Biomechanics in Sport

Name:

Teacher: Mr Trent

Guiding Question: How can the laws of motion be applied to explain the movement of bodies in sport and exercise, and be used to improve performance?

Linking Question B.2.1—How can coaches use Newton's laws to improve the performance of their athletes?

Unit B.2.1: Newton's Laws of Motion

Syllabus Statements:

- **B.2.1.1**—Linear and angular motion can be analysed using Newton's laws of motion.
- **B.2.1.2**—A collision results in a change in momentum in the colliding bodies.
- **B.2.1.3**—The force of friction is determined by the coefficient of friction.
- **B.2.1.4**—Work results from the application of a force over a distance.

(a) Motion and mechanics	
Speed	$s = \frac{d}{t}$
Acceleration	$a = \frac{(v-u)}{t}$
Linear velocity	$v = \frac{\Delta s}{\Delta t}$
Angular velocity	$v = \frac{2\pi r}{T} = \omega r$
Force and weight	$F = ma = \frac{\Delta p}{\Delta t}$ $F_g = mg$
Impulse	$J = F\Delta t$
Linear momentum	$p = mv$
Coefficient of restitution	$C_R = \frac{v_b - v_a}{u_a - u_b}$
Coefficient of static friction	$F_f \leq \mu_s F_N$
Coefficient of dynamic friction	$F_f = \mu_d F_N$

Starter:

Word		Description		Formula
Speed		A scalar quantity that measures how fast an object is moving, regardless of direction.		
Velocity		A vector quantity that describes the rate of change of an object's position, including direction.		
Acceleration		A vector quantity that describes the rate of change of velocity of an object.		

Law		Description		Formula
First Law (Inertia)		An object at rest will stay at rest, and an object in motion will stay in motion at a constant velocity unless acted upon by an external force.		
Second Law (F=ma)		The acceleration of an object depends on the mass of the object and the amount of force applied.		
Third Law (Action-Reaction)		For every action, there is an equal and opposite reaction.		

Activity 1: Newton's Laws of Motion - Core Concepts

Recall: What are Newton's Three Laws of Motion?

1. **Newton's First Law (Law of Inertia):**

2. **Newton's Second Law:**

3. **Newton's Third Law (Action-Reaction):**

Question 1: Explain, in your own words, what "inertia" means in the context of sport. Provide an example of an athlete demonstrating inertia.

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Question 2: A heavier shopping cart needs more force to push than a lighter one. Which of Newton's Laws does this apply to?

- A. First Law
- B. Second Law
- C. Third Law
- D. Law of Gravity

Question 3: Which of Newton’s laws explains why passengers lurch forward when a car suddenly stops?

- A. First Law
- B. Second Law
- C. Third Law
- D. Law of Gravity

Question 4: A 10 kg object accelerates at 3 m/s^2. What is the net force acting on it?

- A. 3 N
- B. 10 N
- C. 30 N
- D. 300 N

Question 5: When a swimmer pushes against the wall of a pool, they move in the opposite direction. Which law is this?

- A. First Law
- B. Second Law
- C. Third Law
- D. Law of Conservation of Energy

Checkpoint Quiz 1: Scalar vs. Vector Quantities

True or False: Determine if the following statements are True (T) or False (F).

1. The motion of an object can be described using acceleration.
2. Speed and velocity are the same thing.
3. Distance and displacement always have the same value.
4. Velocity is measured in meters per second (m/s).
5. Displacement includes direction, but distance does not.
6. A car can have constant speed but changing velocity.
7. Speed is a vector quantity because it tells us how fast and in what direction.

Question 6: What is the fundamental difference between a Scalar quantity and a Vector quantity? Provide two examples for each.

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Question 7: A car travels 100 meters north in 20 seconds. Identify the scalar and vector quantities in this statement.

- **Scalar:**
- **Vector:**

Activity 2: Linear Motion - Speed, Velocity, and Acceleration

Recall:

- **Speed:**

- **Velocity:**

- **Acceleration:**

Question 8: A car speeds up from 0 to 20 m/s in 4 seconds. What is its acceleration?

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Question 9: If a cyclist slows down from 12 m/s to 4 m/s in 4 seconds, what is their acceleration?

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Question 10: An object moves with constant acceleration of 3 m/s^2. If it starts at rest, what is its velocity after 6 seconds?

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Question 11: An object's acceleration is 0 m/s^2. It is moving at 10 m/s. What can you say about its motion and why?

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Force and Momentum

Question 12: What is a "Force"? List three effects a force can have on an object.

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Question 13: What is the difference between "mass" and "weight"?

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The resultant motion of an object is determined by the sum of the forces acting on it.

Question 14: What is a "Resultant Force"? Imagine two rugby players tackle an opponent. Player A applies a force of 600 N to the right, and Player B applies a force of 400 N to the right. What is the resultant force on the opponent?

Question 15: Define "Momentum." What are its units, and why is it considered a vector quantity?

Calculations: Momentum Practice ($p=m \times v$)

1. A 3 kg ball is moving at 2 m/s. What is its momentum?

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2. Find the momentum of a 5 kg object moving at 6 m/s.

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3. An object with a momentum of 12 kg·m/s is moving at 3 m/s. What is its mass?

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4. A 0.2 kg tennis ball moves at 20 m/s. What is its momentum?

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5. A 4 kg object changes its velocity from 3 m/s to 7 m/s. What is the change in momentum?

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6. A 1.5 kg object is moving at –4 m/s. What is its momentum? (Include direction)

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7. A 2.5 kg object has 15 kg·m/s of momentum. What is its velocity?

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Question 16: Two objects collide. One is 3 kg moving at 5 m/s east, and the other is 2 kg at rest. What is the total momentum before the collision?

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Question 17: Explain the "Principle of Impulse" in relation to change in momentum. Provide a practical sporting example (different from the ones in the presentation) where an athlete applies this principle.

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Calculations: Apply the impulse-momentum theorem (Impulse=Force×Time=Change in Momentum).

1. A 2 kg ball increases its velocity from 0 m/s to 5 m/s. What is the impulse?

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2. A 0.5 kg object slows from 4 m/s to 1 m/s. What is the impulse?

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3. A force of 10 N acts for 3 seconds. What is the impulse delivered?

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4. A 5 N force is applied to a puck for 2 seconds. What is the change in momentum?

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5. An impulse of 20 N·s changes the velocity of a 4 kg object. What is its change in velocity?

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6. A 3 kg object changes velocity from 6 m/s to 2 m/s. What is the impulse?

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7. A footballer applies a 12 N force to a ball for 0.25 seconds. What impulse is produced?

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8. If a 7 kg object receives an impulse of 21 N·s, what is its velocity change?

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9. A cricket ball of mass 0.2 kg hits a bat and rebounds. If its velocity changes from +15 m/s to –10 m/s, what is the impulse?

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10. A boxer punches with a force of 300 N over 0.04 seconds. What impulse is delivered to the opponent?

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Question 18: A 0.6 kg hockey puck is sliding on ice with a velocity of 8 m/s east. It is struck by a stick, which applies a force of 15 N west for 0.2 seconds. Calculate the final velocity of the puck after being struck. (Hint: Consider direction for velocity and force).

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Unit B.2.1.2: Collisions and Coefficient of Restitution

Syllabus Statement:

- **B.2.1.2**—A collision results in a change in momentum in the colliding bodies.
- **B.2.1.2**—Collisions involving a ball are affected by its coefficient of restitution.

Question 19: What does the Coefficient of Restitution (COR) measure?

- A. The weight of an object
- B. The bounce of a collision
- C. The speed of running
- D. The angle of impact

Question 20: If a ball hits the ground at 4 m/s and bounces back at 2 m/s, what is the COR?

- A. 0.2
- B. 0.4
- C. 0.5
- D. 0.8

Question 21: Which of these balls would likely have the highest COR?

- A. Tennis ball
- B. Bowling ball
- C. Medicine ball
- D. Wet sponge

Question 22: What does a COR of 1 mean in the context of a collision?

