How Safe is Your Car?

Contents: Reading and questions on road safety, with particular reference to the MOT test and brakes, tyres and seat belts.

Time: 2 periods or more, depending on number of parts attempted.

Intended use: GCSE Physics and Integrated Science. Links with work on motion, friction and energy.

Aims:

- To complement and revise work on velocity, acceleration and Newton's Laws of Motion, and work on friction and energy conversion
- To develop awareness of the MOT road vehicle test, its nature and limitations
- To develop awareness of certain features of safe road use
- To provide opportunities to practise skills in investigation, reading and comprehension.

Requirements: Students' worksheets No. 504

This unit is in three parts.

Part 1 *The MOT test* is introductory and looks at a number of car safety features
Part 2 *Trying to stop in time . . .* is about brakes and tyres
Part 3 *If you don't stop in time . . .* is about seat belts.

The three parts are independent and can be used separately, although Part 1 makes a useful introduction to the other two.

Notes on some of the questions

Qs 1 to 4 The MOT (Ministry of Transport) test must be taken annually by cars over three years old. In 1985 the fee for a successful test was £10.70. A failure also costs £10.70, but there is no extra charge for a successful retest, provided the necessary repairs are carried out by the garage doing the test.

Q.6 *The MOT Tester's Manual* (from HMSO, price £3.95 in 1985) gives details of the testing procedures. The efficiency of the parking brake (hand brake) and service brake (foot brake) are tested on a rolling brake tester. Metal rollers rotate the vehicle's wheels. The brake is applied, and the machine records the braking force exerted on the rollers.

Q.8 Seat belts are examined for cuts and signs of deterioration. The security of the mountings and the operation of the locking mechanisms are also checked.

Q.9 A major shortcoming of the MOT test is that it is conducted only once a year. Faults develop over short periods, and an annual test can only pick them up by luck, or some time after they have developed. For example, 1mm of brake lining may give good results on the day of the test, but not a week later. The test is in any case fairly superficial: it would be difficult to introduce a more thorough test without a substantially increased fee. The AA estimate that MOT tests cost motorists at least £250 million each year, and they believe that, in terms of cost-effectiveness, this money might have been better spent on different road-safety measures. It is estimated that only 8 per cent of accidents can be attributed to vehicle defects. The majority are caused by human error: 95 per cent of all reported injury accidents on the road result primarily from driver error.

Qs 10 and 11 Power-assisted brakes are used to provide the large braking force needed on heavy or high speed vehicles. On cars, they are usually activated by vacuum from the inlet manifold. On lorries, the brakes are usually activated by compressed air.

Q.14

	Thinking distance	*Stopping distance*
Rain	Unchanged (but visibility may be reduced)	Increased
Tired driver	Increased	Unchanged or increased
Alcohol	Increased	Unchanged or increased
Icy road	Unchanged	Greatly increased
Fog	Unchanged, but visibility reduced, so less time to react	Unchanged, or increased if road is wet

With suitable students, the figures on thinking and stopping distances could be handled more quantitatively, using the question below.

This table gives figures for thinking and breaking distances at different speeds.

Speed/km per hour	*Thinking distance/m*	*Braking distance/m*	*Total stopping distance/m*
40	7	8	15
50	9	13	22
60	11	20	31
80	15	34	49
100	19	54	73

(a) Use the figures in the table to plot graphs of:
  (i) Thinking distance versus speed,
  (ii) Braking distance versus speed.

(b) What is the mathematical relationship between:
  (i) Thinking distance and speed,
  (ii) Braking distance and speed?

(c) Try to explain the relationship between:
  (i) Thinking distance and speed,
  (ii) Braking distance and speed.

Answers:

(b) (i) Thinking distance is proportional to speed.
  (ii) Braking distance is proportional to the square of speed.

(c) (i) Assuming thinking *time* is fixed, the *distance* travelled by the car will be proportional to its speed.
  (ii) This follows from the formula $v^2 = u^2 + 2as$, assuming the deceleration is constant.

