GCE Physical Education 2016 Component guide 3: Biomechanical movement

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Introduction

The specification has been developed in consultation with the teaching community, higher education, learned societies and subject associations. Tutors from a range of schools and colleges – in focus groups, phone interviews and face-to-face conversations – have provided feedback at each stage and have helped us to shape the specification. Physical Education academics in UK universities have helped us understand how to build on the strengths of the 2008 A level specification and advised on how progression to undergraduate study could be improved.

Component Guide 3: Biomechanical movement provides an overview of the new specification relating to this topic, to help you get to grips with the changes to content and assessment, and to help you understand what these mean for you and your learners.

Overview of changes

From September 2016, GCE Physical Education will be a linear qualification. This means that all examinations must be sat at the end of the two-year course. From September 2016, AS level Physical Education will be a stand-alone qualification. This means that it cannot be used to contribute towards an A level Physical Education grade. More information about the changes to subject content are given later on in the guide.

Each award will have two examinations – a scientific exam and a Psychological and Social exam. This is a change from 2008. The science examination comprises Topic 1: Applied anatomy and physiology and Topic 2: Exercise physiology and applied movement analysis. A new topic area is Biomechanical movement, which is embedded within both the anatomy and the physiology. This is a topic area that was not included in the 2008 specification.

There is an increased focus on the theoretical content, now worth 70 per cent of the grade.

The subject content includes a more detailed need to develop quantitative skills – now worth up to 5 per cent of the qualification.

Learners will be able to demonstrate an understanding of movement analysis through the use of examples to include linear motion, angular motion, projectile motion and fluid mechanics.

Where AS differs from A level:

All learners will cover the anatomy and physiology section of movement analysis – to include levers, newton's laws, calculation of forces and stability.

Those who go on to study A level will also complete the exercise physiology part and be able to demonstrate an understanding of movement analysis through the use of examples to include **2.4**

Linear motion, 2.5 Angular motion, 2.6 Projectile motion and **2.7 Fluid mechanics**. A level topics are shown in bold type throughout the booklet.

Key content

Topic 1: Applied anatomy and physiology

Topic 1.1.4

The components of an anatomical lever are the fulcrum (F), where the force is applied (effort) (E) and the load/resistance (R). The relationship between these determines the type of lever.

Learners must have knowledge and understanding of how the body uses the lever systems (1st, 2nd and 3rd class) in physical activity and sport.

