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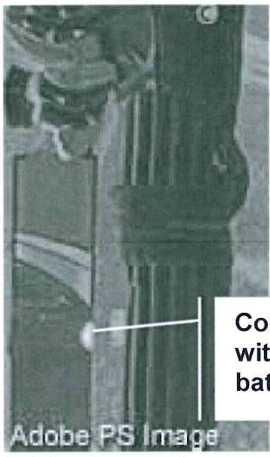
# Question 1

**(16 Marks)**




Original image altered by Curriculum Council for copyright reasons.

In cricket, a batsman is judged 'out' if the ball is caught after hitting the bat. The batsman is 'not out' if the ball is caught after hitting the batsman's leg. A cricket umpire must sometimes decide whether the ball hit the bat, the batsman's leg, or if both have been hit, which happened first. This can be tricky because the bat and the leg may be very close together, and the contact occurs over a very short time.

A technology called Hot Spot can be used to resolve this issue. Hot Spot is an infra-red imaging system, and is used to determine where, or what, the ball actually hit. There are two Hot Spot infra-red cameras, one at each end of the cricket ground. These measure and record the temperature of the bat and the batsman, before and after the ball makes contact. The infra-red images are then processed by a computer to show temperature differences between the 'before' and 'after' images.

The point is to show accurately whether the ball has hit the bat, the batsman's glove, the batsman's leg, or none of these. The black-and-white images produced by Hot Spot can potentially allow an umpire to precisely localise the ball's point of impact, and so reduce the risk of making an incorrect decision.

(a) Using the image above as a reference, which would have the higher temperature? (1 mark)

Circle the correct answer: a light part a dark part not enough information

(b) Explain how the infra-red cameras are able to 'sense' where the contact or collision point has occurred. (2 marks)

(c) The increase in heat energy of the contact point only lasts for a short time. Explain one form of heat transfer that is likely to occur in this situation. (3 marks)

(d) A 161 gram cricket ball moving at 25.0 m $s^{-1}$ hits the edge of a stationary bat transferring 18.1 J of energy to the bat.

(i) Calculate the speed of the ball after the collision. (4 marks)

(ii) At the moment the photograph is taken, about 4 grams of wood absorb the 18.1 J of energy and increase in temperature. Estimate the temperature increase of this portion of the bat, given that the specific heat of the bat is $2.25 \times 10^3$ J $kg^{-1}$ $K^{-1}$. Give your answer to an appropriate number of significant figures. (4 marks)

(e) After the ball is struck, it rolls along the ground and comes to a stop. Use Newton's Second Law to explain this. (2 marks)

# Question 2

**(3 marks)**

Use the mathematical relationship (formula) for momentum to explain why a slow-moving train will generally have more momentum than a high-velocity small-calibre (diameter) rifle bullet. (Calculations are not required.)

# Question 3

**(4 marks)**

Figures 1 and 2 show two types of crash barrier. The barrier in Figure 1 consists of metal posts that support horizontal metal cables. The posts break off easily at the base, and the cables are able to stretch. The barrier in Figure 2 consists of metal posts that support horizontal metal sheets. The posts are fixed strongly in the ground, and the metal sheets resist stretching.

Using your understanding of impulse and Newton's second law of motion, explain why the barrier in Figure 1 is more likely to reduce injury to the occupants of cars that drive off the road.

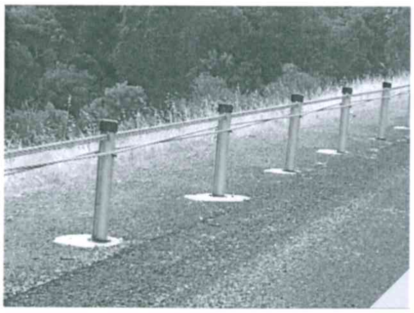


**Figure 1**

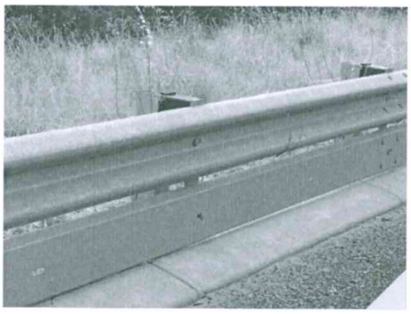


**Figure 2**

# Question 4

**(18 marks)**

Melissa and Aidan are roller skating at the local park. Aidan, who has a mass of 80.0 kg, is skating at 5.00 m $s^{-1}$ west toward Melissa. Melissa, with a mass of 55.0 kg, is stationary. After Aidan collides with Melissa, she moves away with a velocity of 3.40 m $s^{-1}$ west.

(a) Name one physics quantity that will definitely be conserved in this situation. (1 mark)

(b) Calculate Aidan's momentum before the collision including correct units. (3 marks)

(c) Calculate Aidan's velocity (in metres per second) and direction after the collision. (5 marks)

(d) Consider the changes in kinetic energy before and after the collision.

(i) Calculate the total kinetic energy in joules before the collision. (3 marks)

(ii) Calculate the total kinetic energy in joules after the collision. (4 marks)

(iii) Considering your answers to (i) and (ii) above, explain how the law of conservation of energy applies to this collision. (2 marks)

# Question 5

**(6 marks)**

A sudden and strong thunderstorm caused a 40.0 kg branch to break off a tree and fall from 9.00 m above the ground. The branch hit the roof of a house under the tree. Assume the branch was in free fall and the average height of the roof was 3.50 m above the ground.

