS HAVE CHANGED

The aim of this section is to

* investigate how individual children's ideas have been modified by the learning experiences provided in this unit of work.
* provide the opportunity for further remediation if necessary.

Activities:

(a) Survey B

This is a parallel form to Survey A although this fact should not be pointed out to pupils until after they have answered the survey. Pupils make a copy of their answers for reference before handing in their answer sheets.

(b) Checking on Changes

Compare pupils' answers in Survey A and Survey B (See Appendix A). It is desirable to return both Survey A and Survey B to pupils to let them check how their answers have changed.

Go over the survey questions with pupils, reteaching points where necessary.

> In our view this is a most important aspect of the topic, as this learning experience can have a most significant effect on pupils who still have non-scientific views.

Collect back Survey questions and answers.

(c) Rechecking on Changes

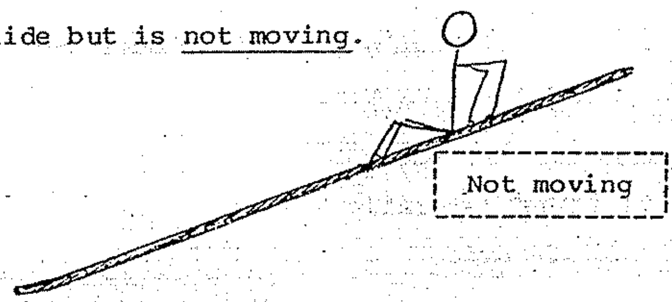
We would strongly recommend that either Survey A or B is used again with the pupils in a surprise test 3-6 months after the topic is complete.

4. A soccer ball is kicked into the goal.

As it moves into the goal what are the forces on it?
(you can choose more than one)

(a) The force of the kick
(b) The force of gravity
(c) The force of friction

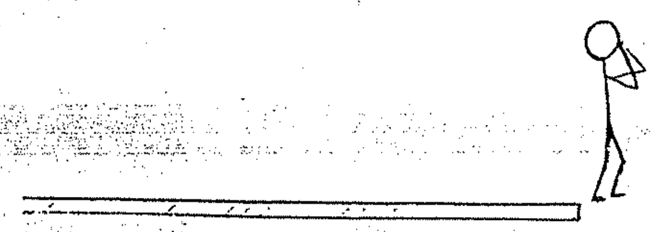
5. A person is on a slide but is <u>not moving</u>.



Which of the following is correct?

(a) There are many forces on the person but the total force is zero
(b) There are many forces on the person and the total force is downward
(c) There are no forces on the person at all

6. A diver steps off the end of a diving board very gently and slowly.



Just after she has stepped off, but <u>before she really started to drop down</u>, would there be a force on the diver?

(a) Yes, there is gravity
(b) No, she is not moving

APPENDIX A

A scientist's answers to the Survey A questions (Note that Survey A and B have equivalent questions, although they are in a different order and for some questions even the position of the correct alternative has been altered).

For fuller explanations you should refer to the Notes for Teachers Paper (Working Paper No. 33).

Survey A. Q.1 a, c
(Survey B. Q.8 d, f)

A force is a push or a pull that may involve contact (e.g. a person sitting on a chair experiences the pull or force of gravity. The chair pushes back (reaction force). If it did not support the person or push back, the person would fall through the chair.)

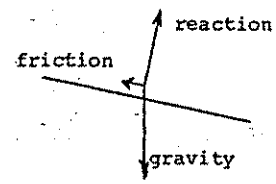
Pressure is force per unit area and although related to force is not considered by physicists to be a force. For example the same force (a person's weight) can put different pressures on a small section of vinyl flooring (depending on whether stilleto or flat heels are being worn).

Survey A. Q.2 c
(Survey B. Q.9 b)

There is only one force acting on the ball in the horizontal direction - that of friction. Friction is in the opposite direction to the ball slowing it down.

Survey A. Q.3 a
(Survey B. Q.10 a)

Because the speed is steady there is no change in momentum; therefore there is no total force.



In this case there are three forces acting. They are the force of gravity, friction, and the reaction force from the road on the skateboarder. The directions of three forces can be shown. They add to zero (see p.22 extension)

Survey A. Q.4 b
(Survey B. Q.6 a)

The force of the earth's gravity always acts downwards on objects near the earth (e.g. ball, or spacecraft).