Q.16 With a tight belt, there is a longer distance over which the stretching of the belt can decelerate the passenger. In addition, with a loose belt there will be a sudden 'snatch' as the passenger moves forward into the belt.

Qs 17 and 18 Wide seat belts ensure a smaller force per unit area. The pressure is applied to parts of the body well able to withstand it, namely the thorax and pelvis.

Q.19 The cut in the belt reduces its cross-sectional area and since the force in the belt is constant, the tensile stress at this point is increased. This results in greater stretching, and possible failure at this point.

Q.20 A belt which has been involved in a collision becomes permanently stretched and will no longer perform satisfactorily. It may also have fabric damage within the locking unit which would not be apparent without stripping the assembly down.

Q.21 Rear seat passengers are less frequent than those in front seats, and until 1986 it was not compulsory for new cars to be fitted with rear seat belts. However, in the years following the introduction of compulsory front seat belt wearing, the number of deaths of rear seat passengers increased, and there was pressure to make rear seat belts compulsory as well. It seems unlikely that compulsory rear seat belt wearing will be introduced until the majority of cars are fitted with them.

Further work

A good deal of practical laboratory work associated with this topic is possible. For example:

1 (a) Brakes and deceleration: see Nuffield Science 13-16, *Cars on the Move.*

(b) Seat belts: experiments using eggs and egg-boxes (from RoSPA (The Royal Society for the Prevention of Accidents) project 'Seatbelt Science'). Fix an egg box to a trolley using rubber bands. Using an egg as a 'passenger', and with the lid on the box, run the trolley down an inclined plane into a rigid 'crash barrier'. It will be found that the 'passengers' can survive quite severe collisions. Repeat with no top on the egg box to simulate the (messy) effect of a passenger being 'thrown clear' in the collision. Ticker tape can be attached to the trolley to measure collision speed, and the effects of different size egg 'passengers' could be investigated.

2 If time permits, students could also investigate other safety features of cars, for example:
Headrests — why do they improve safety?
Steering column, rear view mirror, sunvisors, dashboard, etc. — why are they hazards, and how are the hazards minimized?
Front and rear lights — how do they improve safety, and what checks are made on them in the MOT test?

Further resources

1 RoSPA (The Royal Society for the Prevention of Accidents) has a wide range of material, including films, relating to safety matters in general and road safety in particular. Catalogue available from: Safety Education, RoSPA, Cannon House, The Priory Queensway, Birmingham B4 6BS.

2 The Transport and Road Research Laboratory have useful reports and leaflets relating to car safety. From: TRRL, Old Wokingham Road, Crowthorne, Berkshire RG11 6AU.

3 The Granada TV series *Physics in Action* includes a useful programme entitled *Laws of Motion 1,* which contains sequences relating to braking and seat belts. The programme can be recorded off-air for school use. Transmission times can be found in the ITV for Schools programme schedule.

Acknowledgements Figure 1 supplied by John Van Dyk; Figure 2, Department of Transport; Figure 4 reproduced by permission of the Controller of Her Majesty's Stationery Office; Figure 5 supplied by the Transport and Road Research Laboratory (Crown Copyright).

HOW SAFE IS YOUR CAR?

Each year about a quarter of a million road accidents are reported to the police. Over five thousand people are killed in these accidents. Road accidents have many causes. Drivers and pedestrians make mistakes, particularly after drinking alcohol. In fact, in 95 per cent of all road accidents, the driver is at least partly to blame. But one cause of accidents is the condition, or 'roadworthiness', of the vehicle. In this unit you will be looking at some of the features affecting the roadworthiness of a car. The unit is in three parts:

Part 1 *The MOT test*
Part 2 *Trying to stop in time . . .*, about brakes and tyres
Part 3 *If you don't stop in time . . .*, about seat belts.

Part 1 The MOT test

The 'roadworthiness' of a car is checked when the vehicle is put in for the MOT test. Try to find the answers to questions 1 to 5 about the MOT test. You may have to visit a garage which does MOT tests in order to answer them all.

