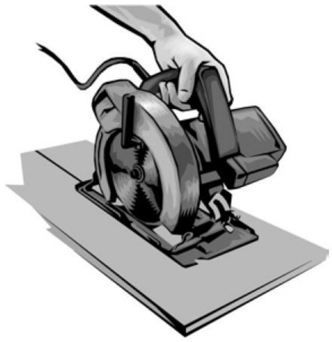
MECHANICS: LINEAR MECHANICS QUESTIONS

ROTATIONAL MOTION (2011;1)

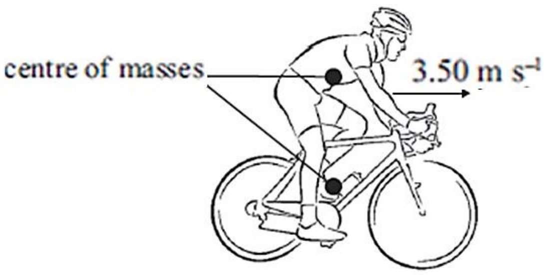


(c) When the saw is cutting through some wood, the blade slows down to a steady speed. Explain how the **forces** acting on the blade keep it rotating at a steady speed. In your answer you should:

- State what forces act on the blade
- Compare the relative size of the forces.

LINEAR MOTION (2010;2)

A cyclist, of mass 55.0 kg, is riding a bike of mass 11.0 kg. The bike and cyclist can be considered a system. While freewheeling (not pedalling) at constant speed of 3.50 ms^{-1}, the cyclist positions himself so that his centre of mass is vertically above the centre of mass of the bike. He then moves his position so that his centre of mass moves towards the front of the bike.



(a) State why momentum will be conserved during this change in position.

(b) Relative to the bike, the cyclist moves his centre of mass forward a horizontal distance of 13.2 cm at a steady speed. Show that the horizontal distance between the centre of mass of the system and the centre of mass of the bike is now 11.0 cm.

The cyclist goes over a steep drop and crashes on the ground. When the bike (with cyclist) hits the ground it is travelling horizontally at 3.50 ms^{-1} and vertically at 1.80 ms^{-1}. It takes 0.835 s, from the first moment of impact, for the bike (and cyclist) to stop.

(c) Calculate the speed of the bike as it hits the ground.

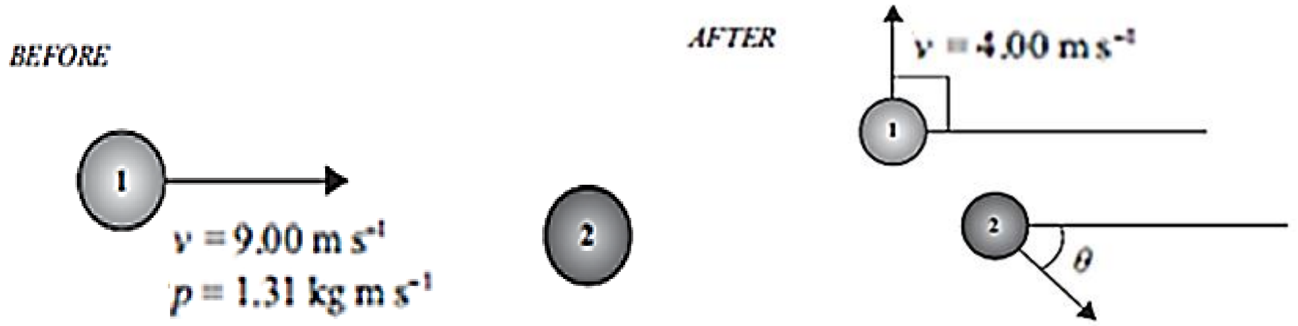
(d) Calculate the size of the average total stopping force which acts on the bike and cyclist.

(e) During the crash, the bike (and cyclist) experience an upwards push from the ground that stops the vertical motion, and friction with the ground that stops the horizontal motion. Horizontal motion stops after 0.835 s but the vertical motion stops in about one tenth of this time. Describe and explain how the vertical and horizontal forces on the bike (and cyclist) will be different.

