CHAPTER 12: Biomechanical movement

Practice questions - text book pages 169 - 172

1) For which of the following is the athlete's centre of mass most likely to lie outside of his or her body?
   a. diver performing a tucked dive.
   b. trampolinist in a fully piked position.
   c. gymnast performing a cartwheel.
   d. gymnast performing a layout somersault.

Answer: b.
Explanation:
- *The centre of mass (CofM) is the single point (on a body) which represents all the spread out mass of the body and so represents the point of balance of the body. Because of body shape, the only position when the CofM can be outside the body is b.*

2) In a first class lever, if the resistance arm is 300 mm and the force arm is 30 mm, what force is necessary to balance a weight of 10 N?
   a. 10 N.
   b. 1 N.
   c. 100 N.
   d. none of the above.

Answer: c
Explanation:
- *The principle of moments states that the force multiplied by its perpendicular distance from the pivot or fulcrum should be the same for both anticlockwise and clockwise moments.*

3) Which of these is not one of Newton's three laws of motion?
   a. a body will continue in a state of rest of uniform velocity unless acted upon by an external force.
   b. for every action there is an equal and opposite reaction.
   c. a body moves in a circle about a point called the axis of rotation.
   d. the acceleration of an object is directly proportional to the force causing it and is inversely proportional to the mass of the object.

Answer: c.
Explanation:
- a. is Newton's 1st law, b. is Newton's 3rd law and d. is Newton's 2nd law and the axis of rotation is an imaginary line about which the body rotates or spins at right angles to the plane and so is not one of Newton's three laws of motion.

4) In a second class lever which one of the following best describes its function?
   a. the load is the same as the effort.
   b. the load is smaller than the effort.
   c. the load is bigger than the effort.
   d. the load is furthest away from the fulcrum.

Answer: b

5) A rugby prop sprints away from a scrum with an acceleration of $0.2ms^{-2}$ for 10s. How far did he travel?
   a. 15 metres.
   b. 10 metres.
   c. 18 metres.
   d. 20 metres.

Answer: b.
Explanation:
- *The prop ran 10m. This is worked out using the equation $s=1/2(u+v)t$. His final velocity will be $0.2ms^{-2}$ x $10s = 2ms^{-2}$ so $S=1/2(0+2)10$ so $S=10m$.*

6) a) Explain with diagrams what is meant by the centre of mass of a body. 2 marks

Answer:
- *The centre of mass of a body is the point (which can lie inside or outside the body) at which the weight (force) of the body acts for the body as a whole.*
- *See figure Q12.1 for an idea of where the centre of mass is in a body depending on shape.*

figure Q12.1 – centre of mass position in the body

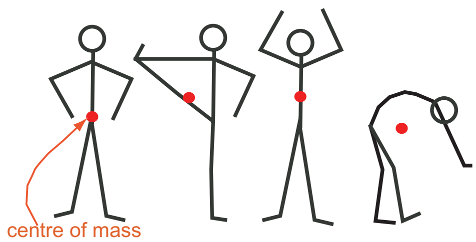


figure 12.20 – a long jumper in flight

b) Explain with the aid of pin-man diagrams how the centre of mass of a long jumper changes from the take-off position to the flight phase shown in figure 12.20. 5 marks

Answer:

For the long jumper:
- *Three marks for 3 diagrams showing the approximate position of the centre of mass - see figure Q12.2.*
- *The idea that this red dot represents the position of the overall mass of the body.*

figure Q12.2 – centre of mass position for long jumper

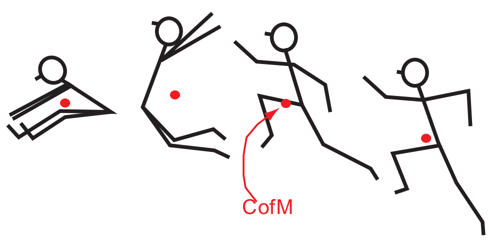
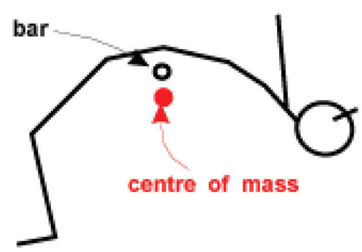


figure Q12.3– centre of mass pases below a high jump bar



c) Sketch a diagram and briefly explain how the centre of mass of a high jumper can pass under the bar, while the jumper successfully clears it. 4 marks

