

CHAPTER 7: Biomechanical movement

Practice questions - text book page 118 - 120

- 1) For which of the following is the athlete's centre of mass most likely to lie outside of his or her body?
- diver performing a tucked dive.
 - trampolinist in a fully piked position.
 - gymnast performing a cartwheel.
 - 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 resistance of 10 N?
- 10 N.
 - 1 N.
 - 100 N.
 - 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?
- the acceleration of an object is directly proportional to the force causing it and is inversely proportional to the mass of the object.
 - body moves in a circle about a point called the axis of rotation.
 - body will continue in a state of rest or of uniform velocity unless acted upon by an external force.
 - for every action there is an equal and opposite reaction.

Answer: b

Explanation:

- a: is Newton's 2nd law, c: is Newton's 1st law, d: is Newton's 3rd law.

- 4) What is the difference between distance and displacement?
- displacement is the distance between the start and end point only, distance is the total distance travelled along the path of motion.
 - displacement is the total distance travelled along the path of motion, distance is the distance between the start and end point only.
 - displacement is the distance between the start and end point only, distance is the distance between the start and end point.
 - displacement is the total distance travelled along the path of motion, distance is the total distance travelled along the path of motion.

Answer: a

- 5) A rugby prop sprints away from a scrum with an acceleration of 0.2ms^{-2} for 10s. How far did he travel?
- 15 metres.
 - 10 metres.
 - 18 metres.
 - 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 $0.2\text{ms}^{-2} \times 10\text{s} = 2\text{ms}^{-2}$ so $S = 1/2(0+2)10$ so $S = 10\text{m}$.

- 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 Q7.1 for an idea of where the centre of mass is in a body depending on shape.

- 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 7.29. 5 marks

Answer:

For the long jumper:

- Three marks for 3 diagrams showing the approximate position of the centre of mass - see figure Q7.2.
- The idea that this red dot represents the position of the overall mass of the body.

figure Q7.2 – centre of mass position for long jumper

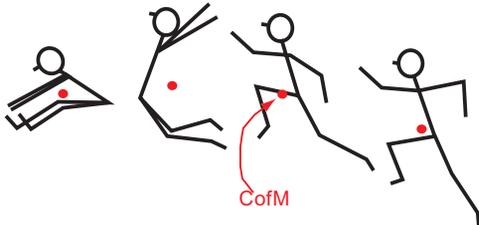


figure Q7.1 – centre of mass position in the body

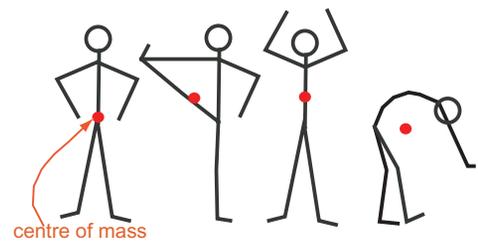


figure 7.29 – a long jumper in flight



figure 7.30 – swimmer starting a race



- 7) Figure 7.30 shows a swimmer holding a balance just before the start of a race. Explain how the position of the centre of mass can affect the swimmer's balance. Describe how the swimmer in figure 7.30 can use his knowledge of balance to achieve his most effective block start. 5 marks

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 Q7.3).
- 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.

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.
- And outside his base of support (his feet) - see figure Q7.4.
- So he will topple forward into the pool - he then pushes hard with his legs to drive forwards in the direction of his swim.

figure Q7.3 – centre of mass position affects stability

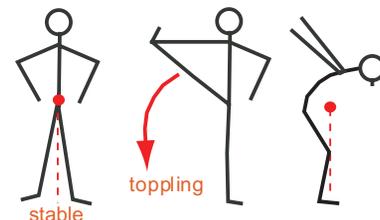
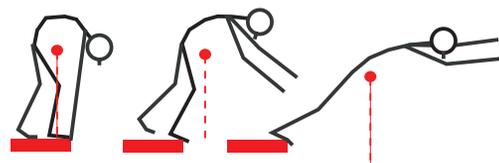


figure Q7.4 – swim start and toppling

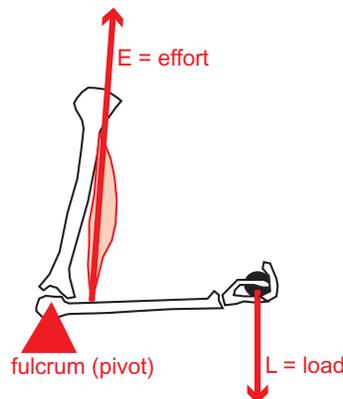


8) Sketch the lever system which would represent the action of the biceps muscle in flexing the arm. Show on your diagram the resistance arm of the lever. 3 marks

Answer:

- See figure Q7.5.
- *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).