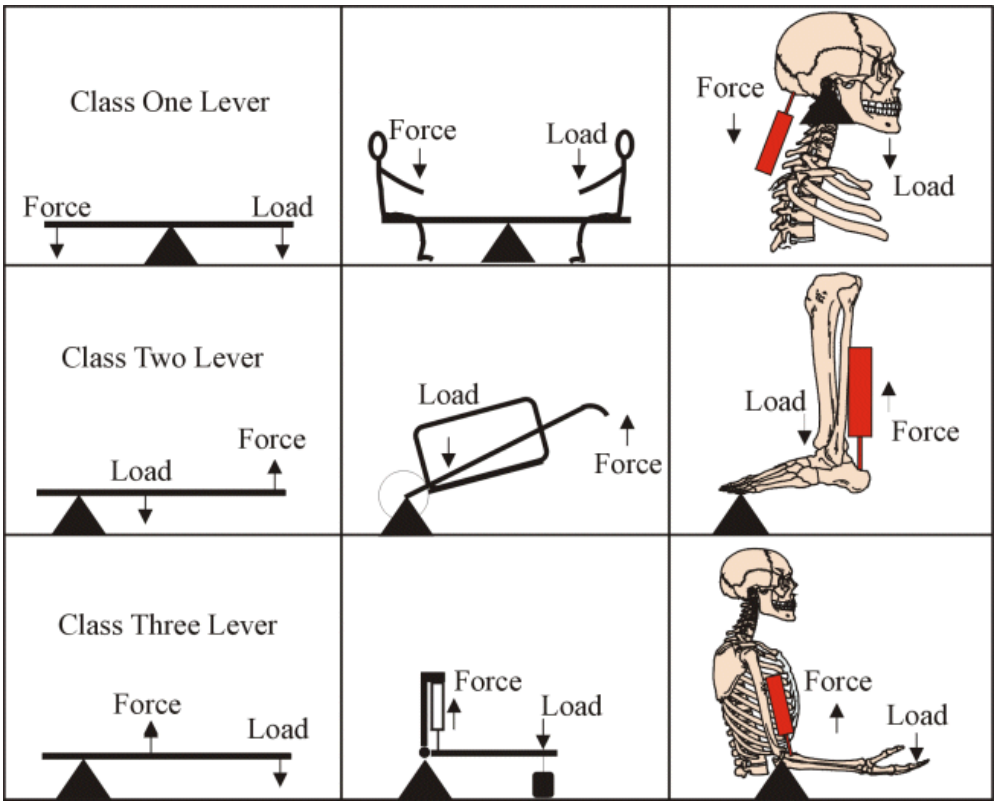

Figure 1

Image source: https://waergo.com/Dev/Survey/images/Fig2small.gif

This should include the mechanical advantages and disadvantages of each lever. **Mechanical advantage** is the relative efficiency of the lever because the optimal length of an implement is determined by the strength of the performer. If the load/resistance is close to the fulcrum and

the effort/force is applied far from the fulcrum, a small effort/force exerted over a relatively large distance can move a large load over a small distance.

However, when the load is far from the fulcrum and the effort/force is applied near the fulcrum, the force exerted by the muscle must be greater than the load to be moved or supported. This lever system is a *speed lever* and operates at a **mechanical disadvantage**.

Having a **short effort arm** allows for **faster movements** over a larger range whereas having a **short resistance arm** allows a **heavier load** to be lifted.

For example, the further it is between the fulcrum and the resistance the greater speed that can be generated. The greater distance between the effort and the fulcrum the less effort is required to move a resistance. In sport, rackets are often used to increase this length, which will increase the force that an object is struck with.

Knowledge of levers can also be beneficial to performers when applying certain tactics. For example, when serving in tennis the player could aim a serve at the opposition's body. This will reduce the opposition's swing and therefore reducing the speed of the return. The same example could be used in cricket, whereby the bowler could bowl a 'tight' line which will in turn reduce the swing of the batter and the force applied to the shot.

Learners should also be able to analyse the effects of different techniques on performance, such as an athlete throwing a javelin with a bent or straight arm.

Useful resources:

- https://www.slideshare.net/klharrison/biomechanics-1-levels-and-planes-axes?qid=3da12cbc-dbff-4a0b-a2f2-c54af20d35bd&v=&b=&from_search=3
- www.slideshare.net/spanglerscience/muscle-leversppt-presentation
- http://sciencelearn.org.nz/Contexts/Sporting-Edge/Looking-closer/What-levers-does-your-body-use?
- http://anatomyandphysiologyi.com/lever-systems-bone-muscle-relationships/
- www.humankinetics.com/excerpts/excerpts/levers-work-to-create-movement-in-the-human-body

- https://www.pearsonschoolsandfecolleges.co.uk/Secondary/PhysicalEducationAndSport/14-16/EdexcelGCSEPE2016/Samples/Samples-from-Edexcel-GCSE-(9-1)-PE-Student-Book/Component-1-Topic-2-(Movement-analysis)-Sample.pdf

- https://www.youtube.com/watch?v=FAzFNyKK3sQ- This clip has examples of each of the three classes of levers

- https://www.youtube.com/watch?v=y3MrdI8BalA – this clip also has examples of each of the three classes of levers

Topic 1.1.5

All three laws need to be understood, learners must have knowledge and understanding of the laws and how each applies to a sporting example.

1. Newton's First Law (The law of inertia)

Every object in a state of rest or uniform **motion** tends to remain in that state of rest or **motion** unless an external force is applied to it.