Answer:
- *The CoM will follow a parabola after take off.*
- *By bending into a position like figure Q12.3 the CoM will lie below the body as shown.*
- *This could be below the high jump bar as shown.*
- *So the jumper clears the bar, but her CoM passes below it.*

d) Explain how a ski jumper can increase her stability on landing to prevent her from falling. 3 marks

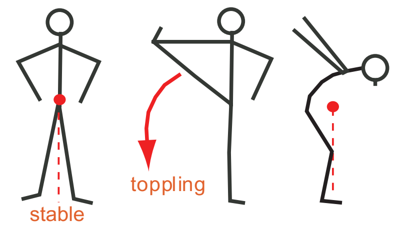
Answer:
- *By landing with feet spread apart.*
- *Thereby Increasing the size of her base of support.*
- *And maintaining centre of gravity within this wide base.*
- *Bending her knees on landing, thus lowering her centre of mass.*
- *Maintaining a vertical projection within the base of support, thereby avoiding the tendency to lean to either side.*

7) Figure 12.21 shows a swimmer holding a balance just before the start of a race.

a) Explain how the position of the centre of mass can affect the swimmer's balance. 2 marks

figure 12.21 – swimmer starting a race

figure Q12.4 – centre of mass position affects stability



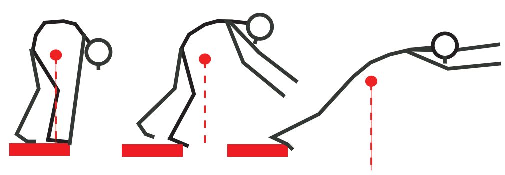
Answer:
- *The swimmer's centre of mass must lie directly above the base of support – in this case his feet.*
- *The bigger the area of support (the further apart his feet) the more stable (able to keep on balance) he will be.*
- *The lower the centre of mass the easier it will be to maintain balance.*
- *If he moves so that the centre of mass moves away from a position directly above his feet, he will begin to topple (see figure Q12.4).*

- *Since his line of action of his weight (the force exerted by gravity on his centre of mass) will not pass through his feet.*
- *Which causes a turning (moment) of the swimmers body – he topples.*

b) Describe how the swimmer in figure 12.21 can use his knowledge of balance to achieve his most effective block start. 3 marks

Answer:
To make a block start:
- *The swimmer will lean forward so that the centre of mass of his body moves forward.*
- *The centre of mass of the swimmer then lies forwards of the block.*

figure Q12.5 – swim start and toppling

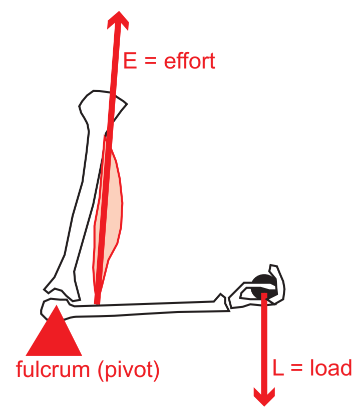


- *And outside his base of support (his feet) - see figure Q12.5.*
- *So he will topple forward into the pool - he then pushes hard with his legs to drive forwards in the direction of his swim.*

8) Sketch the lever system which would represent the action of the biceps muscle in flexing the arm. Show on your diagram the resistance arm of the lever. 3 marks

Answer:

figure Q12.6 – the elbow and forearm lever



- *See figure Q12.6.*
- *E is the effort force in the biceps muscle.*
- *L is the load force applied at the hand.*
- *The triangle is the pivot or fulcrum of the lever.*
- *The resistance arm is the structure (forearm) between hand (load) and elbow (fulcrum).*

9) In figure 12.22 of a jumper taking off, name, sketch and label the lever system operating at knee **B** during this action. 3 marks

