CHAPTER 5: *Linear motion*

Practice questions - text book pages 84 - 86

1) Which of the following pairs of quantities is not a vector/scalar pair?
   a. weight/mass.
   b. reaction force/centre of mass.
   c. velocity/speed.
   d. energy/power.

Answer: d.

2) Which of the following is a vector?
   a. gravitational field strength.
   b. centripetal force.
   c. the ratio of force to acceleration for a moving body.
   d. rate of change of speed.

Answer: b.

3) Which one of the following is a definition of impulse?
   a. rate of change of momentum.
   b. force multiplied by the time of contact in an impact.
   c. change of momentum multiplied by time of contact.
   d. the acceleration of a body during an impact.

Answer: b.

4) A positive impulse will cause:
   a. a forward velocity.
   b. a backward change of momentum.
   c. a forward change of momentum.
   d. a backward change of speed.

Answer: c.

5) A rugby prop brushes off a tackle from a much smaller opponent, which one of the following statements is true about this tackle?
   a. momentum is conserved during the tackle.
   b. momentum is conserved during the tackle provided no other tackler is involved.
   c. the velocity of the tackler is increased.
   d. the velocity of the tackler is reduced.

Answer: b.

6) 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 5.29 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

Answer:

- *See figure Q5.1.*
- *Note that the parallelogram rule is used to estimate the resultant.*
- *The resultant is horizontal, showing that the net force is forwards.*

figure 5.29 – forces acting on a runner

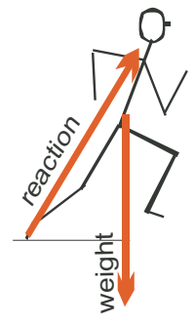
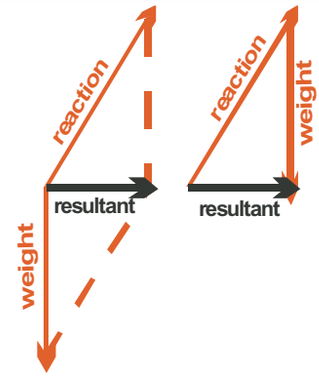


figure Q5.1 – resultant force



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

Answer:

- *See figure Q5.2.*
- *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.*

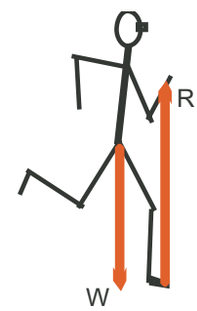
figure Q5.2 – forces acting on a person standing still

d) Sketch a second diagram showing the vertical forces acting on a basketballer just before take-off while performing a jump shot. Represent the relative sizes of any forces you show by the length of the force arrows on your diagram. 2 marks

Answer:

- *See figure Q5.3.*
- *The upward reaction force R acts at the take off foot, W acts at the centre of mass.*
- *Note that the upward arrow is bigger than the downward arrow, which means that there is a net upward force acting on the jumper.*

figure Q5.3 – forces acting on a basketballer



e) Use this second diagram and your understanding of Newton's laws of motion to explain why the basketballer is able to take off. If the vertical upward ground reaction force on him is 2000 N, and his weight is 800 N, estimate the net upward force acting on him. 4 marks

Answer:

- *Newton's second law of motion says that acceleration is linked to net force.*
- *So since here there is a net upward force, there will be an upward acceleration.*
- *Which of course will give him or her a vertical upward velocity which will enable the jumper to take off.*
- *Net upward force F = 2000 - 800 = 1200 N.*

7) The four man bobsleigh develops a large momentum during the first few seconds of its run.

a) Explain the meaning of the term momentum, and explain why the four man bobsleigh travelling at a speed of 28 ms^{-1} has a different momentum to a skier moving at the same speed. 2 marks

Answer:

- *Momentum = mass x velocity, and is therefore a combination of mass and velocity.*
- *A four man bob has four people in it and therefore (approximately) four times the mass of a lone skier. Hence the momentum of the bob when full of its men will be (approximately) four times that of the skier at the same speed.*

b) Explain using Newton's laws of motion how the bobsleigh acquires its large momentum during the first part of a run. 4 marks