(a) Calculate the speed of the branch when it hit the roof. (3 marks)

(b) The roof was strong enough to withstand the impact and the branch settled on the roof. If the impact contact time was 0.400 seconds, calculate the magnitude of the average force exerted on the roof during the impact. (3 marks)

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# Question 6

**(16 marks)**

A 1.55 kg remote control car is accelerated from rest. The car takes 5.66 s to reach its maximum speed of 14.2 m $s^{-1}$.

(a) (i) Calculate the acceleration of the car. (2 marks)

(ii) Determine the force needed to accelerate the car. (2 marks)

(b) Calculate the gain in the car's kinetic energy. Express your answer with appropriate units. (3 marks)

(c) Assuming no energy losses, calculate the power of the motor when the car is travelling at its maximum speed. Express your answer with appropriate units. (3 marks)

(d) Despite the force due to the power output of the motor, the car is unable to go any faster. Explain why the remote control car has a top speed when considering its motion in real life. Use one of Newton's Laws to help your explanation. (3 marks)

(e) The front of the remote control car has a soft, bendable bumper that is attached to the car with a spring. Apply your understanding of change of momentum to explain how the bumper keeps the car from becoming too badly damaged in a collision. (3 marks)

# Question 7

**(18 marks)**

George Stephenson is considered to be the inventor of the steam locomotive. A locomotive hauling carriages is called a train. Early trains were used for hauling freight. He also built England's first public inter-city railway using steam locomotives in 1830.

Over the next hundred years, steam locomotives were developed and by the early twentieth century trains were travelling at an average speed of 45 km $h^{-1}$ although some could reach a maximum speed of 80 km $h^{-1}$. A single locomotive, without the carriages, had a mass of about 200 tonnes, while a fully loaded freight train could have a mass of 12 000 tonnes. To keep a fully loaded train moving at an average speed of 45 km $h^{-1}$ required 3000 horsepower (one horsepower equals 746 W).

Coal was usually used to power steam locomotives. A steam locomotive could hold 140 tonnes of coal and could produce enough energy to power a local neighbourhood.

By the 1950s, diesel locomotives were replacing steam locomotives. Diesel trains are now used for moving freight over long distances, but in many cities, such as Perth, electric trains carry passengers over the short distances between railway stations.

Perth's electric trains run on a 25 kV AC supply from overhead lines with the two rails helping to complete the circuit. While a 120 tonne electric train can travel at a speed of 260 km $h^{-1}$, it usually only reaches a maximum speed of 130 km $h^{-1}$ between railway stations. Electric trains are considered to be safe. However, in 2006, two 120 tonne electric trains collided head-on at their depot. There were no passengers on board and the drivers involved were unhurt but the cost to repair the trains was over a million dollars.

(a) In steam locomotives, the energy from burning coal heats the water and converts it into steam. Using the kinetic theory of matter, explain the process involved in converting water into steam. (3 marks)

(b) Calculate the horsepower required to keep a train moving at 40 km $h^{-1}$ if the engine provides a driving force of $1.45 \times 10^5$ N. Show **all** workings. (4 marks)

(c) Calculate the momentum of an electric train travelling at 30.0 m $s^{-1}$ (108 km $h^{-1}$). Include the correct units in your answer. Show **all** workings. (4 marks)

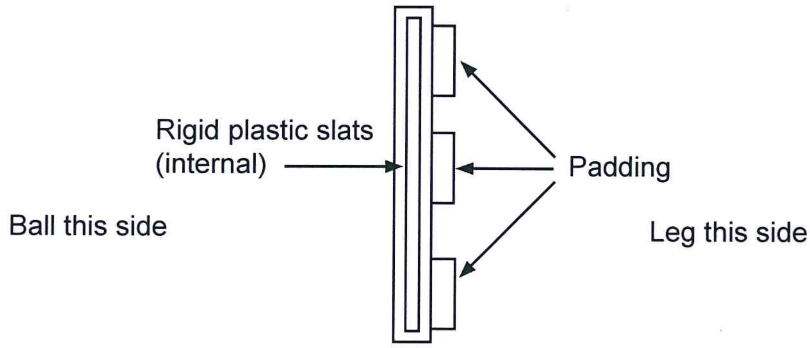
(d) The energy released when 240.0 kg of coal burns can power one 60 W lamp continuously for one year. Calculate the mass, in tonnes, of coal required to power five hundred (500), 60 W lamps for one year. Show **all** workings. (2 marks)

(e) When the two 120 tonne electric trains collided at the depot, Train A was travelling at 3.40 m $s^{-1}$ north, while Train B was travelling at 2.20 m $s^{-1}$ south. After the crash, Train B rebounded to be travelling at 3.00 m $s^{-1}$ north. Assuming that momentum was conserved in this collision, calculate the speed, in metres per second, and the direction of Train A after the collision. Show **all** workings. (5 marks)

Question 8

**(3 marks)**

In the game of cricket, a batsman wears pads on his legs to protect them from injury by a fast moving ball. Each pad has 3 cm of padding between it and the batsman's leg and each pad has rigid plastic slats built into it, as shown in the diagram below.




Side view of a cricket pad

Explain, using your understanding of one of Newton's laws, how the padding reduces injury to the batsman's leg if it is hit by a cricket ball.