figure 12.22 – long jumper taking off

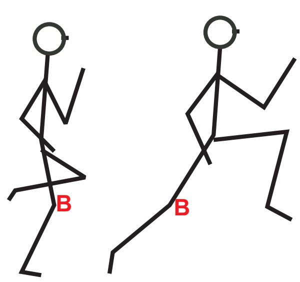


figure Q12.7 – jumper's knee 1

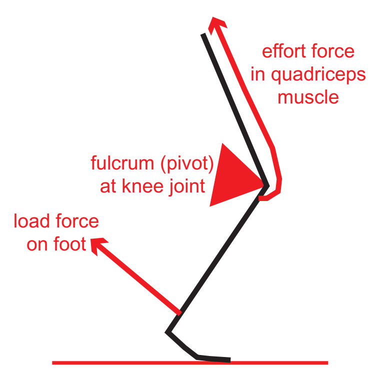
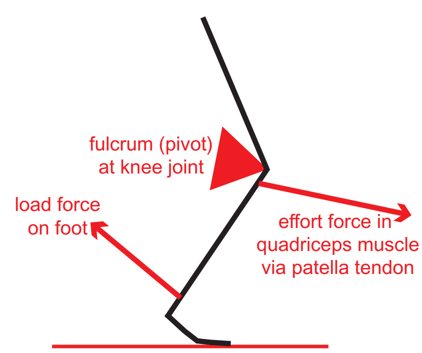


figure Q12.8 – jumper's knee 2

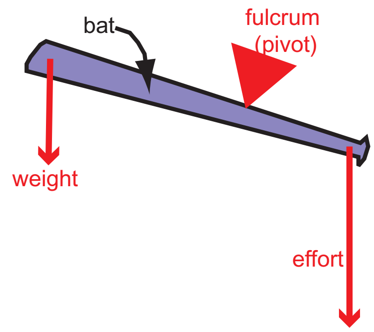


Answer:

- *See figures Q12.7 and Q12.8.*
- *This is a class 3 lever (effort between pivot and load).*
- *Note that the effort (figure Q12.7) is transmitted to the tibia via the patella tendon, which passes over the knee and inserts below the joint (figure Q12.8).*

10) In softball, what order (class) of lever is shown in the hitting action in figure 12.23?
State one disadvantage and one advantage of reducing the bat length for a beginner. 3 marks

figure 12.23 – softball bat



Answer:

- *This is a class 1 lever.*

Advantage of shortening bat length is:

- *Learning the skill involved may be easier - since the strike point is nearer the hand.*

Disadvantage of shortening the bat would be:

- *Less force can be applied as a load for a given effort, hence the strike on the ball would impart less speed to the ball.*

11) Name, sketch and label the lever system which is operating at the ankle of leg **C** when doing the sprint set action illustrated in figure 12.24. 3 marks

figure 12.24 – ankle lever system

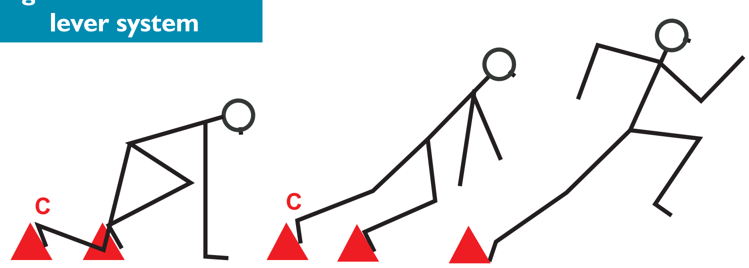
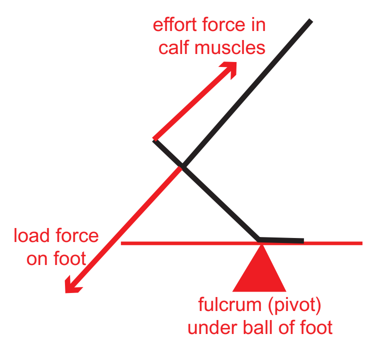


figure Q12.9 – ankle foot lever



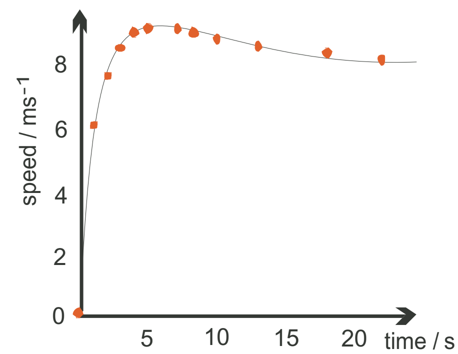
Answer:

- *See figure Q12.9.*
- *This is a class 2 lever.*
- *Note that the load force is a combination of the weight of the athlete acting downwards through the tibia/fibula on the ankle joint, and the reaction to the accelerating force driving the sprinter forwards.*

12) The table shows the speed of a 19 year-old male sprinter during a 200m race.