An example of the law of inertia can be seen in volleyball at the highest arc of a server's toss, that moment when the ball is nearly motionless. It will either fall straight down due to the force of gravity, or sail across the net from the force of a hand striking it. In an example of a moving object, a spiked volleyball moves in a fairly straight line downwards unless deflected by the force of the net, receiver's forearms, blocker's hands or floor.

2. Newton's Second Law (The law of acceleration)

Learners should be using **9.81 m/s²** as acceleration due to gravity. The weight of an athlete is their mass multiplied by 9.81 m/s².

The calculation of force and resultant force: a mass of 1kg exerts a force of 9.81N (10N will be accepted as you can see in the mark scheme on the Sample Assessment Materials question 2, in case learners do not have a calculator). Learners must be able to do a calculation of Force (**Force = Mass x Acceration or F=ma**). Learners should also know how to calculate Acceleration (**Acceleration = Force ÷ Mass or a = F/m**).

The law of acceleration, states that an increase in the velocity of a moving object is directly proportional to the force applied and inversely proportional to the object's mass. The object will accelerate in the direction of the external force.

For example:

Volleyball: The faster the arm swing (acceleration), the more force is exerted on a spiked volleyball at the moment of contact.

Basketball: When you shoot the basketball, it will accelerate in direction of the force exerted on it by the player. If the player shot a ball weighing 0.62kg with 3.2N of force from the free throw line, and then used the same amount of force to shoot once again from the 3-point line, the ball would not make it. This is due to the fact that the force would be too low for the distance and acceleration would also decrease.

Sprinter: a sprinter can increase their acceleration by applying more force which is created by the contraction of the relevant muscles in the lower limbs (in the example the mass is constant).

Or, if a person were to throw a larger object like a bowling ball with the same force, the net force on the bowling ball would be less, acceleration would also decrease, and it would not go as far.

3.Newton's Third Law (The law of action and reaction)

For every action there is an equal and opposite reaction.

For example, in weight lifting the lifter exerts a force on the weight to hold it above their head, but gravity exerts an equal and opposite force of their weight back down to the ground.

In basketball, as the shooter shoots the ball, the shooter's hand exerts a force on the ball pushing it towards the basket. The ball in turn exerts a force upon the shooter's hand.

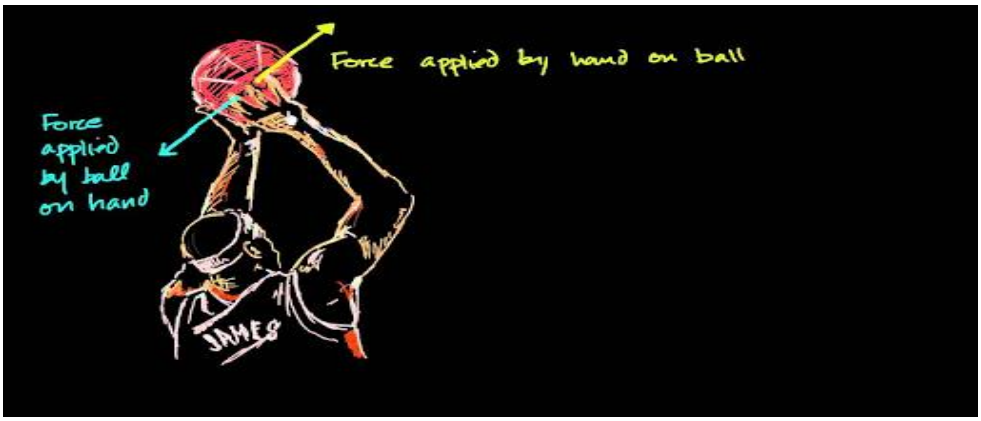

Figure 2

Source: https://www.khanacademy.org/partner-content/lebron-asks-subject/lebron-asks/v/lebron-asks-about-newton-s-3rd-law

Useful resources:

- www.sports-training-adviser.com/lawsofmotion.html
- http://www.teachpe.com/biomechanics/linear-motion/newtons-laws-of-motion
- www.proteacher.org/c/972_laws_of_motion.html

