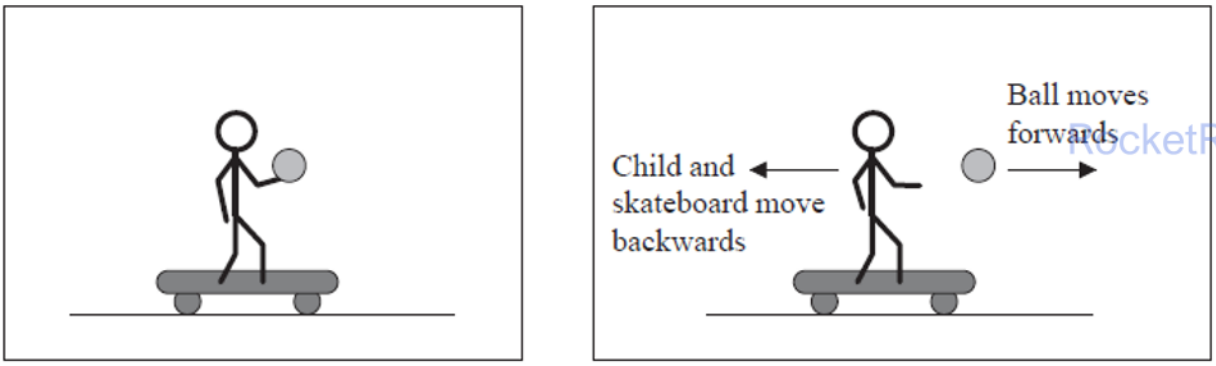
Questions

Q1.

A child is standing on a skateboard and both are stationary. The child throws a ball forward at a high velocity and the child and the skateboard move backwards at a lower velocity.



Before

After

Explain, in terms of momentum, why the child and the skateboard move backwards at a lower velocity.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(Total for question = 4 marks)

Q2.

Trolleys X and Y of masses m and $3m$ respectively are travelling at the same speed towards each other. The trolleys collide and move off together.

Which of the following statements is correct?

☒ **A** The force of X on Y during the collision is greater than the force of Y on X.

☒ **B** The force of X on Y during the collision is less than the force of Y on X.

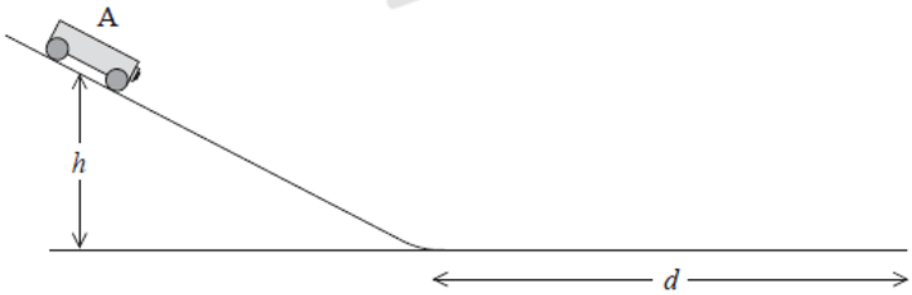
☒ **C** The speed of X after the collision is greater than v.

☒ **D** The speed of X after the collision is less than v.

(Total for question = 1 mark)

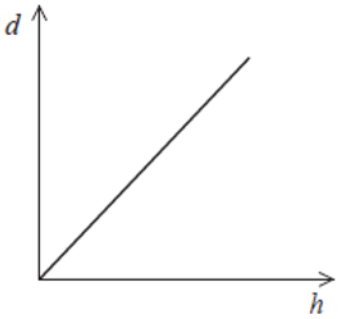
Q3.

A student set up the apparatus shown.



(a) When released from a height h, trolley A ran down the slope and then continued to move horizontally. On the horizontal part of the track a frictional force F brought the trolley to rest over a short distance d. The trolley has a mass m. The student measured d for a range of heights h.

The student plotted the following graph of d against h.



Derive an expression for the gradient of the graph, in terms of F, m and g.