- A. The ball doesn’t move
- B. The ball bounces back perfectly (no kinetic energy loss)
- C. The ball rolls instead of bouncing
- D. The ball loses all energy

Question 23: Two balls are dropped from the same height. Ball A bounces higher than Ball B. Which has the higher COR?

- A. Ball A
- B. Ball B
- C. Both are the same
- D. COR doesn't affect bounce

Activity 3: Investigating COR Design a simple experiment to determine the Coefficient of Restitution for different types of balls (e.g., tennis ball, basketball, golf ball). Outline your method, necessary equipment, and how you would calculate the COR for each ball.

- **Hypothesis:**
- **Equipment:**
- **Method:**
- **Results:**

Unit B.2.1.3: Friction

Syllabus Statement:

- **B.2.1.3**—The force of friction is determined by the coefficient of friction.
- **B.2.1.3**—The coefficients of static and dynamic friction depend on the materials in contact.
- **B.2.1.3**—Frictional force can be modified to improve sports performance.

Question 24: Define "Friction." Name two sports where athletes actively try to **reduce** friction, and two sports where they actively try to **increase** friction.

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Question 25: What is the difference between "static friction" and "dynamic friction"? Which one is usually greater?

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Question 26: Write down the formula for calculating frictional force. Explain what each variable represents.

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Friction Calculations: Use the formula $F=\mu\times N$.

1. If the coefficient of friction is 0.4 and the normal force is 600 N, what is the frictional force?

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2. A curling stone moves on ice with a dynamic coefficient of friction of 0.05. If the normal force is 150 N, find the frictional force.

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3. A football boot has a coefficient of friction of 0.6 with the grass. The normal force is 500 N. What is the frictional force?

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4. A skier applies wax that reduces the coefficient of friction to 0.1. If their body weight applies a normal force of 800 N, calculate the frictional force.

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5. A tennis player slides on a court surface where $\mu = 0.45$, and the frictional force measured is 270 N. What is the normal force acting on the player?

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6. An athlete's shoe experiences a static frictional force of 350 N on a track. If the normal force is 700 N, calculate the coefficient of static friction.

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Activity 4: Friction in Sport Research Task

Choose **one** of the following sports and conduct brief research (you can use your phone/computer if allowed, or discuss with a partner) on how frictional forces are intentionally modified to gain an advantage.

- Athletics – e.g., sprinters using spikes for grip
- Skiing – reducing friction to increase speed
- Tennis – different court surfaces (clay, grass, hard court)
- Wrestling – mats designed with controlled friction for movement and safety
- Soccer – boots designed for grass, turf, or indoor surfaces

Your research should include:

1. A short explanation of what friction is in the chosen sport.
2. The methods used to modify friction (e.g., equipment, surfaces, clothing).
3. The impact on performance (speed, control, safety, stability, etc.).
4. Can you find a real-world example of an athlete or team who changed friction intentionally to gain a competitive edge?

Planning:

- **Sport Chosen:**
- **Explanation of Friction in Sport:**
- **Methods to Modify Friction:**
- **Impact on Performance:**
- **Real-World Example:**

Criteria	Excellent (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
1. Explanation of Friction in Sport	Clear and accurate explanation showing strong understanding of friction and how it applies in the chosen sport	Good explanation with minor errors or limited detail	Basic explanation with some misunderstandings or vague terminology	Incomplete or inaccurate explanation of friction in the sport
2. Methods to Modify Friction	Multiple relevant methods are identified and clearly explained (equipment, surfaces, clothing, etc.)	At least two methods are identified with some explanation	One method identified, limited explanation or unclear	No clear methods identified or explained
3. Impact on Performance	Strong explanation of how friction affects speed, safety, control, or stability, with clear links to the sport	Some explanation of impact, with general link to performance	Limited or vague explanation of impact	No explanation or impact not connected to the sport
4. Real-World Example	A relevant and specific real-world example is provided and clearly linked to friction	Example is mostly relevant but lacks full explanation or detail	An example is included but weakly linked to friction	No example or irrelevant example provided
5. Presentation & Communication	Well-structured, clear, and engaging; correct spelling and grammar	Mostly clear, with some structure and few errors	Some confusion in structure or language; several minor errors	Unclear or rushed; many spelling/grammar mistakes
Comments				

Unit B.2.1.4: Work, Energy, and Power

Syllabus Statements:

- **B.2.1.4**—Work results from the application of a force over a distance.
- **B.2.1.4**—When work is done, energy is transformed from one form to others.
- **B.2.1.4**—Power is a measure of the rate at which work is done.
- **B.2.1.4**—Measuring power output can therefore be a measure of work intensity.
- **B.2.1.4**—Power output can be optimized through correct technique and the effective design of sports equipment.

Question 27: Define "Work" in a scientific context. Is holding a weight still above your head doing work? Explain your answer.

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Question 28: Calculate the work done when a force of 400 N is applied to move an object 3 m.

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Work Done Calculations: (Work=Force×Distance)

1. A footballer applies a force of 300 N to a sled over 5 m. Calculate the work done.

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2. A swimmer pushes off the wall with 250 N of force and moves 2 m. How much work is done?

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3. A weightlifter lifts a 600 N barbell 1.8 m. What is the work done?

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4. A rugby player tackles with a force of 900 N and pushes the opponent back 0.5 m. How much work was done?

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5. A cyclist pushes with 150 N over 20 m. Calculate the work.

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6. A tennis player swings the racket with 50 N of force over 1.2 m. Work done?

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7. A javelin thrower applies 120 N of force over a 3.5 m throw motion. Find the work.

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8. A boxer punches with 400 N of force, moving their glove 0.3 m. Work done?

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9. A rock climber pulls their body (500 N) up a 4 m section. Work done?

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10. A pole vaulter exerts 1000 N of force over 2.5 m during takeoff. Work done?

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Question 29: When work is done, energy is transformed. Explain the energy transformations that occur during a tennis serve, from the initial wind-up to the ball leaving the racket.

- **Answer:**

Question 30: Define "Power" and explain how it differs from "Work." Why is power a better measure of work intensity than just work done?

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Power Calculations: (Power=Work/Time)

1. An athlete does 1000 J of work in 5 seconds. Calculate power output.

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2. A cyclist generates 4500 J of work in 10 seconds. Find the power.

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3. A rower performs 1800 J of work in 4 seconds. What is their power?

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4. A sprinter outputs 1200 J of work in 2 seconds. Calculate power.

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5. A weightlifter completes a 2400 J lift in 3 seconds. What is the power output?

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6. A swimmer does 350 J of work in 0.5 seconds. Power?

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7. A long jumper performs 900 J of work during a 0.75-second takeoff. Calculate power.

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8. A rugby scrum pushes with a combined 10,000 J over 6 seconds. Find the total power.

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9. A basketball player jumps with 800 J of work done in 1.2 seconds. Power output?

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10. A football kicker delivers 1100 J of work over 0.8 seconds. Find power.

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Question 31: Why do sprinters need to focus on generating significantly more power than marathon runners, even though both are athletes?

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Question 32: How could power be measured in shot put? Describe at least two methods or pieces of equipment that could be used.

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Activity 5: Technique, Equipment, and Power Output

Question 33: Explain, with a sporting example, how improving an athlete's technique can lead to higher power output and improved performance.