- https://www.youtube.com/watch?v=MAm6LOUnJ80- provides practical examples of all three laws
- https://www.youtube.com/watch?v=iwP4heWDhvw- Second Law practical example with rocket firing
- https://www.youtube.com/watch?v=R8qygu1RUOI- An applied practical example of 3rd law in Basketball
- https://www.youtube.com/watch?v=8eL0ESxP9dI- Three laws demonstrated on a trampoline
- https://www.youtube.com/watch?v=F9COtJBBzhk- Three laws demonstrated in skateboard/BMX

Topic 1.1.6

Learners should be aware of the principles related to the stability of the body in relation to the centre of mass. Being stable, unstable or neutral depends on the following:

- position of the line of gravity relative to the limits of the base
- the mass of the body
- height of centre of gravity relative to the base
- area of the support base

This is applied in sport, for example a swimmer at the start of a race has the line of gravity close to the forward limit of the base so when the gun goes off they can move forward easily. This is also seen when a track athlete rocks forward into the set position in athletics.

Rugby: when preparing to tackle in rugby, stability can be increased by increasing the size of the base of support and by bringing the centre of gravity lower towards the base of support. This makes them less likely to be knocked over by the ball carrier.

High Jump: the Fosbury Flop keeps the centre of mass low to the ground, and on most occasions, below the bar. The lower the centre of mass, the less energy is required to successfully jump over the bar. With regards to the Scissor kick technique, the bar is below the centre of mass, which makes it a less efficient technique.

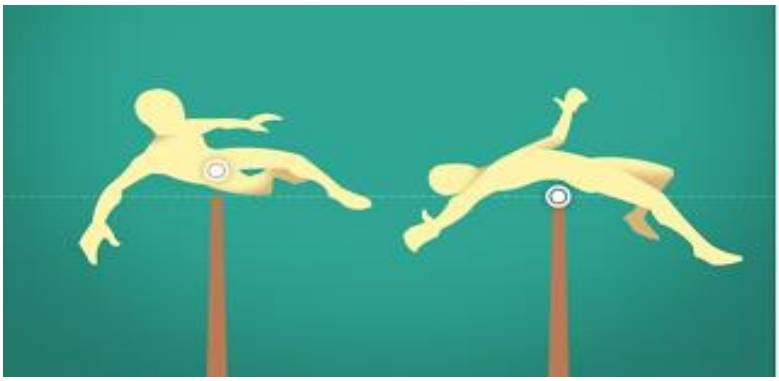

Figure 3

https://sites.google.com/site/s410285053/physics/mini-project-4?tmpl=%2Fsystem%2Fapp%2Ftemplates%2Fprint%2F&showPrintDialog=1

Useful resource:

- https://www.youtube.com/watch?v=xBsuBgFOE-U- Considers stability and centre of mass relationship

Topic 1.1.7

The calculation of force and resultant force: a mass of 1kg exerts a force of 9.81N (10N will be accepted as you can see in the mark scheme on the Sample Assessment Materials in case learners do not have a calculator). Learners must be able to do a calculation of force (mass x acceleration).

Topic 2: Exercise physiology and applied movement analysis

Topic 2.4: Linear motion

Linear motion refers to the change in position of an object in a straight line. This section requires learners to understand how to calculate:

1. **Speed (how fast an object is travelling)**

- **Speed is a scalar quantity (has size but no direction is considered).**
- **Speed = distance (m)/time (sec)(s = d/t)**

2. **Velocity (speed in a particular direction)**

- **This a vector quantity and therefore has size/magnitude and direction**
- **Velocity = displacement (m)/time (sec) and uses the units metres per second (m/s)**

Please note the difference between distance and displacement. Distance measures the actual ground covered. Distance can only be positive. Displacement is measured with reference to a specific point. It is a straight line from the starting point to the end point. It is therefore also the shortest distance between two points and can be positive or negative. For example, a 400m race has a displacement of 0m and a distance of 400m.