speed (ms^{-1})	time (seconds)
0.0	0
6.0	1
7.5	2
8.2	3
8.4	4
8.5	5
8.5	7
8.4	8
8.3	10
8.2	13
8.1	18
8.0	22

figure Q12.10 – speed against time for 200m race



a) Plot a graph of speed against time during this race.
When does he reach maximum speed and what happens to his speed between 8 and 22 seconds? 7 marks

Answer:

- *See speed/time graph in figure Q12.10.*
- *Horizontal axis correctly scaled and labelled.*
- *Vertical axis correctly scaled and labelled.*
- *2 marks for points plotted correctly.*
- *Curve drawn correctly.*

Speed between 8 and 22 seconds:

- *Maximum speed is reached between 5 to 7 seconds.*
- *After 8 seconds there is a gradual slowing down.*

b) Acceleration is the change of speed per second. Use the graph to establish his speed at 0.5 seconds and 1.5 seconds and calculate the average acceleration between 0.5 and 1.5 seconds. 3 marks

Answer:

- *At 0.5 seconds, speed = 3.0 ms^{-1} (allow + or - 0.2).*
- *At 1.5 seconds, speed = 6.8 ms^{-1} (allow + or - 0.3).*
- *Acceleration = change of speed per second = 6.8 - 3.0 (in 1 second) = 3.8 ms^{-2}.*

c) Successful games players are often able to change their velocity rapidly in the game situation. Explain the biomechanics behind this ability using examples from a game of your choice. 6 marks

Answer:

- *The force applied to the person is that between footwear and ground - friction.*
- *The factors which govern the size of friction force are the weight of the individual, the nature of the surface and footwear used.*
- *Newton's 3rd law applies between foot and ground.*
- *The sportsperson pushes on the ground (the action force), the ground pushes back with a reaction force (which is equal in size but opposite in direction to the action force) on the person.*
- *Acceleration = rate of change of velocity, velocity includes the direction.*
- *Newton's 2nd law tells us how much acceleration is produced by the force acting.*
- *The formula: force = mass x acceleration, enables you to work out the acceleration.*
- *Hence the bigger the force (the stronger the person) the greater the change in velocity.*
- *If the force is sideways to the direction of motion at the time, then the direction is changed.*
- *A sideways force causes swerving (change of direction but no change of speed).*
- *A force in the direction of motion causes increase or decrease in speed.*

13) a) A sprinter uses her calf muscles to push on the blocks at the start of a run.
Explain, using Newton's laws, how this enables her to accelerate forwards out of the blocks. 3 marks

Answer:
- *Newton's 3rd law of motion - action and reaction are equal and opposite in direction.*
- *When the sprinter pushes down and back on the ground.*
- *The ground pushes up and forward on her.*
- *Newton's 2nd law of motion - if a force is exerted, then this produces an acceleration in the same direction as the force (forwards).*

b) If the resultant forward force was 300 newtons and the runner's mass was 60 kg, what would be her acceleration? 2 marks

Answer:
- *Newton's 2nd law gives force = mass x acceleration.*
- *Therefore: 300 N = 60 kg x acceleration.*
- *Hence: acceleration* $= \frac{300}{60} = 5\ ms^{-2}$.

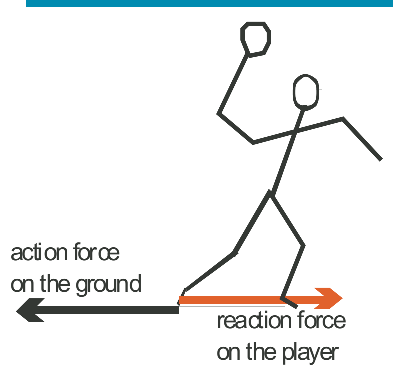
c) What would be the speed of the runner after 1.5 seconds, assuming that the acceleration is the same over that period of time? 2 marks

Answer:
- *Speed changes by* $5\ ms^{-1}$ *each second.*
- *Therefore total change of speed in 1.5 seconds* $= 7.5\ ms^{-1}$.

d) A squash player drives forward into a forehand stroke. Show how Newton's third law of motion explains his ability to do this. 3 marks