Answer:

- *The force applied to the bob comes via Newton's 3rd Law.*
- *Which says that action and reaction are equal in size but opposite in direction.*
- *The four bobmen push hard on the ground backwards (action), and the ground pushes hard forwards on the men (and the bob) (reaction).*
- *The force is linked to the change of momentum (or acceleration) of the bob by Newton's 2nd Law.*
- *This says that Force = rate of change of momentum (= mass x acceleration).*
- *So large forces give large changes of momentum (or acceleration or change of velocity).*

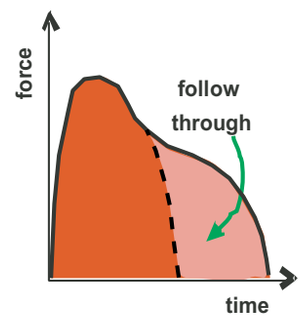
8) The follow-through is an important aspect of a forehand ground stroke in tennis.

a) Sketch a graph of the force applied by the racquet (y axis) against time (x axis). Show the effect of a follow-through on your graph. 2 marks

Answer:

- *See figure Q5.4.*
- *Marks are given for axes labelled and shape of graph.*
- *Follow-through labelled.*

figure Q5.4 – follow-through



b) Explain how the use of a follow-through would affect the motion of the ball. 4 marks

Answer:

- *The force is applied to ball for longer.*
- *Impulse = force x time over which force acts.*
- *Therefore increase in impulse of force acting on ball.*
- *Impulse = change of momentum of ball.*
- *Therefore increase in momentum of ball.*
- *Increase in velocity or speed of ball.*
- *More control of direction.*
- *Ball travels further.*

9) a) In a tennis match, the ball travels towards a player at 35 ms^{-1}. The ball has a mass of 80 g (= 0.08 kg) and

the racket head has a mass of 0.6 kg. The racket head moves towards the ball at 10 ms^{-1}.
Calculate the momentum of the racket and the ball before contact. 3 marks

Answer:

- *Momentum of the racket* = *mass x velocity*
  = *0.6 kg x 10* ms^{-1} = *6* $kgms^{-1}$
  (assuming that the racket moves forward and therefore has + (positive) velocity)
- *Momentum of the ball* = *mass x velocity*
  = *0.08 kg x (-35* ms^{-1}*)* = *-2.8* $kgms^{-1}$
  (assuming that the ball moves in the opposite direction and therefore has - (negative) velocity)

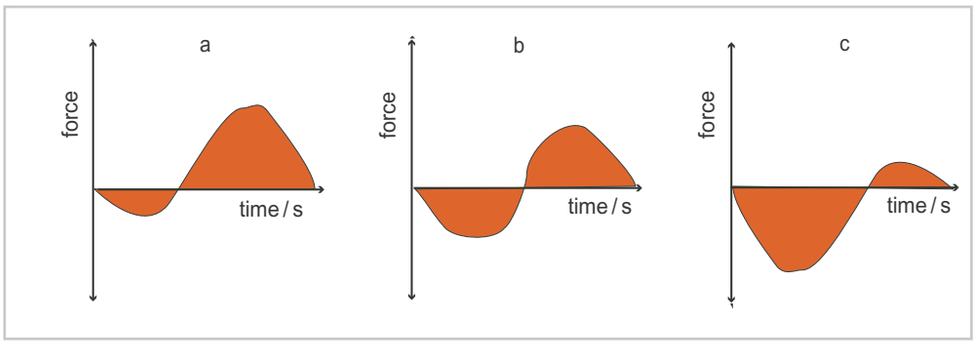
b) If the player stops the racket moving on contact with the ball, calculate the velocity of the ball after contact.
3 marks

Answer:

