Lesson 4 Momentum, impacts and safety

Introductory notes(2 mins)

In this lesson we are going to use the idea of momentum, and especially the rate of change of momentum, to explain safety features in vehicles and other examples of collisions, maybe in sports or activities like bungee jumping.

Remember the longer the impact lasts, the smaller the force that needs to act - from Lesson 3:

Force = (Change in momentum)/Time taken

Introduction to absorbing impacts (8 mins)

Watch this video (2:43) about airbags just to see what they do and how they are activated:

https://www.youtube.com/watch?time_continue=5&v=SSz6y-W-R_A&feature=emb_logo

Answer the following questions, using your textbook or web searches for help if you need it:

1.Copy this statement into your Physics notes:

During a crash the driver's head starts out with the same velocity as the car. An airbag increases the time it takes for the head to come to rest, which will decrease the force on the head. In order to make sure the head does actually come to rest instead of bouncing the airbag has vents that allow air to be pushed out during impact so it deflates instead of staying completely full and keeping its shape.

2. Look back to your notes from Lesson 3 and write down the equation relating Force to Rate of Change of Momentum

3. Using this equation, explain what happens to the size of the impact force when the time of the

collision is increased

4. One reason for having an airbag is to prevent contact with hard parts of the vehicle. Use your answer to Q.3 to explain what the other reason is.

5. List three other safety devices or features designed to reduce impact forces, especially head injuries, in a similar way in examples such as vehicles, sports equipment or soft play areas.

Reducing impact injuries (10mins)

- Go to this link and read just the section in the reddish box entitled

  'Everyday Examples:Landing After a Jump'
  https://openoregon.pressbooks.pub/bodyphysics/chapter/mechanisms-of-injury/#chapter-1940-section-1

- Cut and paste a copy of the graph showing 'Hard' and 'Soft' landing forces into your Physics notes if you can
- Copy and complete these sentences using the text to help you:
    - The size of an impact force can be reduced by increasing the _____ of the impact
    - If you keep your knees rigid when you land from a jump, your upper body comes to rest in a short amount of _____ which is why the force sensor in the experiment records a maximum impact force of _____ N
    - If you bend your knees when you land from a jump, your upper body takes a _____ time to come to rest which is why the force sensor in the experiment records a maximum impact force of only _____ N
    - The flat parts of both the red and blue lines shows the weight of the person standing on the force sensor after each jump. The person's normal weight is approximately _____ N.
    - The effect of landing with rigid knees is to increase the usual, standing force on the person's knees by 2 ½ times - this is not good!

Watch the video clip (4:02) about parcours and count how many impacts you can see:

www.youtube.com/watch?time_continue=69&v=TQe01rxUisk&feature=emb_logo

Practise questions on safety features to reduce impact forces (20mins)

Remember - the key point is 'Increasing impact time reduces impact force' (look at that equation again to see why Force = Change of Momentum/Time Taken)

You might get asked to use this key point in any number of examples an examiner can think of - crumple zones in cars; landing space probes on other planets; body armour in sport; crash helmets; crash mats in gyms and play areas; bubble wrap in parcels - but always use the SAME explanation, increased time, decreased force.

Try some examples - remember that exam questions may cover more than one topic so you may have to remember things from previous work and look up equations you need:

Q1.

A tennis racket is used to hit a tennis ball.

The ball is in contact with the racket for 0.20 seconds and leaves the racket with a horizontal velocity of 46 m/s.

(a) (i) State the equation relating acceleration, change in velocity and time taken. (1)

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(ii) Calculate the acceleration of the tennis ball assuming it is at rest when it is hit.

Give the unit. (3)

acceleration = ...unit.....

(b) The tennis ball has a mass of 57 grams.

(i) State the equation relating momentum, mass and velocity. (1)

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(ii) Calculate the momentum of the tennis ball when its velocity is 46 m/s. (3)

momentum = ... kg m/s

(c) The bottom of a tennis player's shoes are thick and made from a material that compresses when the player's feet land on the ground.