(2)

.....

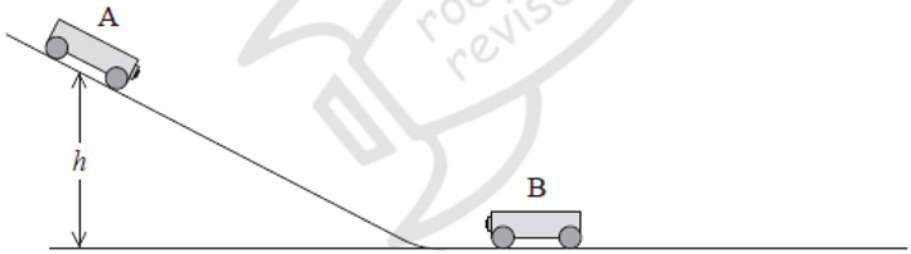
.....

.....

.....

.....

(b) In a second experiment, an identical trolley B was placed at rest at the bottom of the slope. When trolley A was released as before, it rolled down and collided with trolley B. After the collision the two trolleys joined together and moved off to the right with a velocity v.



The student predicted that, provided friction was ignored, $v = \sqrt{\frac{gh}{2}}$.

Assess whether the student was correct.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

(Total for question = 6 marks)

Q4.

A game is played where each player must use a 'mallet' to hit a disc across a table into the opponent's goal.

One player accidentally lets go of a mallet. The mallet travels at a speed of 1.6 m s^{-1} and collides with a stationary disc.

After the collision, the mallet continues in the same direction at a lower speed of 0.3 m s^{-1}. The disc moves in the same direction as the mallet with a velocity *v*, as shown.

before collision

after collision

(a) Calculate a value for *v*.

Assume that frictional forces are negligible.

mass of disc = 0.035 kg
mass of mallet = 0.17 kg

(3)

.....

.....

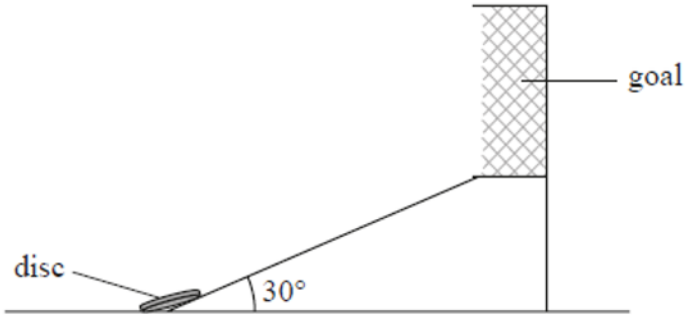
.....

.....

.....

v = ...

(b) To reach the goal, the disc must move up a ramp which is at an angle of 30° to the horizontal.



The velocity of the disc at the bottom of the ramp is 5.0 m s^{-1}. The disc moves up the ramp and work is done by the disc against the frictional force. The disc moves a distance of 6.5 cm up the ramp before moving back down.

Determine the frictional force acting on the disc.

(6)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Frictional force = ...

(Total for question = 9 marks)

Q5.

P and Q are identical spheres. Sphere P moves along a smooth horizontal surface and collides

with sphere Q, which is initially stationary.

After the collision:

- sphere P moves off with a momentum of 0.096 kg m s^{-1} in a direction of 15° to its initial direction.
- sphere Q moves off with a momentum of 0.14 kg m s^{-1} in a direction of 10° as shown.

before the collision after the collision

(a) Use a scaled vector diagram to show that the magnitude of the total momentum of spheres P and Q after the collision is about 0.2 kg m s^{-1}.

(4)

Total momentum of spheres P and Q after the collision = ...

(b) State the principle of conservation of linear momentum.

(2)

.....

.....

.....

.....

.....

(c) Calculate the initial velocity of sphere P.

mass of sphere P = 0.12 kg

(2)

.....

.....

.....