(f) Cycle helmets are made so that they will crumple under impact. Explain why the crumpling of the helmet reduces the risk of serious injury to the cyclist.

QUESTION FOUR (2009;4)

After flying, Sam relaxes with a game of pool. The diagrams below show what appeared to occur during one shot. Ball 1 has a mass of 0.146 kg and ball 2 has a mass of 0.165 kg. Before the collision Ball 1 has a velocity of 9.00 ms^{-1} to the direction shown and a momentum of 1.31 $kgms^{-1}$. After the collision, Ball 1 has a velocity of 4.00 ms^{-1} in the direction shown.



(a) Calculate the velocity of the centre of mass of the system before the balls collide. You can assume that the diameter of the balls is small so that ball 1 is travelling directly towards ball 2.

(b) State what happens to the velocity of the centre of mass of the system during the collision. Give a reason for your answer.

(c) Calculate the size of the change in velocity of ball 1.

(d) Calculate the final velocity (magnitude and direction) of ball 2.

(e) By using ,

$$E_K = \frac{1}{2}mv^2$$

Sam finds that the total linear kinetic energy of the two balls increases during the collision. By considering all possible forms of energy involved, provide a reason why this collision is theoretically possible.

CENTRE OF MASS (2008;2)

Many ski resorts provide chairlifts to carry skiers to the top of the mountain. The chairs hang from a single suspension point on a steel cable. Figure A shows a front view of an empty chair. (Note that the term chair refers to the whole frame, from the pivot down, and the seat.) The whole chair is rigid. It hangs freely from a pivot point on the cable.

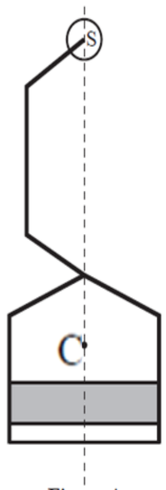


Figure A

(a) An empty chair hangs with the centre of mass (C) vertically below the pivot point (S). Draw vector arrows to represent the two forces that act on the chair. Add labels naming these forces.

(b) A heavy skier sits in the chair at X (Figure B). Explain why the chair moves and why it hangs in this new equilibrium position.

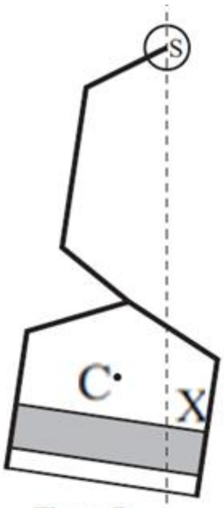
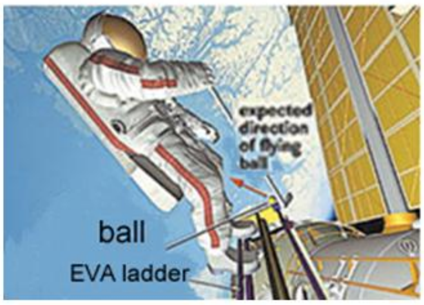


Figure B

GOLF IN SPACE (2008;4)

The universal gravitational constant = 6.67 x 10^{-11} m^3 kg^{-1} s^{-2}.
The radius of the Earth at the equator = 6.38 x 10^6 m
Mass of the Earth = 5.97 x 10^{24} kg

In November 2006, flight engineer Mikhail Tyurin hit a golf ball while he was in space, orbiting Earth on a mission on the International Space Station.

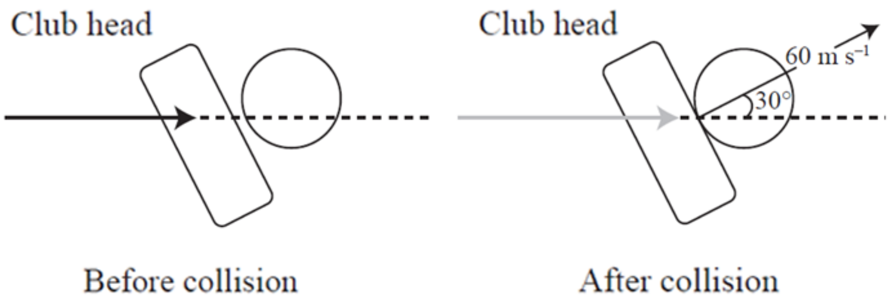



(a) The golf ball was a special light design with a mass of only 3.0 x 10^{-3} kg. The shot took place in low Earth orbit, 350 km above the surface of the Earth. Calculate the force of gravity between the ball and the Earth.