Figure 1 An MOT testing centre

Questions

1 *What does MOT stand for?*
2 *How often does a car have to have an MOT test?*
3 *At what age does a car have to have its first MOT test?*
4 *How much does an MOT test cost?*
5 *If someone you know recently put a car in for an MOT test, find the answers to these questions:*
   (a) Did the car pass or fail?
   (b) If it failed, what did it fail on?
   (c) If it failed, what needed to be done before it passed?

The MOT check-list

Figure 2 shows the check list which is used by MOT testers. Each item on the list has to be checked. If any item fails, the car fails the MOT. Look at the check list, then answer questions 6 to 9.

Questions

6 Section III
   (a) What is the difference between the service brake and the parking brake?
   (b) How do you think they test the efficiency of the brakes?
7 Section IV
   Why is the condition of the tyres important to the safety of the car?
8 Section V
   What particular features do you think the testers look for when they inspect the condition of seat belts?
9 *What are the limitations of the MOT test as a way of improving road safety?*

Figure 2 The MOT Check List

Department of Transport

Check List for Vehicle Inspection

CUSTOMER'S COPY

VT 29

(Revised June 1983)

Vehicle Reg. No. or Chassis No. ..... Make & Model ..... Approx. year of manufacture ..... Recorded mileage .....

Code	Testable Item	Testers Manual Reference. (See Note below)	Pass	Fail	Remarks
01	**Section I – Lighting Equipment**				
02	Oblig. Front Lamps	I/1			
03	Oblig. Rear Lamps	I/1			
04	Oblig. Headlamps	I/2			
05	Headlamp Aim	I/6			
06	Stop Lamps	I/3			
07	Rear Reflectors	I/4			
08	Direction Indicators	I/5			
09					
10	**Section II – Steering & Suspension**				
11	Steering Controls	II/1			
12	Steering Mechanism	II/2			
[illegible]	Power Steering	II/3			
14	Transmission Shafts	II/2.2.15,II/4.4			
15	Stub Axle Assemblies	II/5			
16	Wheel Bearings	II/4			
17	Suspension	II/5,6,7,8,9.			
18	Shock Absorbers	II/10			
19					
20	**Section III – Braking System**				
21	Service Brake Condition	III/3,4			
22	Parking Brake Condition	III/1,2			
23	Service Brake Efficiency	III/5,6,7,8.			
24	Parking Brake Efficiency	III/5,6,7,8.			
25	Service Brake Balance	III/5,6,7,8.			
26					
27	**Section IV – Tyres & Wheels**				
28	Tyre Type	IV/1			
29	Tyre Condition	IV/1			
30	Roadwheels	IV/2			
31					
[illegible]	**Section V – Seat Belts**				
[illegible]	Security of Mountings	V/1			
34	Condition of Belts	V/1			
35	Operation	V/1			
36					
37	**Section VI – General Items**				
38	Windscreen Washers	VI/1			
39	Windscreen Wipers	VI/2			
40	Horn	VI/4			
41	Condition of Exhaust System	VI/3			
42	Effectiveness of Silencer	VI/3			
43	Condition of Vehicle Structure	VI/5			
44					

During the test on this vehicle the defects mentioned below were noticed, which in the opinion of the tester, render the vehicle DANGEROUS for use on the road:-

Warning: A person who drives a dangerously defective vehicle on the road is liable to prosecution and the insurance may not be operative.

Note: The MOT Testers Manual is a comprehensive guide to the inspection procedures applied during the MOT test. It sets out in detail the statutory requirements that vehicles have to meet, the methods of inspection and the principal reasons for failure. The manual may be purchased from Her Majesty's Stationery Office or through any bookseller.

Pass Cert. No. ..... (VT 20)

Fail Cert. No. ..... (VT 21 or VT 22)

Signature of Tester ..... Date of Test .....

Testing Station No. .....

Printed in U.K. for H.M.S.O. 8840212 10/84 9830

Part 2 Trying to stop in time . . .

Most MOT failures are because of unsafe tyres and brakes. Tyres and brakes are essential for stopping the car quickly and safely.