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Question 34: A sprint cyclist applies a force of 900 N to the pedals and moves the bike forward 6 metres in 3 seconds. a) Calculate the work done by the cyclist. [2] b) Calculate the cyclist's power output. [1] c) Explain how using power meters in cycling training can improve performance. [2]

- **a) Work Done:**

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- **b) Power Output:**

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- **c) Power Meters and Performance:**

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Question 35: During a high jump take-off, an athlete converts chemical energy into mechanical energy to elevate their centre of mass. a) Explain the energy transformation that occurs during the take-off phase. [2] b) Describe how correct technique in the approach and plant phases can increase work done. [2] c) State how increasing work done affects jump height. [1]

- **a) Energy Transformation:**

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- **b) Technique and Work Done:**

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- **c) Work Done and Jump Height:**

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Question 36: Two rowers produce the same amount of work per stroke, but one finishes a 500 m sprint faster. a) Define power and explain how it differs from work. [2] b) Suggest how differences in rowing technique might explain the difference in time. [2] c) Explain how rowing shell design could influence power output. [1]

- **a) Power vs. Work:**

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- **b) Rowing Technique:**

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- **c) Rowing Shell Design:**

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Question 37: A shot putter pushes a 7.26 kg shot with an average force of 400 N over 1.8 m. a) Calculate the work done on the shot. [2] b) The release takes 0.6 seconds. Calculate the power output. [1] c) Discuss how improving technique can increase both force and distance, leading to greater power output. [2]

- **a) Work Done:**

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- **b) Power Output:**

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- **c) Technique, Force, Distance & Power:**

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Question 38: An athlete lifts a 100 kg barbell from the floor to overhead (2.2 m) in 1.5 seconds during a clean and jerk. a) Calculate the work done during the lift (assume g = 9.8 m/s^2). [2] b) Calculate the power output. [1] c) Explain how improving lifting technique helps reduce wasted energy and improves mechanical efficiency. [2]

- **a) Work Done:**

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- **b) Power Output:**

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- **c) Technique and Mechanical Efficiency:**

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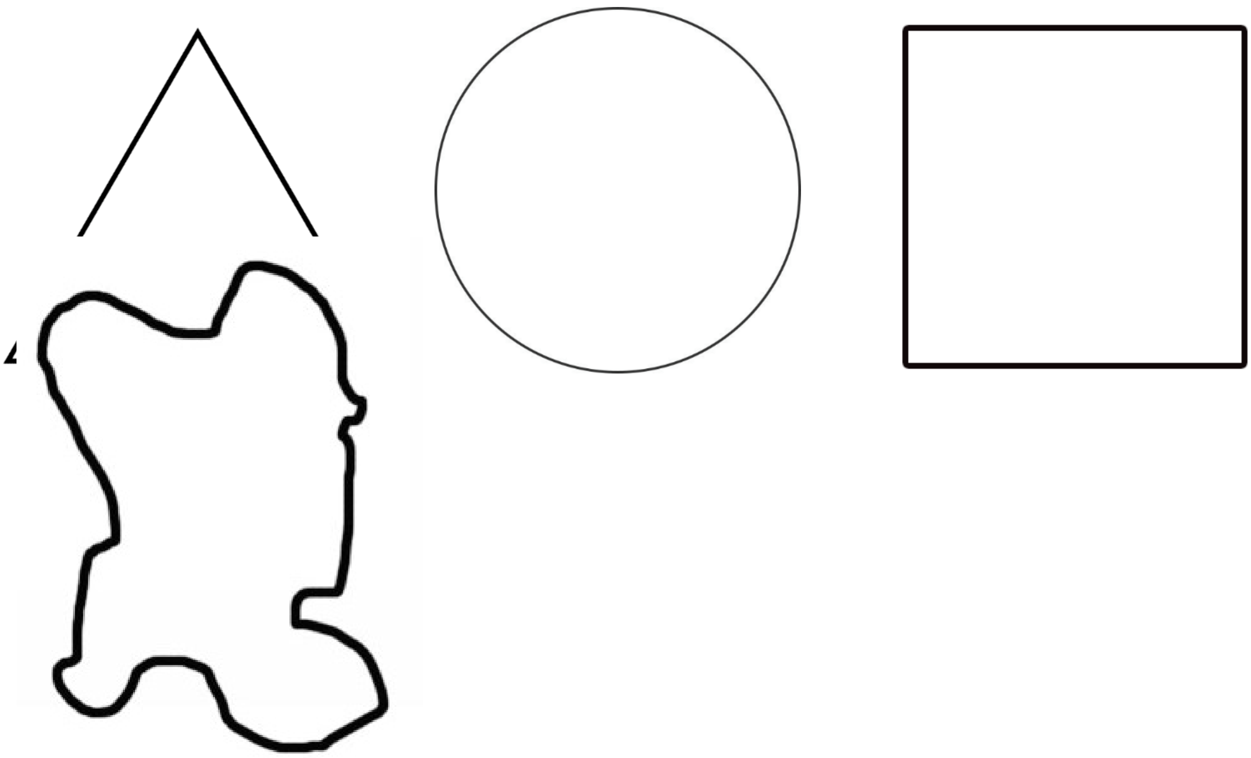
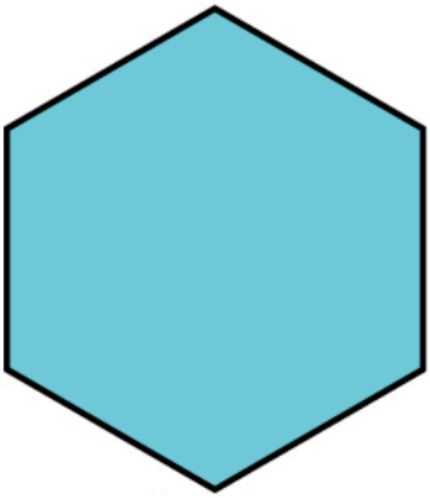
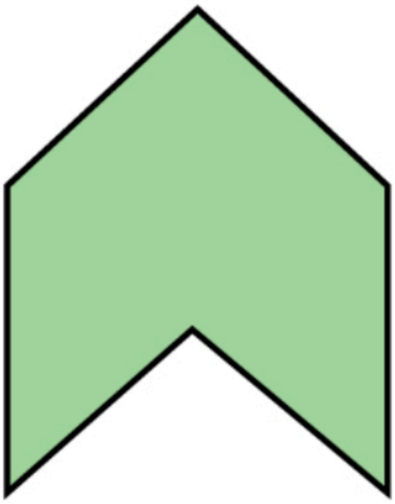
Syllabus Statements:

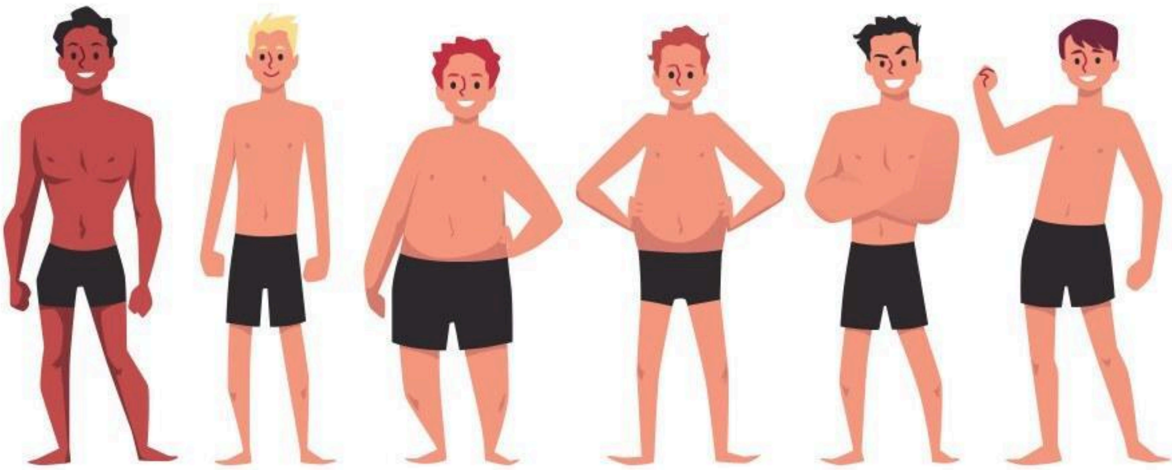
- **B.2.1.3**—Stability—factors affecting stability include the height of the centre of mass relative to the supporting surface.
- **B.2.1.3**—Angular motion—this is produced by the application of a force acting at a distance from the centre of mass: an eccentric force.
- **B.2.1.3**—Angular momentum is conserved when an athlete or object is free of additional eccentric forces.

