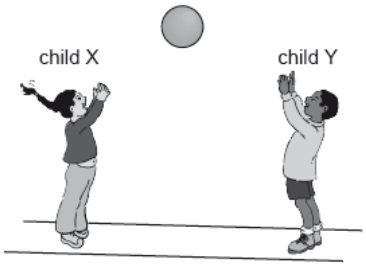
Collisions and Explosions 1 *[27 marks]*

1. Child X throws a ball to child Y. The system consists of the ball, the children and the Earth. What is true for the system when the ball has been caught by Y? *[1 mark]*



[Source: https://pixabay.com/en/playing-ball-kids-boy-girl-31339/]

A. The momentum of child Y is equal and opposite to the momentum of child X.

B. The speed of rotation of the Earth will have changed.

C. The ball has no net momentum while it is in the air.

D. The total momentum of the system has not changed.

Markscheme

D

2. Two objects m_1 and m_2 approach each other along a straight line with speeds v_1 and v_2 as shown. The objects collide and stick together. *[1 mark]*

What is the total change of linear momentum of the objects as a result of the collision?

A. $m_1v_1 + m_2v_2$
B. $m_1v_1 - m_2v_2$
C. $m_2v_2 - m_1v_1$
D. zero

Markscheme

D

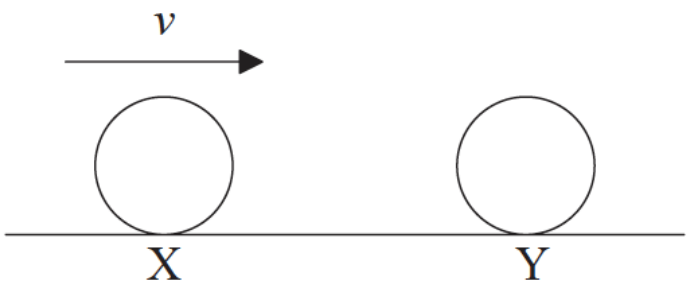
3. In the collision between two bodies, Newton's third law *[1 mark]*

A. only applies if momentum is conserved in the collision.
B. only applies if energy is conserved in the collision.
C. only applies if both momentum and energy are conserved in the collision.
D. always applies.

Markscheme

D

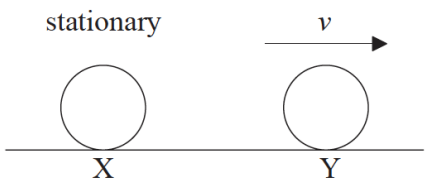
4. A ball X moving horizontally collides with an identical ball Y that is at rest. *[1 mark]*



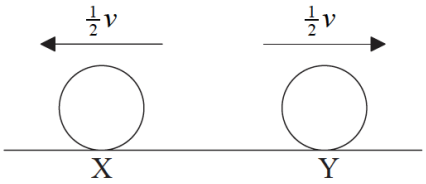
X strikes Y with speed *v*.

What is a possible outcome of the collision?

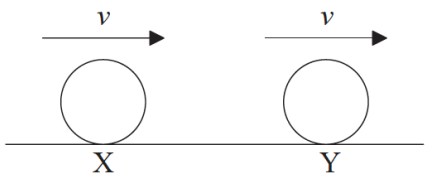
A.



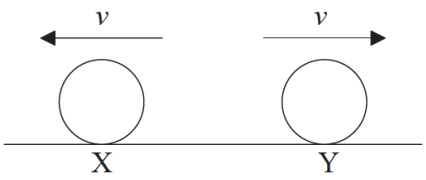
B.



C.



D.



Markscheme

A

This question is in **two** parts. **Part 1** is about momentum change. **Part 2** is about an oscillating water column (OWC) energy converter.