Answer:
- *Newton's 3rd law says that for every action there is an equal and opposite reaction.*
- *In this case the action is the force exerted by the player pushing backwards on the ground (squash court).*
- *The reaction is the forward force exerted by the ground on the player.*
- *See diagram Q12.11.*

figure Q12.11 – forces acting on a squash player

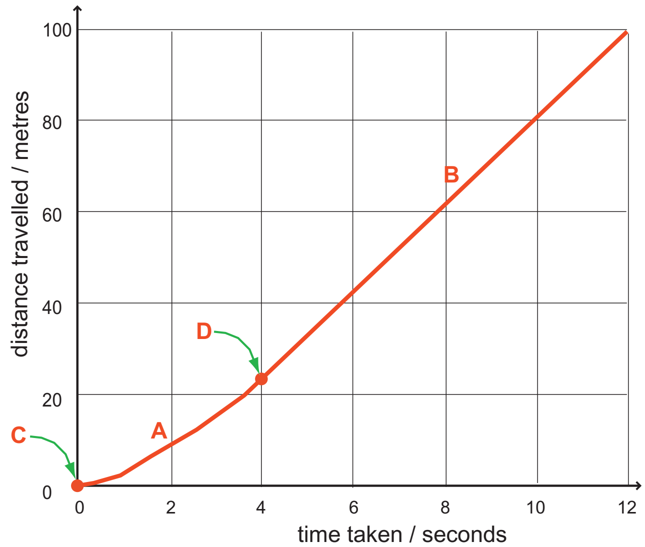


e) Explain why the turn in the discus throw produces greater horizontal range than the standing throw. 3 marks

Answer:
- *Force is applied to the discus over a larger distance.*
- *Over a longer period of time.*
- *Therefore acceleration is produced for a longer time (Newton's 2nd law of motion).*
- *Hence greater velocity given to the discus over and above the standing throw.*

14) Figure 12.25 shows the distance/time graph for a 100m sprint.

figure 12.25 – distance time graph for 100m sprint



a) Describe the motion of the sprinter in sections A and B. 2 marks

Answer:

- ***A -*** *acceleration, the slope/gradient of the graph increases, therefore the speed increases.*
- ***B -*** *constant speed, the slope of the graph remains the same.*

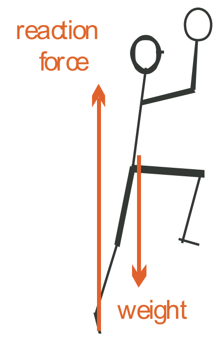
b) Calculate the speed at points C and D and the average acceleration between the points. 3 marks

Answer:

- ***C*** *- the athlete is about to start (just started), and speed is therefore zero.*
- ***D*** *- the gradient of the graph is approximately 19m in 2 seconds.*
- *Giving a speed of 19/2 = 9.5 ms^{-1}.*
- *The average acceleration is 9.5 ms^{-1} in 4 seconds.*
- *Giving acceleration of 9.5/4 = 2.375 metres per second per second (ms^{-2}).*

15) a) Use the diagram in figure 12.26 of a basketballer just about to take off into a jump shot, and your knowledge of Newton's Laws of motion to explain why the basketball jumper takes off. 3 marks

figure 12.26 – basketballer about to take off



Answer:
- *The upward force is bigger than the downward force on the jumper.*
- *Therefore there is a net upward force acting on the jumper.*
- *Newton's 2nd Law says that acceleration is linked to force applied.*
- *Therefore there will be an upward acceleration and the jumper will take off.*

b) If the vertical upward ground reaction force on the jumper is 2000 N, and the weight of the jumper is 800 N, estimate the net upward force acting on him. 1 mark

Answer
- *Net upward force F = 2000 - 800 = 1200 N.*

c) The mass of the jumper is 80 kg, calculate his upward acceleration during this part of the jump. 2 marks

Answer
- *Newton's Second law gives :* Force = mass x acceleration
  Force = 1200 N
  mass = 80 kg
- *therefore* 1200 = 80 x acceleration
  acceleration $= \frac{1200}{80} = 15\ ms^{-2}$.