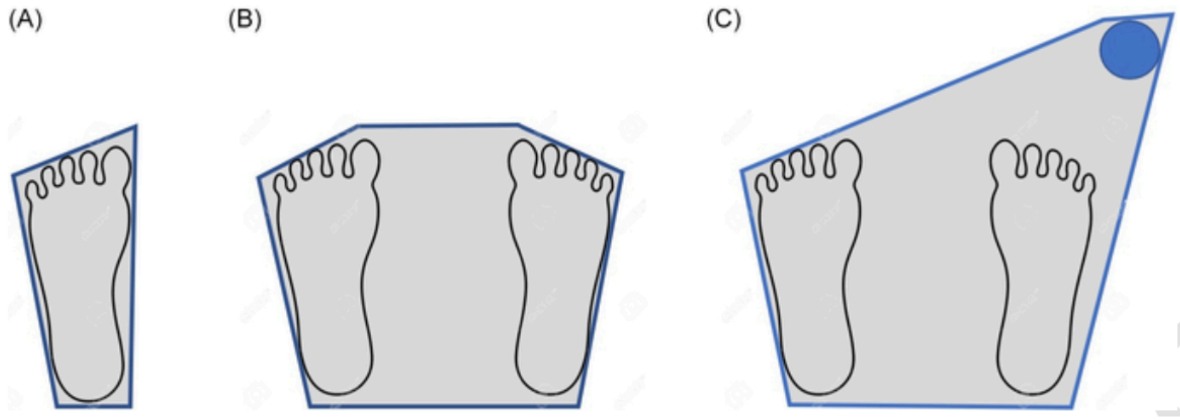
Question 39: List the four key factors affecting stability. For each factor, briefly explain how it impacts an object's stability.







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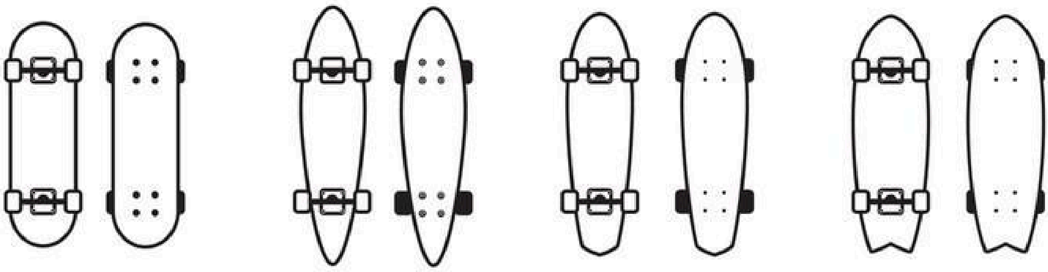

Question 40: A rugby player lowers their stance before a tackle. Explain how this action improves their stability by referencing two of the factors you listed in Question 39.

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Question 41: Where is the centre of mass for:

- A basketball:
- A hammer:
- A person performing a backflip:

Question 42: Define "Angular Motion" and "Eccentric Force." How are they related?

1. A gymnast completes a full rotation (2π radians) in 2 seconds. What is their average angular velocity?

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2. A diver spins at 6 rad/s. How many radians do they rotate through in 1.5 seconds?

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3. A golf club accelerates from 0 to 20 rad/s in 0.4 seconds. Calculate its angular acceleration.

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4. A discus rotates through 10 radians in 2 seconds. What is its average angular velocity?

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4. A cyclist’s wheel spins with a constant angular acceleration of 3 rad/s^2. How fast is it spinning after 4 seconds, starting from rest?

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5. A figure skater spinning at 12 rad/s comes to a stop in 3 seconds. What is her angular deceleration?

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6. A baseball bat starts at rest and reaches 18 rad/s after being swung for 0.6 seconds. Find the angular acceleration.

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7. A gymnast performs a spin where her angular velocity changes from 15 rad/s to 5 rad/s in 2 seconds. What is her angular deceleration?

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8. A rotating wheel has an angular acceleration of 2 rad/s^2. If it starts from rest, how many radians does it rotate through in 5 seconds?

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10. A hockey puck on a training rig accelerates from 10 rad/s to 25 rad/s in 3 seconds. Calculate the angular acceleration and then the angular displacement during that time

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Question 43: Why is it harder to open a door by pushing near the hinge compared to pushing near the handle? Relate your answer to the concept of torque.

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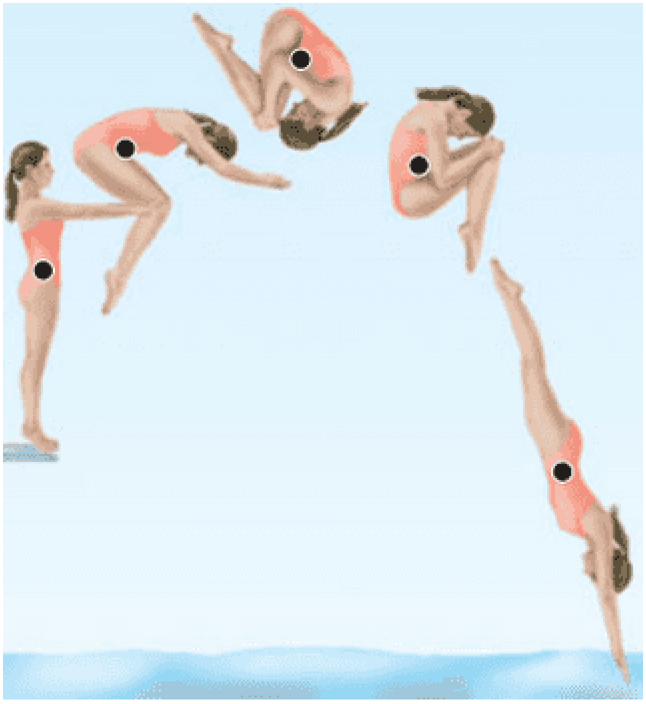

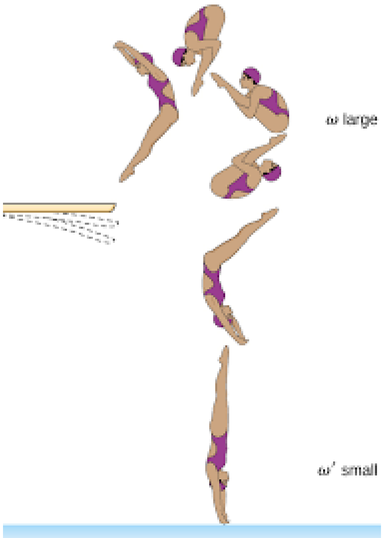
ω large
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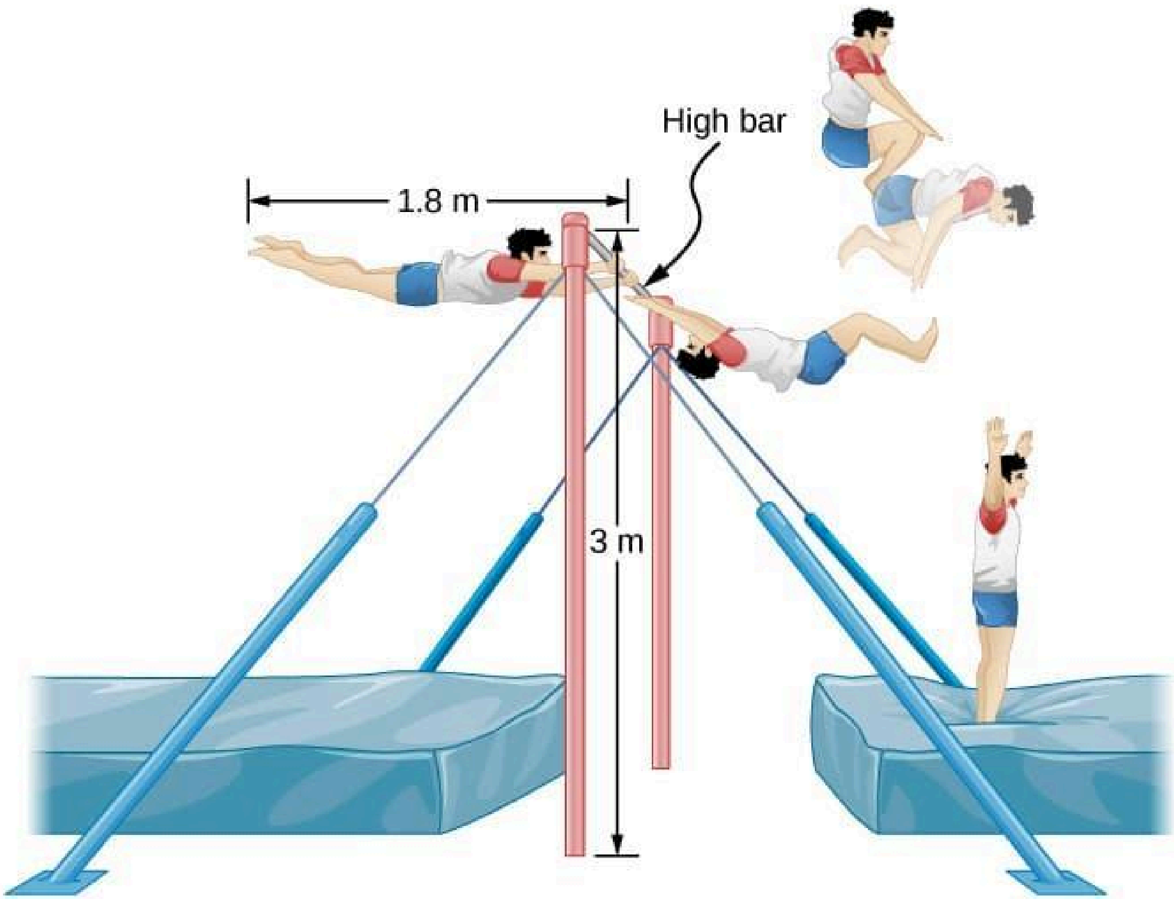
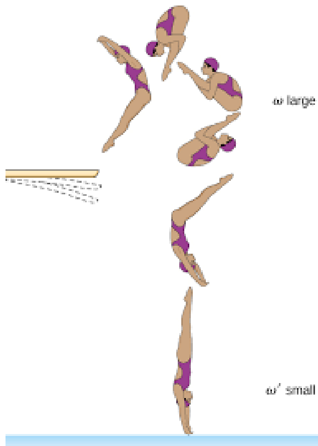