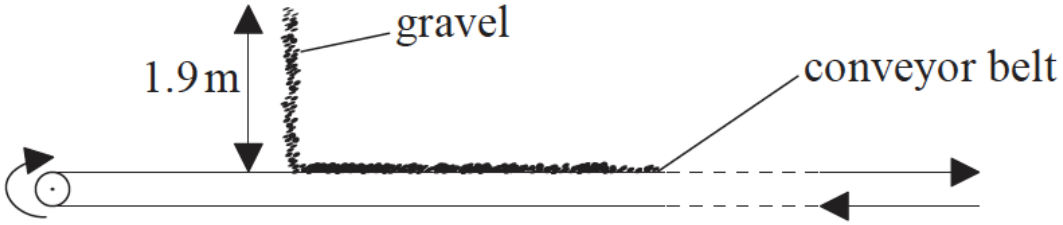
Part 1 Momentum change

5a. State the law of conservation of linear momentum. *[2 marks]*

Markscheme

if no external forces act / isolated system;
momentum is constant / (total) momentum before=(total) momentum after;

5b. Gravel falls vertically onto a moving horizontal conveyor belt. *[7 marks]*



(i) The gravel falls at a constant rate of 13 kg s^{-1} through a height of 1.9 m. Show that the vertical speed of the gravel as it lands on the conveyor belt is about 6 m s^{-1}.

(ii) The gravel lands on the conveyor belt without rebounding. Calculate the rate of change of the vertical momentum of the gravel.

(iii) Gravel first reaches the belt at t = 0.0 s and continues to fall. Determine the total vertical force that the gravel exerts on the conveyor belt at t = 5.0 s.

Markscheme

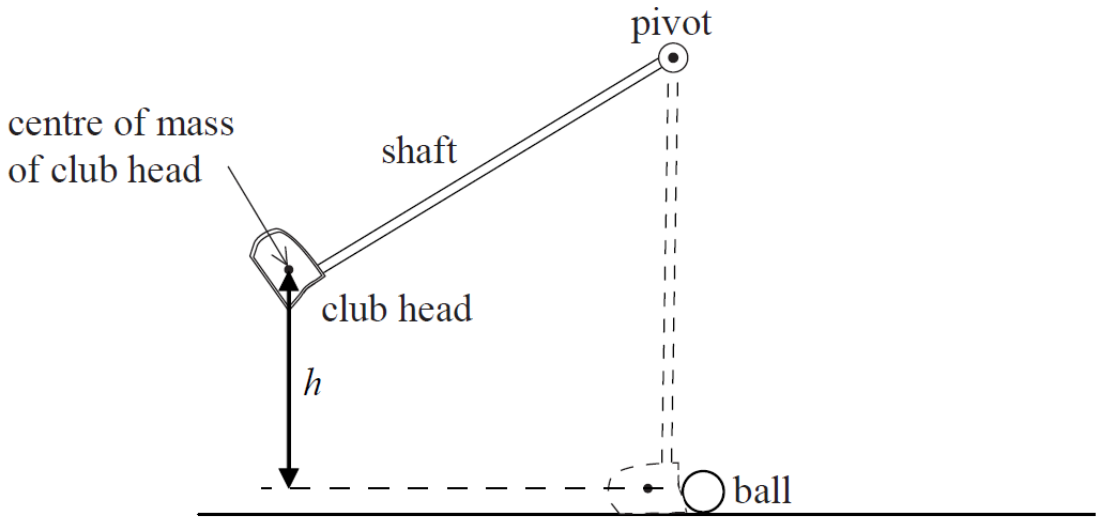
(i) use of $v = \sqrt{2gh}$;
6.11ms^{-1}; *(must show calculation to better than 1 sf)*

(ii) rate of change of vertical momentum=13×6.11;
79N; *(accept answers in the range of 78N to 80N)*

(iii) mass accrued=5.0×13=65kg;
weight of this mass (=65×9.8)=637N; *(650 from g=10ms^{-2})*
total force (637+79=)716N; } *(allow ECF from (b)(ii) and from incorrect weight)*