When a car stops, it **decelerates**. For the car to come to a stop quickly, the deceleration needs to be high. Now, in order to give a body of mass **m** an acceleration or deceleration **a**, we need to exert a force **F** on it, where

$$\mathbf{F = ma}$$

The force **F** is a frictional force. It is exerted on the wheel by the brakes, and on the road by the tyres. If a car is to stop quickly, the deceleration must be large, so **F** will need to be large too. If the car (or lorry) is heavy, **F** will need to be even larger.

So, for safe stopping you need brakes that work efficiently and exert a large frictional force on the wheel. Figure 3 shows how car brakes work.

Questions

10 What are power-assisted brakes?

11 Why do all lorries and most large cars have power-assisted brakes?

12 When brakes are beginning to wear out, they often start to 'pull' the car to one side. Why is this?

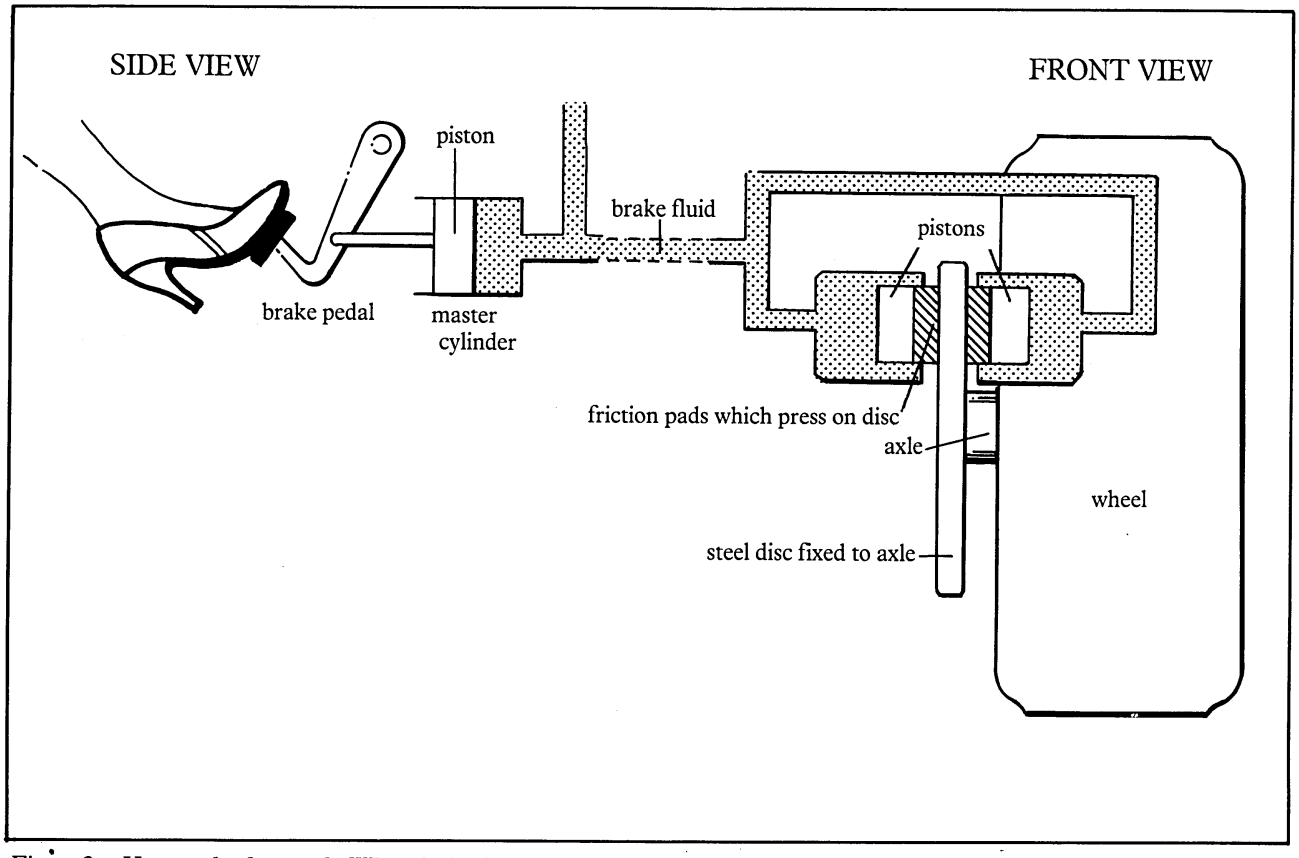

Figure 3 How car brakes work. When the brake pedal is pushed down, the piston in the master cylinder puts pressure on the brake fluid. This pressure is transmitted to the wheel cylinders, where it pushes the friction pads against the disc.