High bar
1.8 m
3 m

The Perfect Dive



Diving Physics: Comprehension Sheet

Based on the article "2016 Rio Olympics: The Physics of the Perfect Dive" from Inverse, answer the following questions:

1. What is the main topic of this article?

2. What are some of the intricate manoeuvres involved in diving, as mentioned in the article?

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4. **Which key physics concepts are explained in the article in relation to diving?**

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5. **How do divers manipulate the principles of physics to perform complex rotations?**

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5. What is the desired outcome when a diver hits the water?

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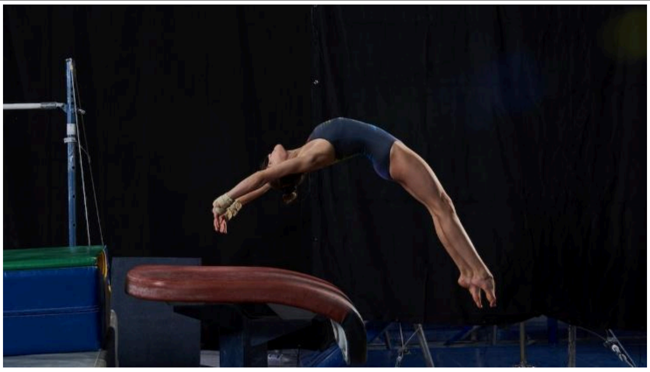
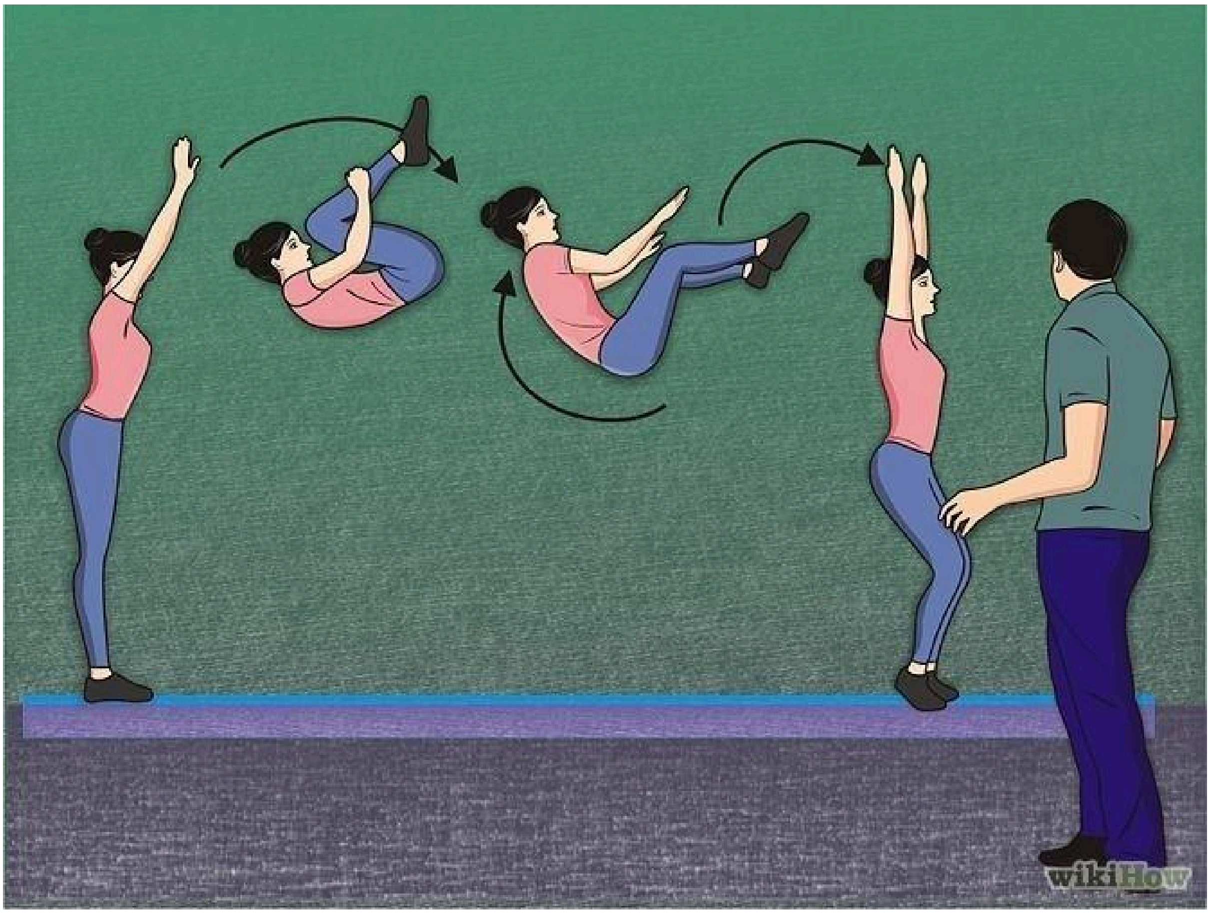
Moment of Inertia – an object’s resistance to spinning faster

	Radius ^{2} (m)	Mass (kg)	Moment of Inertia (kg.m^2)	How would they increase and/or decrease their moment of inertia?
				

BEIJING 2022				
				
				



- Angular Momentum - a measure of the amount of _______________
- Vector
- Angular Momentum (L) = _____________________ (ω) x _________________________(I)
- L = ω x I
- Measured in kg/m2/s

1. A gymnast (55 kg) extends legs 1.2 m from the axis of rotation. The gymnasts spins at a velocity of 7rads/sec. Calculate the angular momentum.