- *Momentum before impact* = *6 + (-2.8)* = *3.2* $kgms^{-1}$
  (total momentum adding together momentum of racket and ball)
- *Momentum after impact* = *3.2* = *mass of ball x outgoing velocity*
  (must be the same as momentum before impact by the law of conservation of momentum)
  = *0.08 x v*
- *Therefore velocity* $v = \frac{3.2}{0.08}$ = *40* ms^{-1}

c) The graphs in figure 5.30 show the forces acting on a runner's foot during a 100 metre sprint.
For each graph, describe the resultant impulse force and the motion that occurs. 6 marks

figure 5.30 – horizontal force acting on a runner's foot



Answer:

- *a: Large positive impulse.*
- *Which means the runner is accelerating or increasing in speed.*

- *b: Resultant impulse = zero.*
- *The runner is running at steady speed or constant speed.*

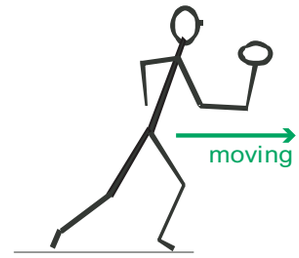
- *c: Resultant negative impulse.*
- *The runner decelerates or slows down.*

10) Tennis players have to change direction quickly during a match to recover to the centre of the court.

Figure 5.31 shows a tennis player just after hitting a forehand and then starting to recover to the centre of the court in the direction shown.

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

figure 5.31 – a tennis player moves between strokes

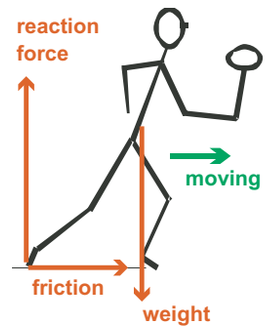


Answer:

- *See figure Q5.5.*
- *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

figure Q5.5 – forces acting on a tennis player between strokes



Answer:

2 marks for two of:

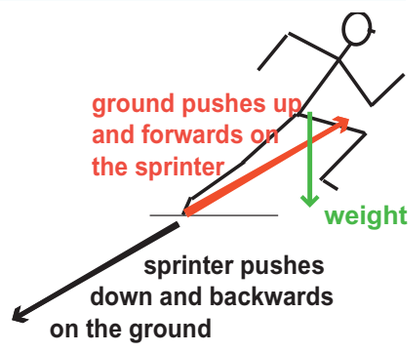
- *Type or roughness of footwear.*
- *Type or roughness of court surface.*
- *Amount of reaction force - how hard player presses into ground.*
- *Friction force depends on the contact force pressing the two surfaces (foot and ground) together.*

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.*

11) A sprinter uses her calf muscles to push on the blocks at the start of a run. Sketch a pin man diagram of the forces acting and use this to explain how this produces a forward force on her. 3 marks

figure Q5.6 – forces acting on a sprinter

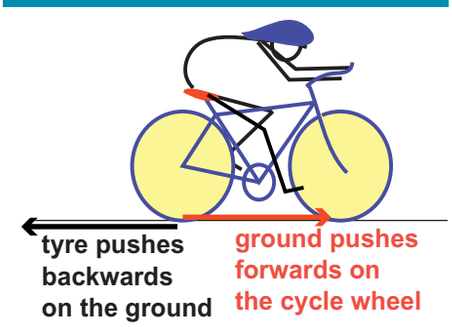


Answer:

- *See figure Q5.6.*
- *The black force (black arrow) is the force of her pushing on the ground.*
- *The red forces are those acting on the sprinter.*
- *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.*
- *The reaction force is this upward and forward force.*

12) Explain the nature of the reaction force which provides forwards impulsion for a cyclist. 4 marks

figure Q5.7 – forces on a cyclist



Answer:

- *See figure Q5.7.*
- *The rear tyre of the bicycle pushes hard backwards on the ground.*
- *Provided friction is big enough to avoid slipping, this friction force becomes the force acting as reaction to the backward drive of the tyre on the ground.*
- *Hence the ground exerts a force forward on the bike.*