Safe stopping also requires tyres to keep a grip on the road. This 'grip' is the frictional force between tyre and road. If the tyres slip (skid) over the road, the force they exert on the road becomes smaller. This means the car takes longer to stop. Water lubricates the tyre and the road, making the frictional force less. To avoid this, tyres have *treads* which help clear water from under the tyre. If these treads are worn, the tyre becomes particularly dangerous in wet weather.

Stopping distances

Figure 4 is taken from the Highway Code. It shows the distances needed to stop when travelling at different speeds. The distances are for a well maintained car in good weather conditions.

Notice that the stopping distance is made up of two parts:

1 *The thinking time* It takes a little time between a person seeing that something has to be done, and the muscles actually doing it. During this time, the car moves through the thinking distance.

2 *The braking distance* This is the distance the car travels between applying the brakes and coming to a stop.

Answer questions 13 to 15.

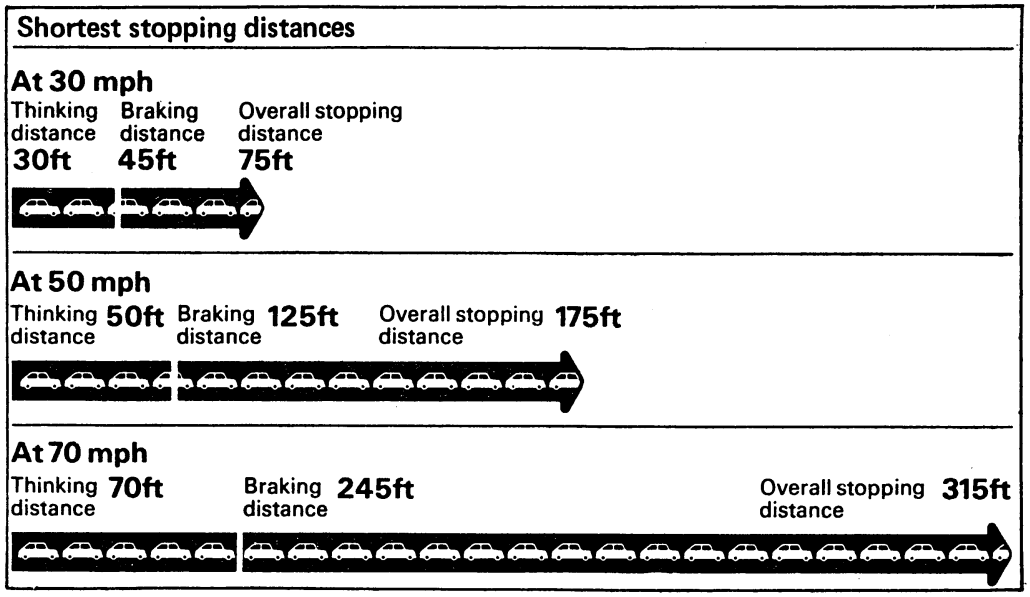

Figure 4 Shortest stopping distances (from Highway Code)

Questions

13 When a car uses its brakes to come to a stop, it loses all its kinetic energy. What is this energy changed to? Where does the change take place?

14 The stopping distances in Figure 4 are for an alert driver, in a good car with good brakes and tyres, on a dry road. What difference will each of the following make to: (a) the thinking distance;
(b) the stopping distance?
(i) Rain
(ii) A tired driver
(iii) A driver with alcohol in his or her blood
(iv) Icy road
(v) Fog.

15 In foggy weather, giant 'motorway pile-ups' are quite common. Cars run into the back of one another. Sometimes hundreds of vehicles are involved. How could these pile-ups be prevented?