3. **Acceleration (is the rate of change in velocity)**

- **It is also a vector quantity (has size/magnitude and direction)**
- **Acceleration = (final velocity – initial velocity)/time taken (m/s/s) or (m/s^2).**
- **The formula can also be written as change in velocity/ time taken (m/s/s) or (m/s^2).**

Learners will need to be able to draw graphs and to complete calculations of the distance and displacement, speed and average speed, velocity and acceleration. Speed = distance/time (s =d/t); Velocity = displacement/time or distance/time (m/s); Acceleration = (final velocity – initial velocity)/time taken (m/s^2).

They will also need to be able to plot, label and interpret graphs of motion. To include distance/time, speed/time graphs and velocity/time graphs. For example, in the Sample Assessment Materials Q9aii in the A level Scientific Principles paper with its mark scheme showing the graph.

Useful resources:

- **www.physicsclassroom.com/class/1DKin/Lesson-1/Speed-and-Velocity is a useful website for an explanation of linear motion**

- **www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/forces/represmotionrev4.shtml has a simple explanation of acceleration**

Topic 2.5: Angular motion

Angular motion is when there is motion of a body about a fixed point or fixed axis therefore causing rotation or spin as seen with a diver or gymnast somersaulting. The

principles that applied to linear motion also apply to angular motion (rotational movement) i.e. velocity, displacement and acceleration.

Learners will need to know the factors affecting moment of inertia which are mass and distribution of mass from axis of rotation.

Learners must understand the effects of increasing or decreasing the moment of inertia when rotating about an axis (whole body or specific joint).

For example, when performing a somersault in diving, the moment of inertia is decreased (by tucking arms and legs in), but the angular velocity is increased, therefore an increase in rotations. On the other hand, if a diver wanted to enter the water straight and controlled they would straighten their body to increase the moment of inertia. This in turn would slow down rotation and reduce angular velocity. Learners should be able to use this knowledge to analyse techniques, for example, to explain why a performer may have over or under rotated when performing a somersault on a trampoline.

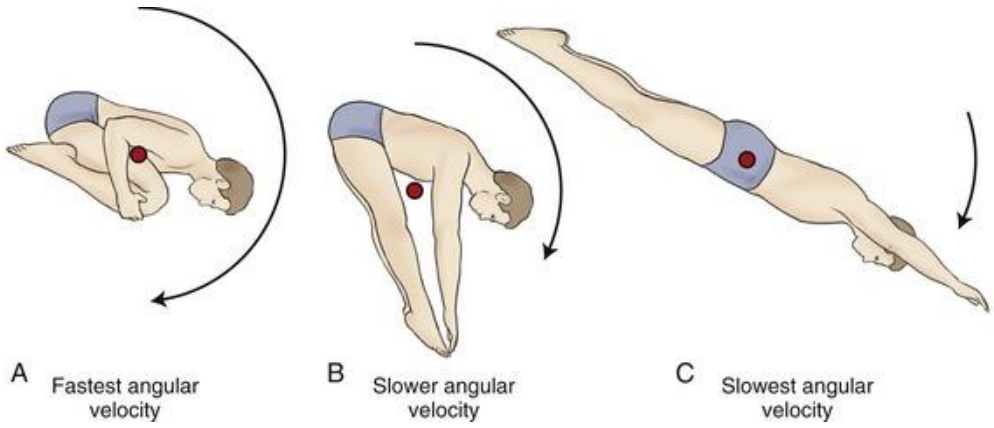

Figure 4

https://clinicalgate.com/biomechanical-principles/

If there are no outside forces acting on a symmetrical rotating body, angular momentum is conserved. Conservation of angular momentum during flight, moment of inertia and its relationship with angular velocity refers to the fact that angular momentum stays the same. Using the example above, in order to slow down, a gymnast or diver needs to extend out of the tuck position before they land to decrease angular momentum.