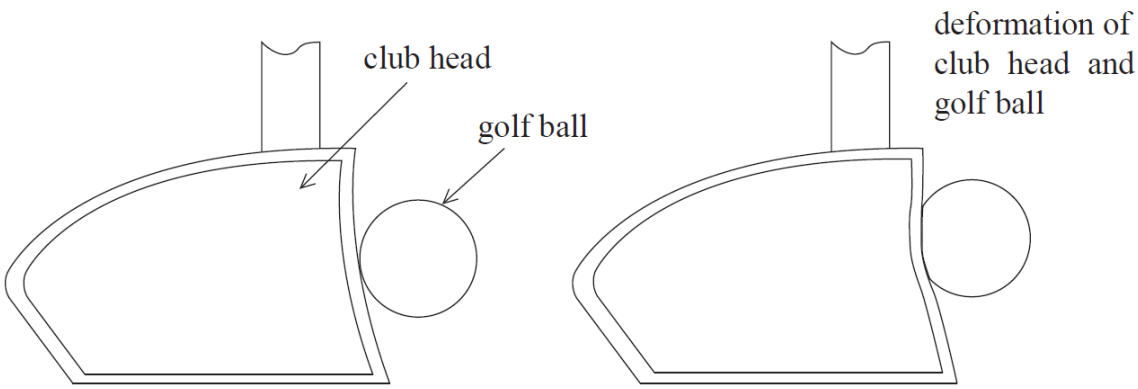
Impulse and momentum

The diagram shows an arrangement used to test golf club heads.



The shaft of a club is pivoted and the centre of mass of the club head is raised by a height *h* before being released. On reaching the vertical position the club head strikes the ball.

6a. The diagram shows the deformation of a golf ball and club head as they collide during a test. *[2 marks]*



Explain how increasing the deformation of the club head may be expected to increase the speed at which the ball leaves the club.

Markscheme

deformation prolongs the contact time;

increased impulse => bigger change of momentum/velocity;
or
(club head) stores (elastic) potential energy on compression;

this energy is passed to the ball;

6b. In a different experimental arrangement, the club head is in contact with the ball for a time of 220 μs. The club head has mass 0.17 kg and the ball has mass 0.045 kg. At the moment of contact the ball is at rest and the club head is moving with a speed of 38 ms^{-1}. The ball moves off with an initial speed of 63 ms^{-1}. *[5 marks]*

(i) Calculate the average force acting on the ball while the club head is in contact with the ball.

(ii) State the average force acting on the club head while it is in contact with the ball.

(iii) Calculate the speed of the club head at the instant that it loses contact with the ball.

Markscheme

(i) any value of $\frac{\text{mass} \times \text{velocity}}{\text{time}}$;

1.3 x 10^4 (N);

(ii)-1.3 x 10^{-4} (N);

Accept statement that force is in the opposite direction to (c)(i).

Allow the negative of any value given in (c)(i).

(iii) clear use of conservation of momentum / impulse = change of momentum;

21(ms^{-1});

or

$a = \left(\frac{F}{m} = \frac{-13000}{0.17} =\right) (-)\,76500\ (ms^{-1})$;

$v = (u+at = 38 - 76500 \times 0.00022 =)\ 21\ (ms^{-1})$;

*Award **[2]** for a bald correct answer.*

Part 2 Momentum

7a. Far from any massive object, a space rocket is moving with constant velocity. The engines of the space rocket are turned on and it accelerates by burning fuel and ejecting gases. Discuss how the law of conservation of momentum relates to this situation. *[3 marks]*

Markscheme

identifies the system as rocket + exhaust gases / total momentum of rocket and gas is equal before and after; (*it must be clear that this is the system, a mention of rocket and gases is not enough)*

no external forces act on this system / closed system;

increase/change in momentum of the gases is equal and opposite to the increase/change of momentum of the rocket;

7b. Jane and Joe are two ice skaters initially at rest on a horizontal skating rink. They are facing each other and Jane is holding a ball. Jane throws the ball to Joe who catches it. The speed at which the ball leaves Jane, measured relative to the ground, is 8.0 m s^{-1}. The following data are available. *[4 marks]*

Mass of Jane = 52 kg
Mass of Joe = 74 kg
Mass of ball = 1.3 kg

Use the data to calculate the

(i) speed *v* of Jane relative to the ground immediately after she throws the ball.

(ii) speed *V* of Joe relative to the ground immediately after he catches the ball.

Markscheme

(i) attempts to use conservation of momentum, *eg* $8.0 \times 1.3 = 52 \times v$;
$v = 0.20\ (ms^{-1})$;
*Award **[2]** for a bald correct answer.*

(ii) identifies new mass as 75.3(kg);
$V = 0.14\ (ms^{-1})$;