Explain why these shoes reduce the risk of injury to the tennis player. (3)

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.....**(Total for question = 11 marks)**

Q2.

A pilot begins to land an aircraft.

(a) The height of the aircraft decreases from 200 m above the ground to 100 m.

(i) What happens to the gravitational potential energy of the aircraft?

Put a cross X next to your answer. (1)

A it becomes zero

B it decreases

C it does not change

D it increases

(ii) The velocity of the aircraft remains constant.

What happens to the kinetic energy of the aircraft?

Put a cross X next to your answer. (1)

A it becomes zero

B it decreases

C it does not change

D it increases

(b) The aircraft lands with its wheels on the runway as shown. The aircraft is moving forwards.

(i) Draw an arrow on the diagram to show the direction of the momentum of the aircraft. (1)

(ii) The velocity of the aircraft when it lands is 75 m/s. The mass of the aircraft is 130 000 kg.

Calculate the momentum of the aircraft. (2)

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(iii) The aircraft comes to a stop. State the momentum change of the aircraft from when it lands to when it stops. (1)

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(c) When the aircraft lands, the momentum of each passenger also changes.

(i) Explain why it is more comfortable for a passenger if the aircraft takes a longer time to slow down. (2)

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(ii) Suggest why some aircraft need a very long runway to land safely. (2)

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(Total for Question is 10 marks)

Now mark your work, using the mark scheme below and HIGHLIGHTING and correcting any mistakes - if you simply change them, you will not remember WHY you made that mistake. Make a note of anything you need your teacher to explain to you.

These questions are from the Edexcel Exam Board but are typical of GCSE questions on momentum and safety features.

Summary (5min)

Examples of Reducing Impact Forces: Write as many examples as you can think of where reducing impact forces by increasing impact time is important - the more you can think of, the more prepared you will be for exam questions on any example.

Mark Scheme:

Q.1

Question number	Answer	Additional guidance	Mark
(a)(i)	Acceleration = change in velocity ÷ time taken	allow in words or acceptable symbols	1

Question number	Answer	Additional guidance	Mark
(a)(ii)	Process includes: • substitution • evaluation • unit e.g. acceleration = 46/0.20 (1) acceleration = 230 (1) unit = m/s^2 (1)	mark independently	3

Question number	Answer	Additional guidance	Mark
(b)(i)	Momentum = mass × velocity	allow in words or acceptable symbols e.g. $p = m \times v$	1

Question number	Answer	Additional guidance	Mark
(b)(ii)	Process includes: • conversion of mass to kg • substitution • evaluation e.g. 0.057 kg seen anywhere (1) (p =) 0.057 × 46 (1) (p =) 2.6 (kg m/s)(1)	2622 gains 2 marks allow 2.622	3

Q.2

Answer	Acceptable answers	Mark	
(a)(i)	B it decreases		(1)
(a)(ii)	C it does not change		(1)
(b)(i)	horizontal arrow (judge by eye), pointing to the right anywhere on the diagram		(1)
(b)(ii)	substitution: (1) 130 000 × 75 evaluation: (1) 9 750 000 (kgm/s) (Ns)	give full marks for correct answer, no working Ignore minus sign 9.75 x 106 (kgm/s) (Ns)	(2)
(b)(iii)	9 750 000 kgm/s	same value as answer to (b)(ii)	(1)

		Ignore minus sign	
(c)(i)	An explanation linking two of the following: · force is smaller/less (1) · momentum changes more slowly (1) · lower deceleration (1) · use of the formula (1)	pressure is smaller/less slower deceleration force is proportional to rate of change of momentum/F= (mv – mu)/t	(2)
(c)(ii)	Any two from: (for loaded aircraft) · has more mass (1) · has more momentum (1) · has more k.e. (1) · higher velocity · brakes need to do more work (1)	accept reverse argument for empty aircraft heavier/more passengers/more cargo higher speed/moving faster	(2) exper t