Useful resource:

- **www.wired.com/2012/08/diving-and-the-moment-of-inertia/ This is in more detail than learners need, but a useful background read for information surrounding the factors that can increase and decrease moment of inertia**

Topic 2.6 Projectile motion

Objects, implements and even the human body can act as projectiles in sport. Learners will need to understand practical examples of projectile motion and show knowledge, understanding and application of projectile motion in refining technique in different sporting contexts. For example, the angle that you release an object at in athletics field events.

There are forces acting during flight that affect projectile motion:

- **gravity**
- **air resistance**
- **lift forces**

Learners must be able to analyse how these factors affect different sporting events.

There are also factors that determine the horizontal displacement of a projectile:

- **velocity of release**
- **height of release**
- **angle of release**

Discussing how an athlete may modify technique to take these into account will be important. For example, the optimal angle of release for basketball shooting is between 48-55 degrees above the horizontal axis, however in javelin the optimal angle of release between 32-38 degreees. However, this is all dependent on the other two factors.

Figure 5

http://www.instructables.com/id/The-3-Point-Parabola-Increase-Shot-Efficiency-Usin/

A coach may modify technique or there may be technique or technology changes to equipment to facilitate this.

Useful resources:

- **www.study.com/academy/lesson/projectile-motion-definition-and-examples.html - is a useful look at projectile motion.**

- **https://www.youtube.com/watch?v=HOiH1eVCggw- a clip of Steph Curry's shooting mechanics**

- **http://www.quinticsports.com/projectile-motion/ - research into optimising technique to improve performance in javelin**

Topic 2.7: Fluid mechanics

This topic considers when a force acts because something moves through air (aerodynamics) or water (hydrodynamics). The law of resistance states that the faster an object moves (increase in velocity), the more resistance it will encounter.

Learners will need practical examples to support their theoretical knowledge. Examples such as swimming through water and flight of tennis balls or cricket balls through air will assist in the understanding of this topic. For example, how are flight paths for a shot put, a tennis ball and a shuttlecock different, and analyse why.

There are various factors affecting fluid friction and air resistance:

- **velocity**
- **drag force**
- **mass**
- **streamlining and surface characteristics of body.**

Learners will need knowledge and understanding of these factors and to apply them to an example, such as the swimmer who wears a particular design of swim suit to assist with streamlining and reduction of drag forces. Knowledge of this topic will also enable learners to understand how it has influenced technological advancements in technique modification, clothing/suits and equipment/apparatus. For example, air resistance will affect these events: sprinting, cycling, projectiles such as shot put, shuttlecock and tennis ball and a javelin throw.

Learners need an understanding of interaction of lift forces with objects:

- **upward and downward lift forces**
- **angle of attack**
- **the Bernoulli effect.**

These topics are discussed in Wesson, et al.'s textbook in detail.

Learners must have knowledge and understanding of types of spin:

- **topspin**
- **backspin**
- **sidespin**
- **Magnus effect and how they impact on flight path and bounce.**

For example, learners should be able to analyse the effects of different types of spin on different balls (a tennis ball, a cricket ball, etc.) and explain how it affects performance.

Useful resources:

- **https://theconversation.com/fast-suits-and-olympic-swimming-a-tale-of-reduced-drag-and-broken-records-7960 - reducing drag in swimming**
- **https://www.youtube.com/watch?v=-aUOzYAuL48 - this clip demonstrates the technology that has been devised in cycling technique and equipment to reduce drag**

- **www.slideshare.net/klharrison/biomechanics-4 - is a useful power point for presenting projectile motion, lift forces and types of spin.**
- **https://www.youtube.com/watch?v=W4tGaoSz14g & https://www.youtube.com/watch?v=jMNBlrX9Zfo- these clips help to explain the science behind swing and spin in cricket bowling**

Delivery approaches including ideas for practical delivery

This unit lends itself to a practical approach as much as possible.