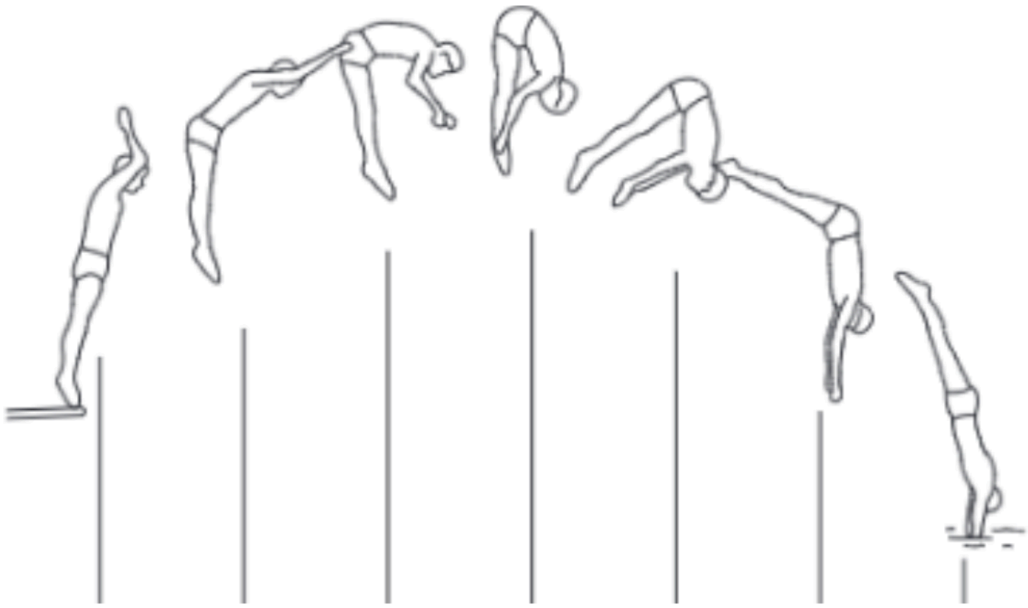
2. A figure skater (60 kg) extends arms 0.9 m from spin axis spinning at a velocity of 42rads/sec. Calculate the angular momentum.

3. A diver (70 kg) in pike at 1.4 m vs tuck at 0.6m, at a rate of 9 rads/sec. Calculate the angular momentum.

4. A baseball bat and angular momentum of 28kg.m2.s and has (2.5 kg) centre of mass 0.75 m from hands. Calculate the angular velocity.

5. A sprinter's leg (12 kg) rotates around the axis of the hip. They have an angular momentum of 36kg.m2.s and an angular velocity of 20rads/sec. Calculate the distance radius of the leg from the hip axis.

Explain the changes in moment of inertia and angular velocity if the angular momentum is conserved (6 marks)



Question 45: Define "Moment of Inertia" and write its formula. What are its units? How does the distribution of mass affect an object's moment of inertia?

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Question 46: What is the principle of "Conservation of Angular Momentum"? Why does a gymnast tuck during a somersault or twist in the air?

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Question 47: An object with moment of inertia 0.5 $kg \cdot m^2$ spins at 6 rad/s. What is its angular momentum? (Hint: $L = I \times \omega$)

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Checkpoint Quiz 3: Stability and Angular Motion

1. What is the definition of stability in biomechanics?

A. The ability to resist being tipped over

B. The speed at which an object rotates

C. The force applied to cause rotation

D. The tendency of an object to stay in motion

2. Which of the following actions would increase an athlete's stability?

A. Increasing its height

B. Narrowing its base of support

C. Lowering its center of gravity

D. Reducing its mass

3. Which sporting example best demonstrates a person increasing their stability?

A. A sumo wrestler adopting a wide stance

B. A high jumper taking off from one foot

C. A gymnast performing a handstand

D. A cyclist leaning into a turn at high speed

4. What is "torque" in the context of angular motion?

A. The force that causes linear motion

B. The rate of change of angular position

C. A rotational force that causes an object to rotate

D. The resistance of an object to angular acceleration

5. How can an athlete maximize the torque they generate?

A. Increasing the force applied

B. Applying the force closer to the axis of rotation

C. Applying the force perpendicular to the lever arm and further from the axis of rotation

D. Applying the force parallel to the lever arm

6. What two factors determine an object's angular momentum?

A. Mass and angular velocity

B. Moment of inertia and linear velocity

C. Moment of inertia and angular velocity

D. Force and time

7. Why does a figure skater pull their arms inwards to spin faster?

A. It increases the moment of inertia and decreases angular velocity.

B. It decreases angular momentum.

C. It decreases the moment of inertia and increases angular velocity.

D. It allows the gymnast to stop rotating more easily.

8. What is the principle of Conservation of Angular Momentum?

A. It states that angular momentum is always converted into linear momentum.

B. It states that angular momentum remains constant unless acted upon by an external torque.

C. It states that torque is directly proportional to angular velocity.

D. It states that the moment of inertia is always constant for a given object.

9. During a dive, why does a diver extend their body before entering the water?

A. It increases the moment of inertia and decreases angular velocity.

B. It decreases the moment of inertia and increases angular velocity.

C. It increases angular momentum.

D. It increases the moment of inertia, which decreases angular velocity allowing for a controlled landing.

10. What is moment of inertia?

A. The resistance of an object to changes in linear motion

B. The rotational equivalent of mass, describing an object's resistance to angular acceleration

C. The speed at which an object rotates

D. The force applied to stop rotation

1. **A**
2. **C**
3. **A**
4. **C**
5. **C**
6. **C**
7. **C**
8. **B**
9. **D**
10. **B**

Activity 6: Biomechanics in Your Favorite Sport & Activity 7: Technology and Biomechanics

1. Create a canva document
2. Choose your favourite sport.
3. Identify at least three different biomechanical principles (from Newton's Laws, momentum, friction, work/power, stability, or angular motion) that are crucial for successful performance in that sport.
4. For each principle, describe how it is applied and give a specific example.
5. Research a piece of sports equipment or technology that has been specifically designed using biomechanical principles to enhance performance or reduce injury.
6. Explain how the equipment works and which biomechanical principles it utilizes.

Planning Space

Criteria	Excellent (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
1. Identification of Biomechanical Principles	Three or more biomechanical principles identified clearly and accurately	Three principles identified with minor errors	Two principles identified, but may lack clarity	Fewer than two principles or inaccurate identification
2. Application and Examples	Each principle is clearly applied to the sport with detailed, specific examples	Principles are applied with mostly clear examples	Examples are general or partly unclear	Little or no application or unclear/missing examples
3. Technology or Equipment Chosen	Clearly researched, relevant technology explained in detail	Technology is mostly relevant with some explanation	Technology is loosely linked with limited explanation	Technology not explained or unrelated
4. Explanation of Biomechanical Principles in Equipment	Clear explanation of how equipment uses at least one biomechanical principle	Some explanation given, may lack depth or clarity	Brief or vague explanation of biomechanics	No link to biomechanics or unclear explanation
5. Presentation & Visual Design	Canva document is well-organized, creative, and visually engaging	Mostly clear design with good effort in visuals	Some visual effort, but cluttered or plain	Minimal effort in design or difficult to read
6. Grammar, Spelling & Clarity	No errors; writing is clear and professional	Few errors; ideas mostly clear	Several errors; some confusion in communication	Many errors that impact clarity or understanding
Comments				

Activity 8: Problem Solving Scenario A long jumper is struggling to improve their jump distance. Using your knowledge of biomechanics, suggest three different areas (e.g., technique, strength, equipment) they could focus on, and explain the biomechanical reasoning behind each suggestion.

1. **Area 1:**

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2. **Area 2:**

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3. **Area 3:**

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1. What is the definition of inertia in the context of sport?
    A. The ability of an object to resist changes in its state of motion.
    B. The force that opposes motion between two surfaces in contact.
    C. The rate at which velocity changes over time.
    D. The amount of matter in an object.

2. Which of Newton's Laws explains why a heavier object requires more force to accelerate than a lighter one?
    A. First Law
    B. Second Law
    C. Third Law
    D. Law of Universal Gravitation

3. When a high jumper pushes off the ground, the ground exerts an equal and opposite force on the jumper, propelling them upwards. Which of Newton's Laws does this illustrate?
    A. First Law
    B. Second Law
    C. Third Law
    D. Law of Conservation of Energy

4. A 5 kg shot put is accelerated at 6 m/s^2. What is the net force acting on the shot put?
    A. 0.83 N
    B. 11 N
    C. 30 N
    D. 60 N

5. What is the fundamental difference between a scalar quantity and a vector quantity?
    A. Scalar quantities have magnitude only, while vector quantities have both magnitude and direction.
    B. Scalar quantities have direction only, while vector quantities have both magnitude and direction.
    C. Scalar quantities are measured in meters, while vector quantities are measured in meters per second.
    D. Scalar quantities are always positive, while vector quantities can be negative.