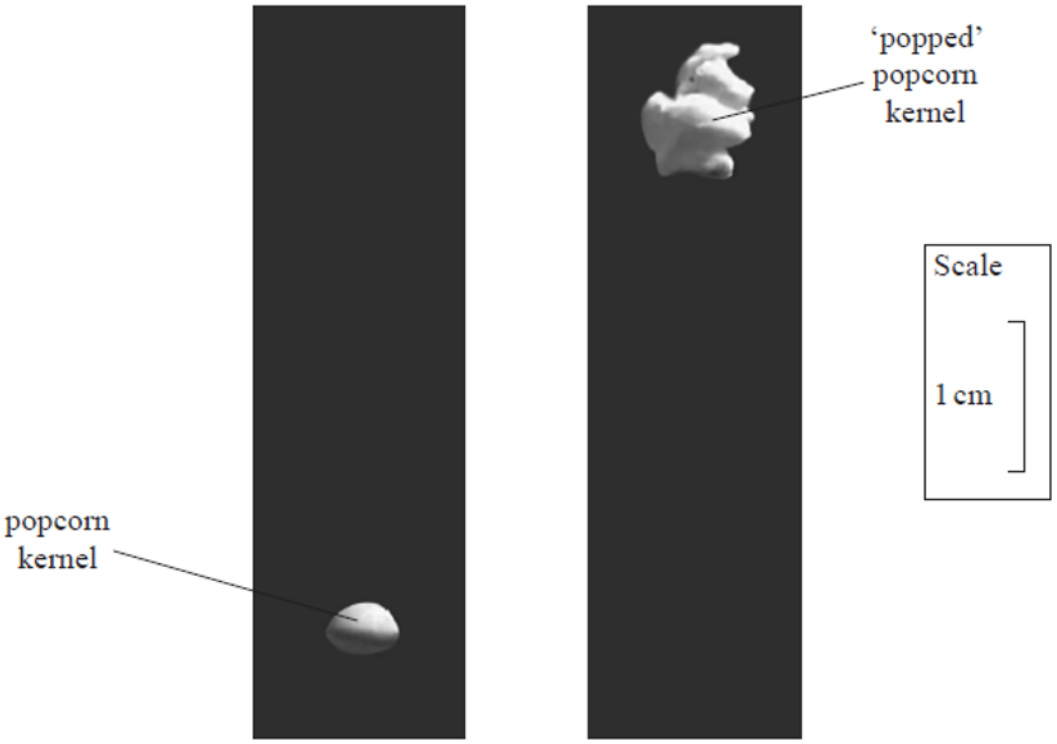
.....

Initial velocity of sphere P = ...

(Total for question = 8 marks)

Q6.

Popcorn kernels contain water. When heated, the water turns to steam. The kernel 'pops' and moves upwards.



(a) The photographs above show a popcorn kernel just before popping and at the maximum height after popping. The time between the two photographs was 83 ms.

(i) Determine the maximum height after popping.

(2)

.....

.....

Maximum height = ...

(ii) Calculate the initial speed of the 'popped' popcorn kernel.

(3)

.....

.....

.....

.....

.....

Initial speed = ...

(b) The average water content in a popcorn kernel is 14% of the total mass of the kernel.

A kernel is heated until it pops. Steam is ejected downwards, and the popped kernel moves upwards with an initial speed of 1.5 m s^{-1}.

Calculate the speed at which the steam is ejected.

total mass of unpopped kernel = 0.11 g

(4)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Speed = ...

(Total for question = 9 marks)

Q7.

Which of the following quantities has the SI base units kg m^2 s^{-3}?

☒ **A** force

☒ **B** momentum

☒ **C** power

☒ **D** work done

(Total for question = 1 mark)

Q8.

Two objects are travelling directly towards each other and then collide. Object A is a mass of 2 kg initially travelling to the right at 3 m s^{-1} and object B is a mass of 5 kg initially travelling to the left at 2 m s^{-1}.

What is the total momentum of A and B after the collision?