16) a) The graph in figure 12.27 shows the start of a 100m sprint swim race. Using Newton's laws of motion, explain how the swimmer achieves the initial forward motion. 3 marks

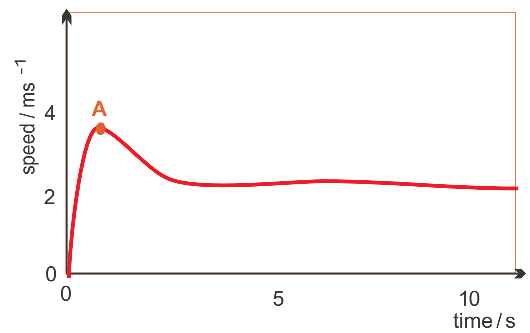


figure 12.27 – start of 100m swim race

Answer
- *Newton's 3rd Law.*
- *Every action has opposite and equal reaction.*
- *Backward force exerted by the swimmer on the block.*
- *Equal force forward from the block onto the swimmer.*

b) Describe what has happened to the swimmer at point A and explain the motion that occurs. 3 marks

Answer
- *The swimmer has hit the water/enters the water at this point.*
- *At this point the swimmer begins to experience drag/fluid friction.*
- *And hence deceleration occurs, the swimmer slows down.*

17) a) What characterises a vector quantity? 2 marks

Answer:
- *A vector has size (or value or magnitude).*
- *And direction. For example, force. velocity, acceleration, weight.*

b) Figure 12.28 shows the forces acting on a runner at the start of a race. Use a vector diagram to show how you could work out the resultant force acting. 3 marks

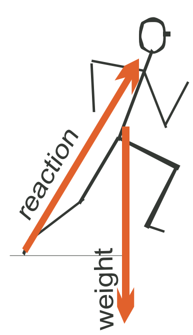


figure 12.28 – forces acting on a runner

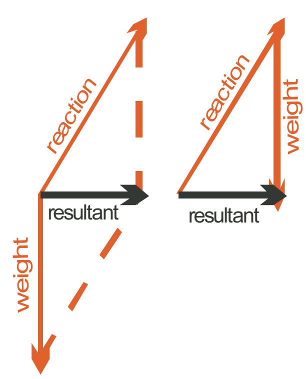


figure Q12.12 – resultant force

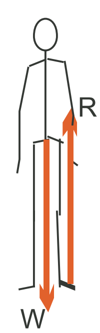


figure Q12.13 – forces acting on a person standing still

Answer:
- *See figure Q12.12.*
- *Note that the parallelogram rule is used to estimate the resultant.*
- *The resultant is horizontal, showing that the net force is forwards.*

c) Sketch a pin man drawing of a person standing still showing all the forces acting on him. 2 marks

Answer:
- *See figure Q12.13.*
- *Note that the force arrows are equal indicating that the forces cancel out - there is zero net force.*
- *The upward reaction force R acts at the feet, the weight W acts at the centre of mass.*

18) Tennis players have to change direction quickly during a match to recover to the centre of the court. Figure 12.29 shows a tennis player just after hitting a forehand and then starting to recover to the centre of the court in the direction shown.

figure 12.29 – a tennis player moves between strokes

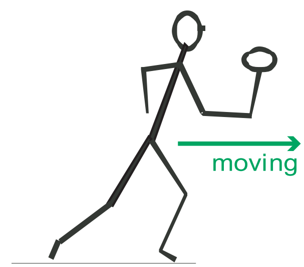
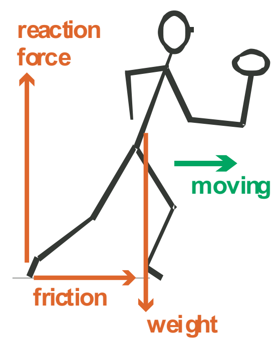


figure Q12.14 – forces acting on a tennis player between strokes



a) Draw a pin diagram of the tennis player as he pushes off the court surface to recover to the centre of the court, showing all forces acting on the tennis player at this point. All forces must be clearly identified. 3 marks

Answer:
- *See figure Q12.14.*
- *Weight acts downwards from centre of mass of tennis player.*
- *Friction acts forwards from the rear foot (in the same direction as the proposed direction of motion).*
- *Reaction force acts upwards on the rear foot (length of arrow the same or bigger than the weight arrow).*

b) Explain the factors that affect the horizontal force at this point. Apply Newton's second law of motion to explain the effect of this force on the player. 4 marks

Answer:
Factors affecting the horizontal force:
2 marks for two of:
- *Type or roughness of footwear.*
- *Type or roughness of court surface.*
- *Amount of reaction force - how hard player presses into ground - friction force depends on the contact force pressing the two surfaces (foot and ground) together.*

2 marks for two of:
- *Using Newton's 2nd law, F = m x a, or acceleration is proportional to force.*
- *Greater frictional force the greater the acceleration of player.*
- *Direction of frictional force = direction of acceleration = direction of motion of the player.*