6. Which of the following is an example of a vector quantity?
   A. Mass
   B. Time
   C. Velocity
   D. Speed

7. A runner covers 400 meters on a circular track and finishes at their starting point. What is their displacement?
   A. 0 meters
   B. 100 meters
   C. 400 meters
   D. 800 meters

8. A car accelerates from rest to 30 m/s in 5 seconds. What is its acceleration?
   A. 0.17 m/s^2
   B. 6 m/s^2
   C. 150 m/s^2
   D. 30 m/s^2

9. A cyclist slows down from 15 m/s to 5 m/s in 2 seconds. What is their acceleration?
   A. -5 m/s^2
   B. 5 m/s^2
   C. 10 m/s^2
   D. -10 m/s^2

10. An object moves with a constant acceleration of 2 m/s^2. If it starts at rest, what is its velocity after 8 seconds?
    A. 4 m/s
    B. 8 m/s
    C. 16 m/s
    D. 24 m/s

11. What can be said about the motion of an object if its acceleration is 0 m/s^2, and it is moving at 20 m/s?
    A. It is speeding up.
    B. It is slowing down.
    C. It is moving at a constant velocity.
    D. It is changing direction.

12. Which of the following is NOT an effect a force can have on an object?
    A. Change its shape.
    B. Change its motion.
    C. Increase its mass.
    D. Change its direction.

13. What is the key difference between "mass" and "weight"?
    A. Mass is a vector, weight is a scalar.
    B. Mass is a measure of gravity, weight is a measure of matter.
    C. Mass is the amount of matter, weight is the force of gravity on that mass.
    D. Mass is measured in Newtons, weight in kilograms.

14. Two forces act on a rugby player: 800 N to the north and 300 N to the south. What is the resultant force?
    A. 1100 N North
    B. 500 N North
    C. 500 N South
    D. 1100 N South

15. What are the units for momentum, and why is it considered a vector quantity?
    A. kg·m/s, because it has magnitude only.
    B. N·s, because it has direction only.
    C. kg·m/s, because it has both magnitude and direction.
    D. N, because it is a force.
16. A 4 kg ball is moving at 3 m/s. What is its momentum?
    A. 1.33 kg·m/s
    B. 7 kg·m/s
    C. 12 kg·m/s
    D. 24 kg·m/s

17. A 6 kg object changes its velocity from 2 m/s to 5 m/s. What is the change in momentum?
    A. 18 kg·m/s
    B. 30 kg·m/s
    C. 12 kg·m/s
    D. 3 kg·m/s

18. What does the Coefficient of Restitution (COR) primarily measure?
    A. The weight of an object
    B. The bounce of a collision
    C. The speed of running
    D. The angle of impact

19. If a basketball hits the ground at 6 m/s and bounces back at 3 m/s, what is its Coefficient of Restitution (COR)?
    A. 0.25
    B. 0.5
    C. 1.0
    D. 2.0
20. Which of these objects would likely have the lowest Coefficient of Restitution (COR)?
    A. Golf ball
    B. Squash ball
    C. Wet sponge
    D. Hard rubber ball
21. What does a Coefficient of Restitution (COR) of 1 indicate in a collision?
    A. The object does not move.
    B. The collision is perfectly elastic with no kinetic energy loss.
    C. The object sticks to the surface.
    D. The object loses all its energy.

22. A tennis ball and a cricket ball are dropped from the same height. The cricket ball bounces higher. Which ball has a higher Coefficient of Restitution (COR)?
    A. Tennis ball
    B. Cricket ball
    C. Both are the same
    D. COR doesn't affect bounce

23. What is "friction"?
    A. A force that causes objects to accelerate.
    B. A force that opposes motion between surfaces in contact.
    C. A force that pulls objects towards the center of the Earth.
    D. A force that causes objects to rotate.

24. In which sport would athletes actively try to reduce friction?
    A. Rock climbing
    B. Gymnastics (on a mat)
    C. Skiing
    D. Wrestling

25. What is the difference between "static friction" and "dynamic friction"?
    A. Static friction acts on moving objects, dynamic friction on stationary objects.
    B. Static friction is always greater than dynamic friction.
    C. Static friction is a pushing force, dynamic friction is a pulling force.
    D. Static friction is a type of air resistance, dynamic friction is a type of fluid resistance.

26. The formula for calculating frictional force is $F = \mu \times N$. What does 'N' represent in this formula?
    A. Net force
    B. Normal force
    C. Number of contacts
    D. Newton's constant

27. If the coefficient of friction is 0.5 and the normal force is 400 N, what is the frictional force?
    A. 80 N
    B. 200 N
    C. 400 N
    D. 800 N

28. A bobsled slides on ice with a dynamic coefficient of friction of 0.08. If the normal force is 1000 N, what is the frictional force?
    A. 8 N
    B. 80 N
    C. 125 N
    D. 800 N

29. A runner's shoe experiences a static frictional force of 450 N on a track. If the normal force is 750 N, calculate the coefficient of static friction.
    A. 0.3
    B. 0.6
    C. 1.67
    D. 300

30. What is "work" in the context of physics?
    A. The rate at which energy is transformed.
    B. The application of a force over a distance.
    C. The ability to do work.
    D. The amount of matter in an object.

31. A weightlifter lifts a 50 kg barbell vertically by 2 meters. How much work is done against gravity (assume $g = 9.8\ m/s^2$)?
    A. 100 J
    B. 250 J
    C. 490 J
    D. 980 J

32. What is "power" in the context of physics?
    A. The total energy expended.
    B. The work done divided by the time taken.
    C. The force applied multiplied by distance.
    D. The rate of change of momentum.
33. A cyclist does 1200 J of work in 3 seconds. What is their power output?
    A. 400 W
    B. 3600 W
    C. 1200 W
    D. 300 W

34. A gymnast applies a torque of 10 Nm and has an angular acceleration of 2 rad/s². What is her moment of inertia?
    A. 0.2 kg·m²
    B. 5 kg·m²
    C. 12 kg·m²
    D. 20 kg·m²

35. Which action produces more torque: 30 N at 0.3 m from the pivot or 20 N at 0.5 m from the pivot?
    A. 30 N at 0.3 m (9 Nm)
    B. 20 N at 0.5 m (10 Nm)
    C. Both produce the same torque.
    D. Cannot be determined.

36. How long does it take a spinning top to reach 20 rad/s from rest if it accelerates at 4 rad/s²?
    A. 4 seconds
    B. 5 seconds
    C. 8 seconds
    D. 24 seconds

37. What is the principle of "Conservation of Angular Momentum"?
    A. Angular momentum is always converted into linear momentum.
    B. Angular momentum remains constant unless acted upon by an external torque.
    C. Angular momentum is directly proportional to angular acceleration.
    D. Angular momentum decreases as the moment of inertia decreases.

38. Why does a gymnast tuck during a somersault in the air?
    A. To increase their moment of inertia and slow down rotation.
    B. To decrease their moment of inertia and increase angular velocity.
    C. To increase their angular momentum.
    D. To reduce air resistance.

39. An object with a moment of inertia of 0.8 kg·m² spins at 5 rad/s. What is its angular momentum ($L = I \times \omega$)?
    A. 0.16 kg·m²/s
    B. 4 kg·m²/s
    C. 5.8 kg·m²/s
    D. 6.25 kg·m²/s

40. Which factor primarily influences the force of friction according to the syllabus statements?
    A. The speed of the object
    B. The type of materials in contact
    C. The surface area of contact
    D. The temperature of the surfaces

Paper 1B: Data Response Questions (25 Marks)

Question 1: A diver performs a somersault from a diving board. The dive can be analyzed using various biomechanical principles.

(a) A diver pushes off the diving board.

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(i) Identify the type of lever system involved when the diver applies force to the board just before takeoff. [1]

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(ii) Explain how Newton's Third Law applies to the diver's takeoff from the board. [3]

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(b) Once airborne, the diver performs a somersault.