☒ **A** 4 kg m s^{-1} to the left

☒ **B** 4 kg m s^{-1} to the right

☒ **C** 16 kg m s^{-1} to the left

☒ **D** 16 kg m s^{-1} to the right

(Total for question = 1 mark)

Q9.

The diagram shows two bumper cars, P and Q, at an amusement park.

Q was stationary. P was moving at a speed of 2.10 m s^{-1} towards Q.

P collided with Q. After the collision, P and Q moved off in the same direction. P moved with a speed of 1.15 m s^{-1}. Q moved with a speed of 1.57 m s^{-1}.

(a) (i) Show that the total mass of Q was about 150 kg.

total mass of P = 250 kg

(3)

.....

.....

.....

.....

.....

.....

(ii) State **one** assumption you made in your calculation in (a)(i).

(1)

.....

.....

(iii) The collision lasted a total time of 1.35 s.

Calculate the average horizontal force on Q during the collision.

(3)

.....

.....

.....

.....

.....

Average horizontal force = ...

(b) Explain why P decelerates during the collision. Your answer should make reference to Newton's laws of motion.

(3)

.....

.....

.....

.....

.....

.....

(Total for question = 10 marks)

Q10.

Speed skating on ice is an Olympic sport. Collisions between skaters sometimes occur.

(a) State the principle of conservation of momentum.

(2)

.....

.....

.....

.....

(b) Two speed skaters are skating as shown.

(Source: © sportpoint/Shutterstock)

Initially, skater B is directly behind skater A. Skater B is moving faster and collides with skater A.

During the collision, skater B locks his arms around skater A so that they move forward together with a speed of 6.2 m s^{-1}.

Deduce whether momentum is conserved in this collision.

initial speed of skater A = 5.5 m s^{-1}
mass of skater A = 65 kg
initial speed of skater B = 7.5 m s^{-1}
mass of skater B = 60 kg

(3)

.....

.....

.....

.....

.....

.....

(c) The kinetic energy of the two skaters after the collision is much less than their combined

kinetic energy before the collision, so the collision is inelastic.

Explain the decrease in kinetic energy in this collision.

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 7 marks)

Q11.

An aluminium sphere collides head-on with a stationary steel sphere. The two spheres move off separately after the collision.

(a) State the principle of conservation of momentum.

(2)

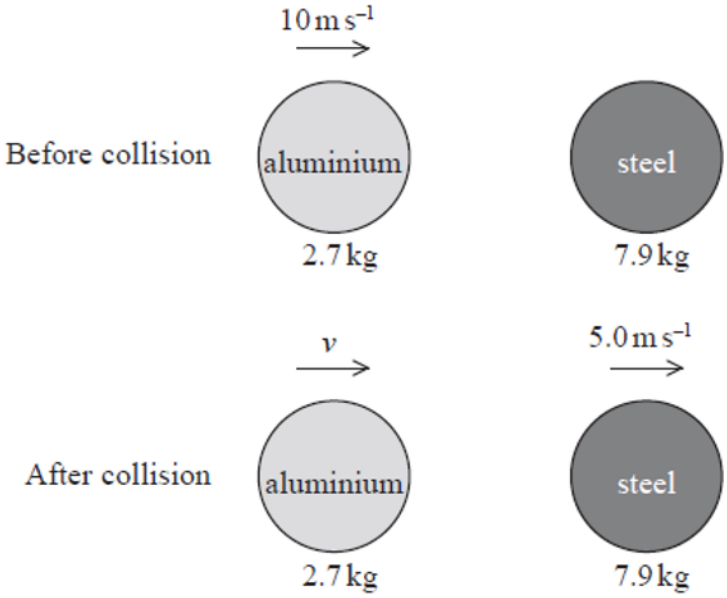
.....

.....

.....

.....

(b) The aluminium sphere has an initial velocity of 10.0 m s^{-1}. Immediately after the collision the velocity of the steel sphere is 5.0 m s^{-1}.



Calculate the velocity v of the aluminium sphere immediately after the collision.

mass of aluminium sphere = 2.7 kg
mass of steel sphere = 7.9 kg

(3)

.....

