CHAPTER 3: Linear motion

Practice questions - text book pages 64 - 65

1) Define what is meant by a scalar and a vector quantity. 2 marks

Answer:

- *A vector has size (or value or magnitude).*
- *And direction. For example, force. velocity, acceleration, weight.*
- *A scalar has size or magnitude only (no direction).*
- *For example, mass, energy, power, speed.*

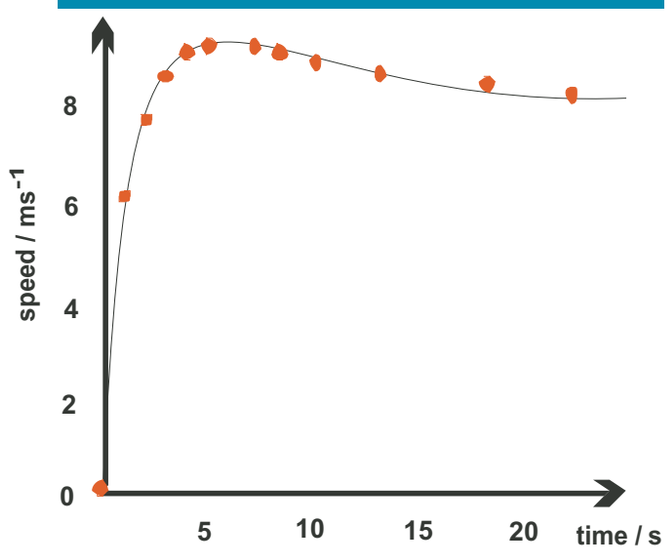
2) The table shows the speed of a 19 year-old male sprinter during a 200m race.

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

Table 3.1 – **data for a 200 metres sprint**

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 Q3.1 – speed against time for 200m race



Answer:

- *See speed / time graph in figure Q3.1.*
- *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}.*

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:

6 marks for six of:

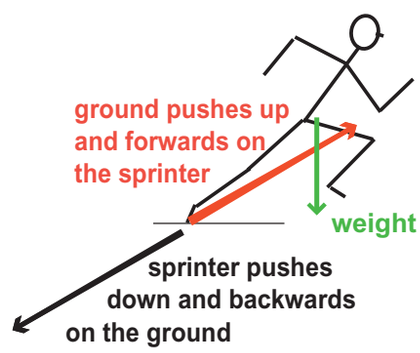
- *The force applied to the person is that between footwear and ground - friction.*
- *The factors which govern the size of friction force are the weight of the individual, the nature of the surface and footwear used.*
- *Newton's 3rd law applies between foot and ground.*
- *The sportsperson pushes on 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.*

3) 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

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 (figure Q3.2).*
- *Newton's 2nd law of motion - if a force is exerted, then this produces an acceleration in the same direction as the force (forwards).*

figure Q3.2 – forces acting on a sprinter

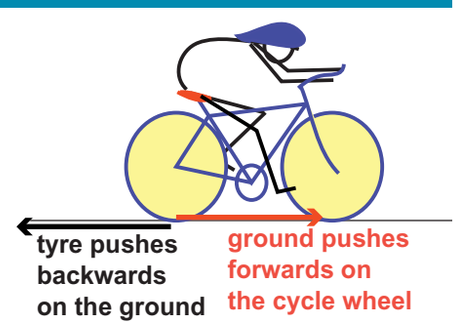


4) Explain the nature of the reaction force which provides forwards impulsion for a cyclist. 4 marks

Answer:

- *See figure Q3.3.*
- *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.*

figure Q3.3 – forces on a cyclist



5) A weight lifter exerts an upward force of 2000 N on a barbell of 170 kg. What is the vertical acceleration? 2 marks

Answer:

- *Using Newton's 2nd law, force = mass x acceleration.*
- *Force = 2000 N, mass = 170 kg, therefore 2000 = 170 x a.*
- *Hence* $a = \frac{2000}{170} = 11.765\ ms^{-2}$.

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 3.19 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 Q3.4.*
- *Note that the parallelogram rule is used to estimate the resultant.*
- *The resultant is horizontal, showing that the net force is forwards.*

figure 3.19 – forces acting on a runner

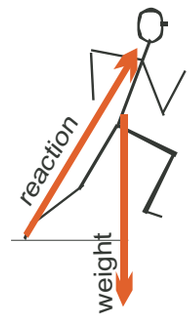
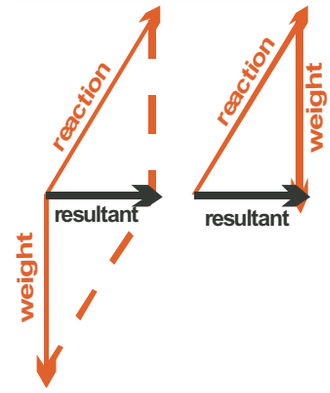


figure Q3.4 – resultant force

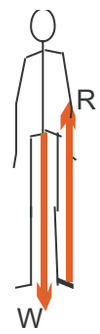


c) Sketch a pin man drawing of a person standing still showing all the forces acting on him. 2 marks

Answer:

- *See figure Q3.5.*
- *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 Q3.5 – forces acting on a person standing still

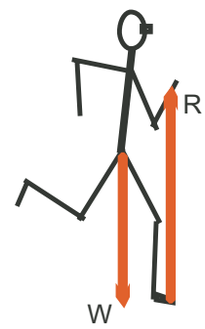


d) Sketch a second diagram showing the vertical forces acting on a basketballer just before take-off while performing a jump shot. Represent the relative sizes of any forces you show by the length of the force arrows on your diagram. 2 marks

Answer:

- *See figure Q3.6.*
- *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 Q3.6 – 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 2000N, and his weight is 800N, 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.*

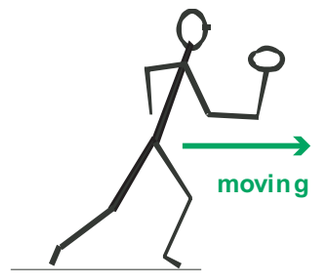
7) Tennis players have to change direction quickly during a match to recover to the centre of the court.
Figure 3.20 shows a tennis player just after hitting a forehand and then starting to recover to the centre of the court in the direction shown.

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

Answer:

- *See figure Q3.7.*
- *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).*

figure 3.20 – a tennis player moves between strokes



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:

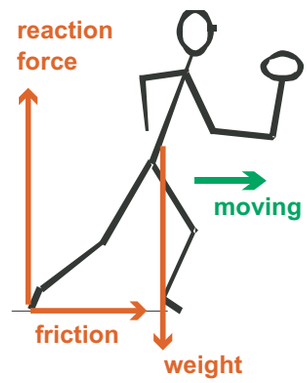
2 marks for two of:

- *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.*

figure Q3.7 – forces acting on a tennis player between strokes



8) Figure 3.21 shows the distance/time graph for a 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}).*

figure 3.21 – distance time graph for 100m sprint