figure Q7.5 – the elbow and forearm lever



9) In figure 7.31 of a jumper taking off, name, sketch and label the lever system operating at knee B during this action. 3 marks

figure Q7.6 – jumper's knee 1

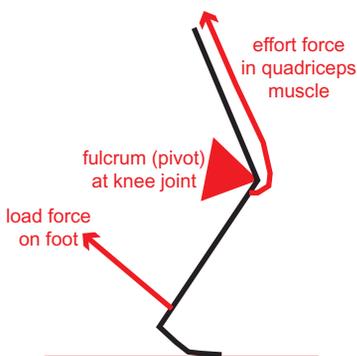


figure Q7.7 – jumper's knee 2

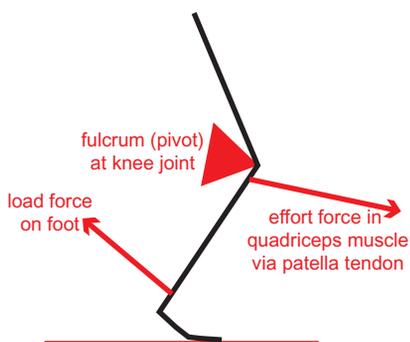
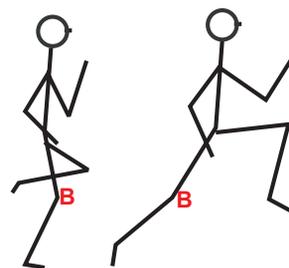


figure 7.31 – long jumper taking off



Answer:

- See figures Q7.6 and Q7.7.
- This is a *class 3* lever (effort between pivot and load).
- Note that the effort (figure Q2.6) is transmitted to the tibia via the patella tendon, which passes over the knee and inserts below the joint (figure Q2.7).

figure 7.32 – softball bat

10) In softball, what order (class) of lever is shown in the hitting action in figure 7.32? State one disadvantage and one advantage of reducing the bat length for a beginner. 3 marks

Answer:

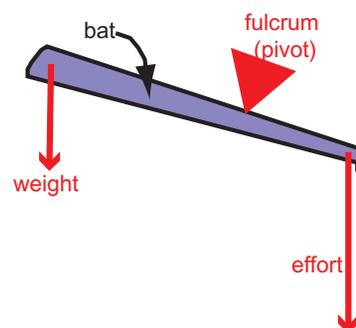
- This is a *class 1* lever.

Advantage of shortening bat length is:

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

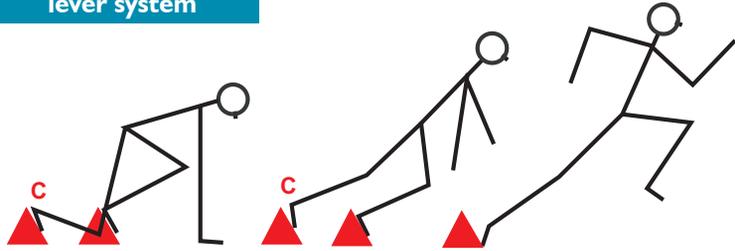
Disadvantage of shortening the bat would be:

- 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) a) 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 7.33. 3 marks

figure 7.33 – ankle lever system



Answer:

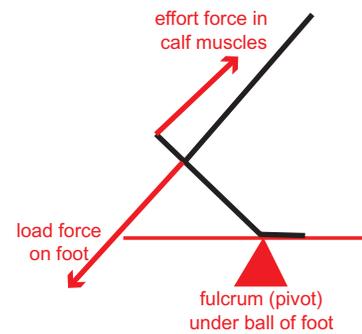
- See figure Q7.8.
- This is a **class 2** lever.
- Note that the load force is a combination of the weight of the athlete acting downwards through the tibia/fibula on the ankle joint, and the reaction to the accelerating force driving the sprinter forwards.

b) Class 2 of a lever always has a mechanical advantage. Explain why is this so? 2 marks

Answer:

- This is because the load force is always bigger than the effort force.
- Since the load force is nearer to the fulcrum than the effort force.
- And distance multiplied by force must be the same for both side of the lever.

figure Q7.8 – ankle foot lever

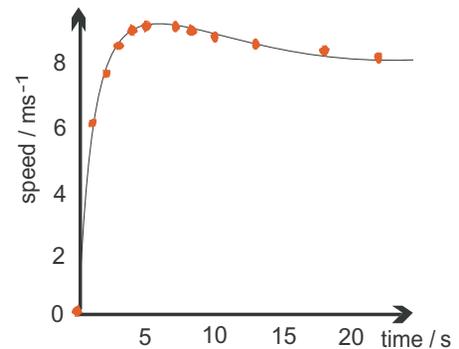


12) The table shows the speed of a 19 year-old male sprinter during a 200m race.