.....

.....

.....

v = ...

(Total for question = 5 marks)

Q12.

A railway carriage of mass 7.15×10^4 kg moving at 4.50 m s^{-1} collides with a second railway carriage of
mass 5.35×10^4 kg moving in the same direction.

The carriages join together. Immediately after the collision they move at a speed of 3.62 m s^{-1} .

(a) Show that the total momentum of the carriages immediately after the collision was approximately 4.5×10^5 kg m s^{-1}.

(2)

.....

.....

.....

.....

(b) Calculate the velocity of the second carriage before the collision.

(2)

.....

.....

.....

.....

.....

Velocity of second carriage = ...

(c) Calculate the change in total kinetic energy during the collision.

(2)

.....

.....

.....

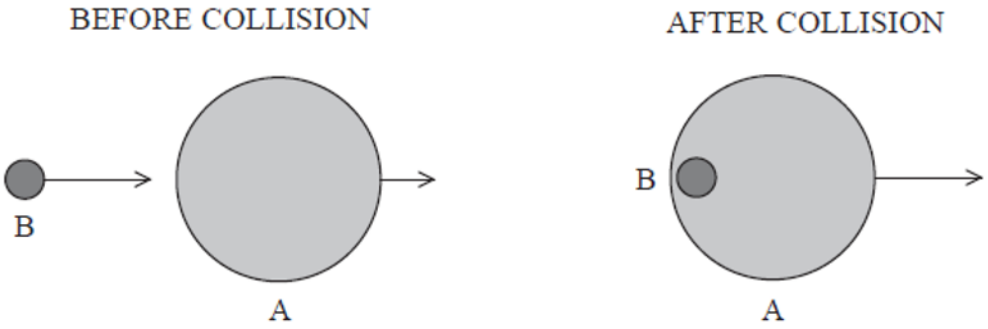
.....

Change in total kinetic energy = ...

(Total for question = 6 marks)

Q13.

A slow moving asteroid A was hit by a faster asteroid B. Asteroid B was absorbed by asteroid A as shown.



(a) State the principle of conservation of linear momentum.

(2)

.....

.....

.....

.....

(b) Before the collision, asteroid A had a velocity of 2.19×10^3 m s^{-1} and a momentum of 1.80×10^{17} kg m s^{-1}.

(i) Show that the mass of asteroid A was about 8.2×10^{13} kg.

(2)

.....

.....

.....

.....

(ii) Calculate the velocity of the asteroids after the collision.

mass of asteroid B = 5.90×10^{12} kg
velocity of asteroid B before the collision = 15.0×10^3 m s^{-1}

(3)

.....

.....

.....

.....

.....

.....

.....

.....

Velocity of asteroids = ...

(Total for question = 7 marks)

Q14.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of the following is an SI unit for momentum?

☒ **A** kg m s^{-1}

☒ **B** J m^{-1}

☒ **C** m s^{-2}

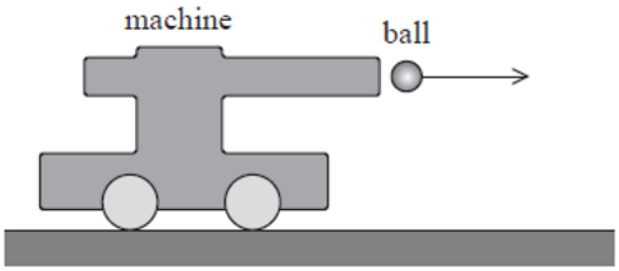
☒ **D** N s^{-1}

(Total for question = 1 mark)

Q15.

The diagram shows a machine used to launch tennis balls in a horizontal direction.

The machine is on frictionless wheels.



Before a tennis ball is launched, the machine is stationary.

(a) Explain, in terms of momentum, why the machine starts to move as the ball is launched.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) Calculate the velocity of the machine just after the ball is launched.

velocity of ball = 4.5 m s^{-1}
mass of ball = 0.056 kg
mass of machine = 2.9 kg

(3)

.....