(b) Explain why the tiny, light ball could remain in a stable orbit at the same velocity as the massive, heavy space station.

(c) Consider the golf shot as a collision between a club head, of mass 0.20 kg, and the ball. Velocities are measured relative to the orbiting space craft. The ball (mass 3.0 x 10^{-3} kg) is initially stationary. After being hit, it has a velocity of 60 ms^{-1}.

(i) Calculate the momentum lost by the club head during the collision and show the direction of this lost momentum on the 'After collision' diagram.



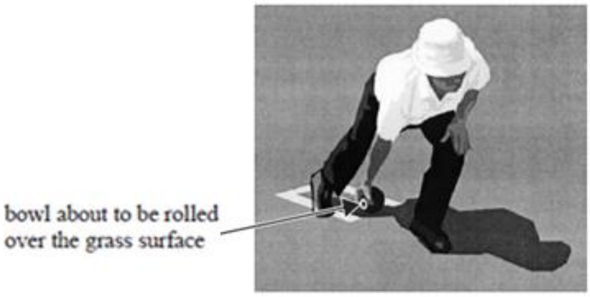
(ii) The initial velocity of the club head is 40 ms^{-1} horizontally. Analyse the collision using momentum vectors to show that the velocity of the club head is virtually unchanged by the collision.

(iii) Explain how it is possible for the ball to leave the club head faster than the initial speed.

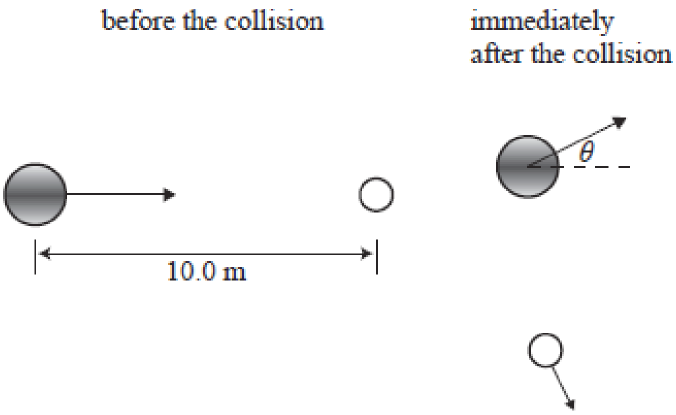
(d) When Tyurin took the shot from outside of the space craft, his feet were held by his colleague. Describe what sort of motion would have occurred if he had taken the golf shot while he was floating freely in orbit.

QUESTION ONE (2007;1)

In lawn bowls, players roll the bowls over a horizontal grass surface towards a small target ball called a jack. The aim of the game is to get more of your bowls closer to the jack than those of your opponents.



When the bowl is rolled at high speed, the path of the bowl can be considered to be straight. Consider the bowl hitting the stationary jack so that, immediately after the collision, the jack and the bowl are travelling at right angles to each other. The bowl has mass 1.50 kg; the jack has mass 0.25 kg.



The speed of the centre of mass of the system of bowl and jack is 5.4 ms^{-1} (assume this speed is constant).

(a) Show that the momentum of the system of bowl and jack is 9.5 $kgms^{-1}$.

(b) State why the momentum of the bowl before the collision is 9.5 $kgms^{-1}$.

In the diagram above, the position of the moving bowl, before the collision, is 10.0 m from the jack.

(c) Show that the distance of the centre of mass of the system of bowl and jack from the jack is 8.57 m.

(d) Calculate the time it takes the bowl to travel from the position shown to the jack.

The momentum of the bowl after the collision is 8.7 $kgms^{-1}$.

(e) Calculate the angle, θ (in the diagram above), through which the bowl turns during the collision.

(f) During the collision, the bowl and jack are in contact for 0.025 s. Calculate the size of the force exerted on the bowl.