(i) Define angular momentum. [2]

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(ii) Explain how the diver manipulates their body position during the somersault to increase their angular velocity. Refer to the principle of conservation of angular momentum in your answer. [5]

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(c) A diver hits the water.

(i) Explain how impulse and momentum are related in the context of the diver entering the water. [4]

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(ii) Describe how a diver attempts to minimize splash upon water entry, applying biomechanical principles. [5]

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(d) Discuss two ways in which technological advancements in diving boards or pool design could further improve a diver's performance, referencing biomechanical principles. [5]

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Paper 2: Extended Response and Data Analysis (72 Marks)

Question 1: A sprinter's performance depends heavily on the efficient application of linear and angular motion principles.

(a) Define the following terms and provide a sporting example for each:

(i) Acceleration [2]

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(ii) Linear Momentum [2]

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(iii) Torque [2]

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(b) A sprinter with a mass of 70 kg starts from rest and reaches a velocity of 10 m/s in 2.5 seconds.

(i) Calculate the average acceleration of the sprinter. [2]

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(ii) Calculate the net force acting on the sprinter during this acceleration phase. [2]

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(iii) Calculate the work done by the sprinter during this acceleration phase, assuming they cover a distance of 12.5 meters. [2]

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(iv) Calculate the average power output of the sprinter during this acceleration phase. [2]

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(c) Discuss how Newton's Laws of Motion are applied by a sprinter throughout a 100-meter race, from start to finish. [12]

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Question 2: Friction plays a critical role in various sports, sometimes needing to be maximized and other times minimized.

(a) Define static friction and dynamic friction. Discuss which is typically greater and explain why. [4]

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(b) A high-performance running track is designed to optimize a sprinter's performance. Explain how the surface material of the track is engineered to modify friction for improved speed and grip. [6]

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(c) Consider the sport of curling. (i) Explain why curlers sweep the ice in front of the stone. Relate your answer to the concepts of friction and temperature. [6]

(ii) Discuss how the design of the curling stone (e.g., its bottom surface) minimizes friction with the ice. [4]

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(d) A golfer applies wax to their clubface to reduce friction with the ball at impact. Evaluate the effectiveness of this strategy based on biomechanical principles. [4]

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Paper 1A: Multiple Choice Questions

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2. B
3. C
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8. B
9. A
10. C
11. C
12. C
13. C
14. B
15. C
16. C
17. A
18. B
19. B
20. C
21. B

22. B
23. B
24. C
25. B
26. B
27. B
28. B
29. B
30. B
31. C
32. B
33. A
34. B
35. B
36. B
37. B
38. B
39. B
40. B

Paper 1B: Data Response Questions

1(a)

(i) First-class lever. [1]

(ii) Diver pushes down on the board (action force); [1] Board pushes up on the diver (equal and opposite reaction force); [1] This reaction force propels the diver upwards. [1]

(b)

(i) Angular momentum is the product of an object's moment of inertia and its angular velocity; [1] It is a measure of the amount of rotation an object has. [1]

(ii) Diver tucks their body/pulls limbs closer to axis of rotation; [1] This decreases their moment of inertia (I); [1] According to the principle of conservation of angular momentum ($L = I \times \omega$); [1] Since angular momentum (L) is conserved (assuming negligible external torque); [1] Angular velocity (ω) must increase to compensate for the decrease in I. [1]

(c)

(i) Impulse is defined as force multiplied by time (Impulse = $F \times \Delta t$); [1] Impulse is equal to the change in momentum (Impulse = Δp); [1] When the diver enters water, there is a rapid change in their momentum; [1] The water exerts a force over a short time causing this change. [1]

(ii) Diver aims for a vertical/streamlined entry; [1] Minimizes surface area exposed to water/reduces resistance; [1] Keeping body compact/hands together/head tucked; [1] Cuts through water with minimal disturbance/displacement; [1] Reduces splash/minimizes impact force. [1]

(d)

a. Optimized Diving Board Material/Spring Mechanism:

i. New materials could have a higher coefficient of restitution/better elastic properties; [1]

ii. Allowing more efficient energy transfer/greater initial upward velocity; [1]

b. Advanced Pool Design (e.g., water agitation systems):

i. Bubblers/sprayers on the water surface; [1]

ii. Breaks surface tension/reduces water resistance/makes water "softer"; [1]

iii. Minimizes splash/reduces impact force on diver. [1]

Max 2 points if only general improvement is discussed without specific biomechanical link.

Paper 2: Extended Response and Data Analysis

Question 1: Analyzing Linear and Angular Motion in Sprinting

(a) (i) Acceleration: The rate of change of velocity; [1] Example: A sprinter increasing speed from the blocks. [1]

(ii) Linear Momentum: Product of mass and velocity (p=mv); [1] Example: A bowling ball hitting pins. [1]

(iii) Torque: Rotational force/force causing rotation around a pivot; [1] Example: A cyclist pushing down on a pedal. [1]

(b)(i) $a = (10 - 0) / 2.5 = 4 \text{ m/s}^2$. [2]

(ii) $F = m \times a = 70 \text{ kg} \times 4 \text{ m/s}^2 = 280 \text{ N}$. [2]

(iii) $W = F \times d = 280 \text{ N} \times 12.5 \text{ m} = 3500 \text{ J}$. [2]

(iv) $P = W / t = 3500 \text{ J} / 2.5 \text{ s} = 1400 \text{ W}$. [2]

(c) a. Newton's First Law (Inertia):

i. Sprinter is initially at rest in blocks; [1]

ii. Requires an external force to overcome inertia and start moving; [1]

iii. Maintains state of motion during the race unless acted upon by forces like air resistance. [1]

b. Newton's Second Law (F=ma):

i. Force applied against blocks determines initial acceleration; [1]

ii. Greater net force (propulsive - resistive) leads to greater acceleration; [1]

iii. Sprinter continuously applies force to overcome air resistance and maintain speed/acceleration. [1]

iv. F=ma applies during acceleration phases and any changes in velocity. [1]

c. Newton's Third Law (Action-Reaction):

i. Starting Blocks: Sprinter pushes back on blocks (action); [1]

ii. Blocks push forward on sprinter (reaction), propelling them forward. [1]

iii. Foot-Ground Contact: Each stride, foot pushes down/backward on track (action); [1]

iv. Track pushes up/forward on foot (reaction), generating propulsive force. [1]

v. Arm Swing: Backward arm swing creates forward reaction force assisting momentum. [1]

2(a)

a. Static Friction: Force opposing the start of motion between surfaces in contact. [1]

b. Dynamic Friction: Force opposing ongoing motion between sliding surfaces. [1]

c. Static friction is typically greater than dynamic friction; [1]

d. Because more force is required to break the initial intermolecular bonds/interlocking between surfaces than to maintain motion once they are sliding. [1]

(b)

a. Track surfaces are made of synthetic materials (e.g., rubber); [1]

b. Designed to provide high coefficient of static friction with sprinter's spikes/shoes; [1]

c. Allows powerful push-off/prevents slipping during acceleration; [1]

d. Texture/granules on surface enhance grip; [1]

e. Minimizes dynamic friction once foot is lifted/in flight phase; [1]

f. Promotes efficient energy transfer and forward propulsion. [1]

(c)

(i) Curlers sweep to reduce friction between stone and ice; [1] Sweeping creates a thin layer of water/melts ice surface; [1] This water acts as a lubricant; [1] Which lowers the coefficient of dynamic friction; [1] Allows stone to travel further/with less deceleration/greater control. [1]

(ii) Curling stone has a concave bottom/running band; [1] Only a small ring is in contact with the ice; [1] Concentrates weight/pressure over small area; [1] Promotes localized melting/formation of water film under the running band, reducing friction. [1]

(d)

a. Ineffective/Detrimental: Applying wax to reduce friction on a golf clubface is generally detrimental; [1]

b. Golf performance relies on sufficient friction/spin between clubface and ball; [1]

c. Friction imparts backspin/sidespin for trajectory control, lift, and accuracy; [1]

d. Reducing friction would lead to less spin/uncontrolled flight/reduced lift. [1]