.....

.....

.....

.....

.....

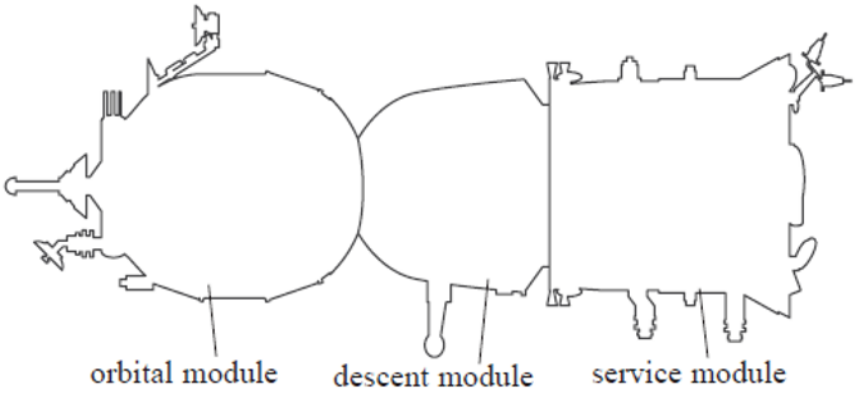
Velocity of machine = ...

(Total for question = 6 marks)

Q16.

A spaceship is used to take astronauts and equipment to the International Space Station. The

spaceship consists of an orbital module, a descent module and a service module, as shown.



(Source: © NASA)

The astronauts return to Earth in the descent module.

Before entering the Earth's atmosphere, the modules separate.

The orbital module (O) and service module (S) move away from the descent module (D) in opposite directions,
as shown below.

(a) Determine the velocity v of the descent module after separation.

You should only consider momentum along a horizontal line through the centres of the three modules.

mass of O = 1350 kg
mass of D = 2950 kg
mass of S = 2100 kg

(4)

.....

.....

.....

.....

.....

.....

Magnitude of v = ... Direction of v = ...

(b) The velocity of the descent module can be changed using a rocket motor. The rocket motor ejects hot

gases at high velocity.

(i) Explain why the velocity of the descent module changes when the rocket motor is used.

Your answer should refer to Newton's laws of motion.

(3)

.....

.....

.....

.....

.....

.....

(ii) When the rocket motor is operating, the velocity of the descent module changes by 0.58 m s^{-1} during a time of 5.0 seconds.

mass of descent module = 2950 kg

Calculate the average force exerted on the hot gas during this time.

(3)

.....

.....

.....

.....

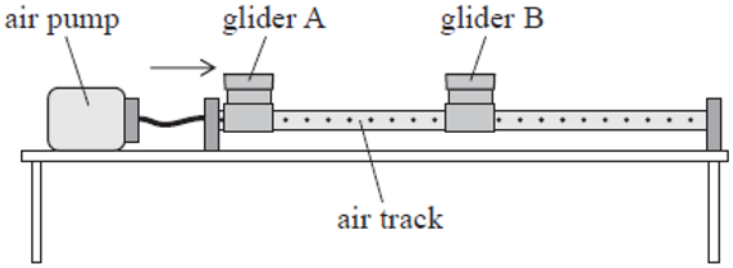
Average force = ...

(Total for question = 10 marks)

Q17.

A teacher demonstrated the principle of conservation of linear momentum using two gliders, A and B, and an air track. A has the same mass as B.

A and B were initially stationary, then A was pushed gently towards B as shown.



(a) State the principle of conservation of linear momentum.

(2)

.....

.....

.....

(b) A magnet was attached to each glider. The gliders collided and stuck together.

A data logger and sensor were used to record the velocity of A. The velocity recorded after the collision was half the velocity recorded before the collision.

(i) Deduce whether these results show that the law of conservation of linear momentum is obeyed.

(2)

.....

.....

.....

.....

(ii) Explain why the force of attraction between the two magnets did not affect this demonstration.

(2)

.....

.....

.....

.....

(Total for question = 6 marks)