Figure 5 This close-following warning sign lights up automatically if vehicles are travelling too close together.

Part 3 If you don't stop in time . . .

Sometimes, the brakes and tyres of a vehicle do not stop it in time. The result is a crash, and the people inside may be badly hurt or even killed. Modern cars are designed to reduce crash injuries as much as possible. The car is designed to 'crumple' at the front and rear, but leave the 'passenger cell' intact (Figure 6). (This is why you should never carry passengers in the luggage area of an estate or hatch-back car.)

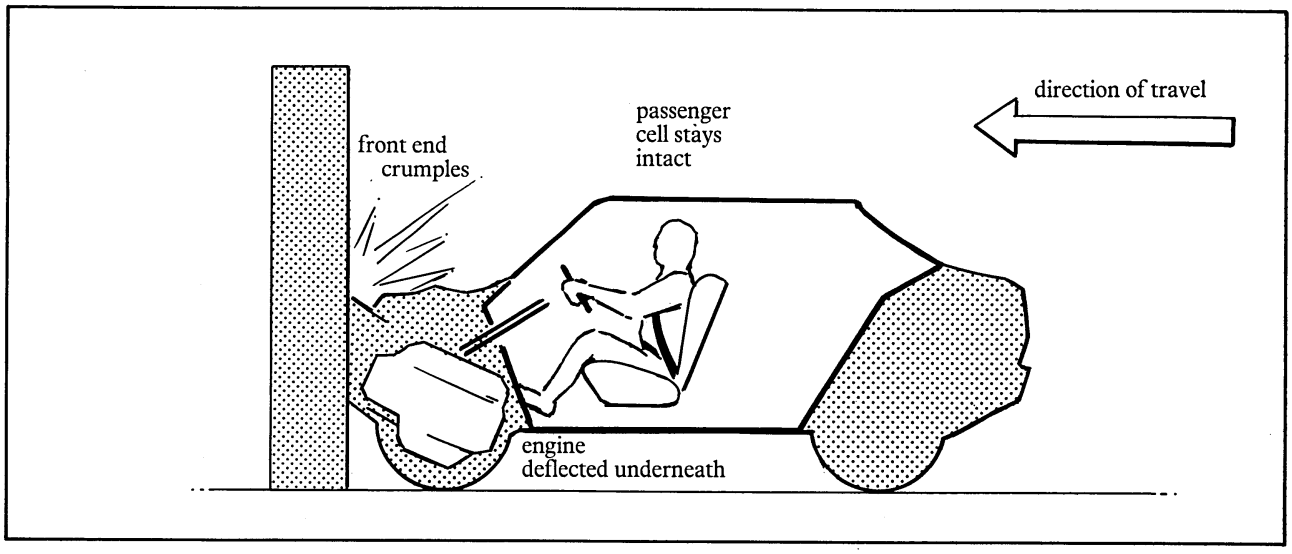

Figure 6 Modern cars have 'passenger cells' to protect passengers

A passenger in a car travelling at speed has a lot of kinetic energy. If the car crashes, it stops suddenly. But the passenger inside continues moving (Newton's First Law of Motion). Unless the passenger is thrown out of the car, they cannot move far. If they have no seat belt, they will hit some part of the car, and stop. All the passenger's kinetic energy will be converted to other forms of energy, and the passenger will probably be badly injured (Figure 7).