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

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

figure Q7.9 – speed against time for 200m race



Answer:

- See speed/time graph in figure Q7.9.
- 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.

12) continued

- 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: $300 \text{ N} = 60 \text{ kg} \times \text{acceleration}$.
- Hence: $\text{acceleration} = \frac{300}{60} = 5 \text{ ms}^{-2}$.

- 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:

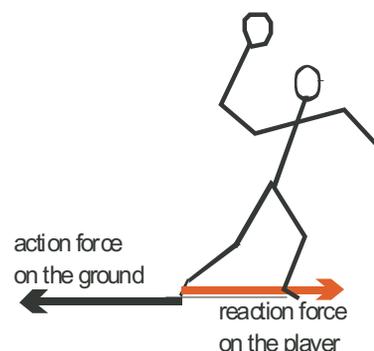
- **Speed changes** by 5 ms^{-1} each **second**.
- Therefore total change of speed in 1.5 seconds = 7.5 ms^{-1} .

- 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 Q7.10.

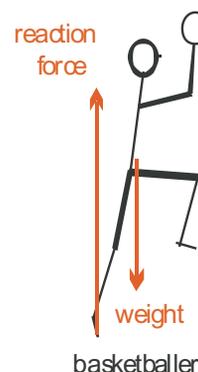
figure Q7.10 – forces acting on a squash player



14) a) Use the diagram in figure 7.34 of a basketballer just about to take off into a jump shot, and your knowledge of Newton's Laws of motion explain why the basketball jumper takes off

3 marks

figure 7.34 – 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 2000N, and the weight of the jumper is 800N, estimate the net upward force acting on him.

1 mark

Answer:

- Net upward force $F = 2000 - 800 = 1200 \text{ N}$.

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

2 marks

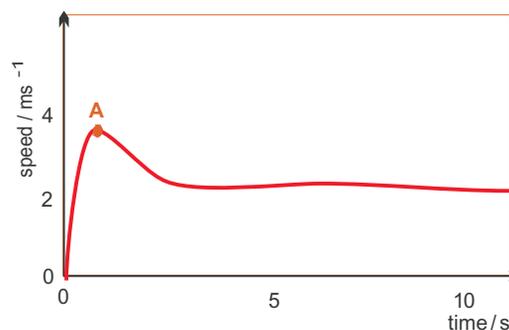
Answer

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

15) a) The graph in figure 7.35 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 7.35 – 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.

16) Tennis players have to change direction quickly during a match to recover to the centre of the court. Figure 7.36 shows a tennis player just after hitting a forehand and then starting to recover to the centre of the court in the direction shown.

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.

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. 10 marks

figure 7.36 – a tennis player moves between strokes

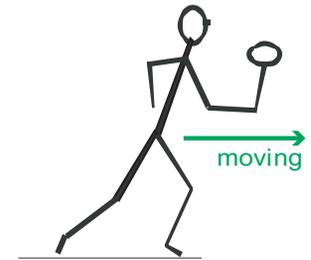
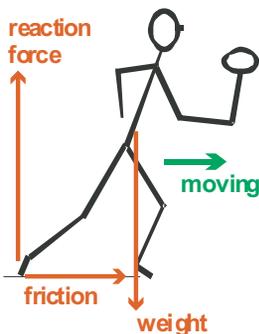


figure Q7.11 – forces acting on a tennis player between strokes



Answer:

- See figure Q7.11.
- **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).

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**, $F = m \times a$, 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.

17) How do the following technologies aid analysis and feedback for improving sporting performance?

9 marks

a) Video and computer software analysis.

Answer:

- Enables **observational feedback** of the performance.
- The ability to **compare** with the required **technical model**.
- Using software systems such as Dartfish for individual sports.
- Which provides **frame to frame comparison** between the performer and a technical model.
- And Prozone, which looks at the **movement of players** on the pitch by using up to 12 fixed cameras and sensors.
- Analysing positions and speeds of players at up to 10 times per second.
- Enabling a coach or manager to **analyse strategies** and tactics within the game.

b) Force plate technology.

Answer:

- Force plate technology provides information about the **pattern of force** made by a foot striking the plate.
- This information tells the coach/athlete the precise way in which the foot is active **during the strike with the ground**.
- And enables him or her to assess whether changes in **foot posture** are required.
- Force plate technology is used in conjunction with a 3D scanner in the construction of **personalised footwear**.

c) Wind tunnels

Answer:

- Air is blasted past a stationary object in a tunnel using smoke to illustrate layers of flow of the air.
- During the test, the wind speed and direction are changed to provide an assortment of force and moment of inertia data.
- The task is to avoid vortex generation in the air flow, since smooth (laminar) flow generates less drag.
- Manufacturers can use this information to test their equipment such as bike design, shoe covers and helmets in order to minimize drag.