Survey A. Q.5 b
(Survey B. Q.7 a)

Refer back to Q.1.

Survey A. Q.6 a
(Survey B. Q.5 a)

Because the car's momentum is not changing the total force is zero. (Refer to p. 21)
There are three forces on the car as explained in Q.3.

Survey A. Q.7 a, b
(Survey B. Q.4 a, b)

The force of gravity pulls the ball towards the earth. It doesn't fall immediately to the earth because it gained momentum (momentum is not a force) when the person was actually kicking it. The friction between the ball and the air has the effect of slowing the ball in the direction it is moving. There is <u>no</u> force of the kick in the position shown. The force of the kick ended the second the ball left the player's boot.

Survey A. Q.8-10 a, a, a
(Survey B. Q.1-3 a, a, a)

Force is basically a push or pull acting on an object. In this case there is only one significant force on the ball, the force of gravity which is a <u>constant force</u> acting on the ball <u>at all times</u> in a <u>downward</u> direction. Its effect is to slow down the ball moving upwards until it becomes momentarily stationary. Even at that instant, the force of gravity acts. Since this force continues to act, the ball falls, speeding up as it does so. (Another force, that of friction between the ball and the air, acts on the ball opposite to the direction of its motion while it is moving. In this example the speeds reached are not large. Hence friction will be negligible compared to the force

APPENDIX C

Answers to Worksheet Questions

2.2

1. A; three times as much momentum as B.
2. A; twice as much momentum as B.
3. They both have the same amount of momentum; ________
4. B; four times as mucy momentum as A.

2.4

1. No; no; ______.
2. Yes; Yes; the car is gaining momentum as it speeds up.
3. Yes; No; ______.
4. Yes; Yes; the bike loses momentum as it slows down.
5. Yes; Yes; the ball is slowing down because of the friction between the ball and the air also the momentum is decreasing and changing direction because of gravity.

3.1

1. The trolley quickly speeds up; increased; push in the direction of motion.
2. The trolley quickly speeds up; increased; pull in the direction of motion.
3. The trolley quickly speeds up; increased; push in the direction of motion.
4. The ball begins to move very fast; increased; push in the direction of motion.
5. The bicycle starts moving; increased; push in the direction of motion.
6. The trolley slows down (or stops); decreased; push in the direction opposite to the motion.
   (Some pupils find it difficult to think of a wall or something, actually pushing on the trolley. This is discussed further in Section 3.7).
7. The trolley slows down (stops); decreased; push in the direction opposite to the motion.
8. The ball stops (initially); decreased; push in the direction opposite to the original motion.
9. The ball slows down (stops); decreased; push in the direction opposite to the motion.
10. The cycle slows down (stops); decreased; pull in the direction opposite to the motion.

3.3

i) It hardly slows down at all.
ii) It is not really changing.
iii) It is zero. Note: momentum is not a force.

3.5

The answers apply for all three examples:

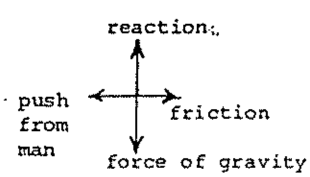
1. When you are not touching it.
2. It gradually slows down, as it goes upwards.
3. It is getting less.
4. The pull of gravity.
5. Downwards.

3.6

In all these cases the momentum has <u>decreased</u> because of the force of friction in the opposite direction.

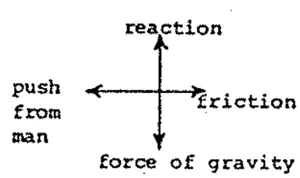
4.5

1. Yes



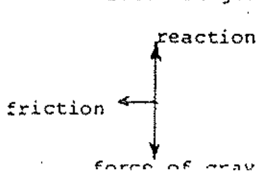
zero

2. Yes



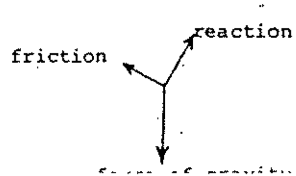
not zero ←

3. Yes



not zero ←

4. Yes



not zero ↘