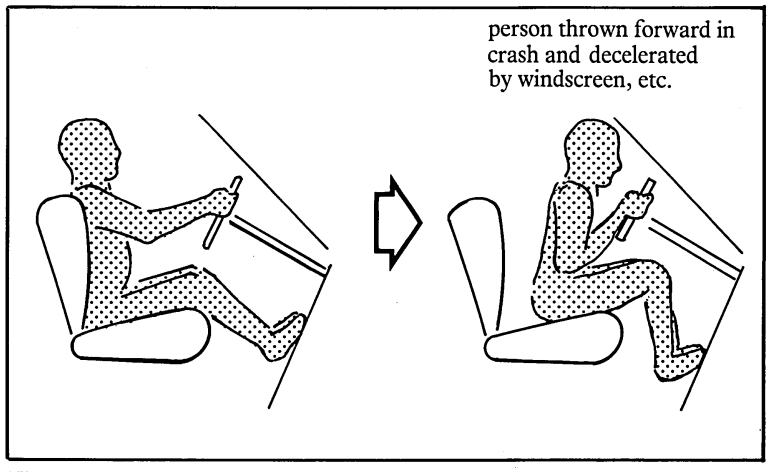

Figure 7 An accident without seat belt

Seat belts are designed to absorb the passenger's energy. When the car stops in the crash, the passenger continues moving forward, and the force on the seat belt causes the belt to stretch. This stretching absorbs energy. If the belts were made of a material that did not stretch, like steel, they would do a lot of damage. Seat belts are designed to stretch just enough to bring the passenger to a safe stop, but not enough to let the passenger hit the windscreen or other part of the car (Figure 8).

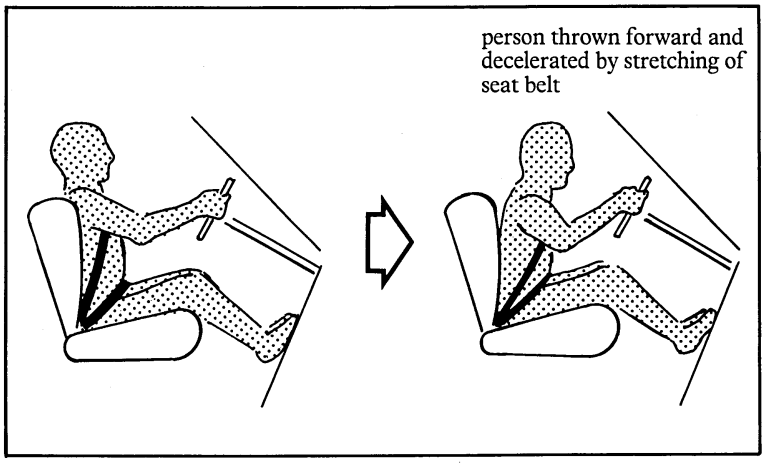

Figure 8 An accident with seat belt

The wearing of seat belts was made compulsory in Britain in 1983. Statistics suggest that this has saved over two hundred lives a year, and thousands of serious injuries.

Answer questions 16 to 22.

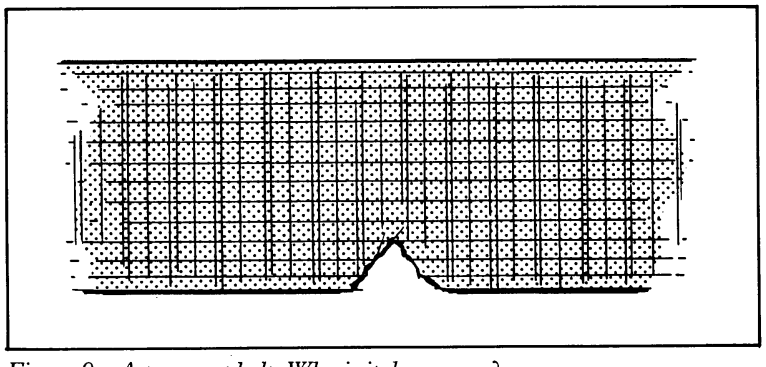

Figure 9 A torn seat belt. Why is it dangerous?

Questions

16 *Why is it important that seat belts are worn* tightly*?*

17 *Why do seat belts need to be wide?*

18 *Why do most seat belts pass across the chest* and *over the lap?*

19 *Figure 9 shows a seat belt that has become slightly torn at the edge. Why might this seat belt be dangerous in a crash?*

20 *Seat belts which have been 'used' in a collision should always be replaced by new ones. Why is this?*

21 *It is not compulsory for* rear *seat passengers to wear belts. Do you think it should be?*

22 *A man was heard to say: 'I don't see why I should wear a seat belt if I don't want to. It's my life.' Do you agree with his point of view?*