Topic	Ideas for delivery
Levers	Making levers models, weights session in a gym identifying the different levers, demos (including opening a door, tightening a nut with fingers and then spanner, nut crackers, crow bar, using a screwdriver to open a tin of paint, arm wrestling, cutting a thin piece of paper and then thick card using only the points on scissors). Watch the following YouTube video on levers https://www.youtube.com/watch?v=F6X_ydbOR1g (class 1, 2 and 3 levers with exercise examples) then create your own YouTube video explaining the levers with practical examples of your own. Your own videos must include advantages and disadvantages.
Newton's Three Laws of Motion	Tennis play – forces acting on the tennis ball in different scenarios. Use practical examples to illustrate all the laws: Newton's 3rd law – ice skater standing at the wall pushes on wall and goes back or letting go of a blown up balloon (balloon moves opposite direction to movement of air) Watching a rugby tackle and what happens to both players. Time everyone running 10m, 20m, 30m, 40m, 50m, etc. graph times. Use a chart and calculate speeds of runners at different points. Use

	a compass to determine direction and calculate velocity. Calculate mass of runners and then acceleration. Try running and stopping on different surfaces to introduce friction. Observe a game of kickball and then write a paragraph using the words motion, time, distance velocity, speed, acceleration, force, friction and inertia. Newton's 3rd law – via bouncing basketballs – the harder you push down the more it bounces up. Think of their own practical examples using words force, exert, action and reaction. Newton's 2nd law by penny push (coin collision) – push two coins into each other and observe what happens. Create a prezi using Newton's three laws of motion – must be applied to practical examples. Watch a space rocket launch for Newton's laws of motion. For lots of practical ideas about teaching this topic go to: www.proteacher.org/c/972_laws_of_motion.html
Calculation of forces	Practical examples and attempt calculations.
Linear motion	**Calculations of distance travelled, or use of apps to record distances travelled. Do practical calculations of split times, acceleration and velocity in different events. E.g. Usain Bolt in every 10m of a 100m race and compare to your scores.** **Draw distance-time graphs.** **Draw velocity-time graphs or speed-time graphs using practical investigations. Be able to comment on the gradients.**
Angular motion	**Trampolining or gymnastics practical to include rotations, twists and spins plus observations of elite diving, trampoline and gymnastics clips. For example, turn with arms in and out to spin faster, tuck v pike somersaults to observe differences in speed of rotation.** **Mark different axes of rotation on a diagram of a skeleton.**
Projectile motion	**Practicals in athletics field events looking at angles of release – analysis through videoing and comparison to perfect model. Calculate angles of release and distance achieved.**
Fluid mechanics	**Use of tennis spins and cricket ball spins as examples, reduction of drag in bikes, learners designing new aerodynamic clothing for a sport of their choice, looking at kit and equipment and how it is designed.** **Practicals where learners do the different types of spin themselves with tennis and cricket balls.** **Swimming is a good example for drag and streamlining.**

Quantitative skills guidance

These topics fit very well with the quantitative skills requirement. They lend themselves to calculation style questions.

Examples might include:

- Drawing, plotting and interpreting distance-time, or velocity-time or speed-time graphs and being able to analyse and interpret them.
- Calculating mass, forces, resultant forces, speed, velocity and acceleration. You must remember to use the correct units.

Sample questions

Regular testing of learners on the key terms in the glossary that are part of the specification is important (see Appendix 7, page 88).

When practising questions ensure that tutors and learners are using the command words in the specification and that learners understand the requirements of each command word.

The Sample Assessment Materials contain examples of Biomechanical movement questions. In the A level SAMs there are questions 2A and 9A.

In the AS SAMs there are example questions numbers 6a and b.

To ensure understanding questions could be given to learners starting:

- Newton's… law is used…
- Calculate…
- Graph…
- Using examples explain the…
- Linear motion…
- Fluid mechanics…
- Projectile motion is used in sport…
- Angular motion helps us to understand…

Resources and references

Useful textbooks

- Burkett, B. (2010) *Sports mechanics for coaches*, Champaign, IL: Human Kinetics
- McGinnis, P. (2013) *Biomechanics of Sport and Exercise*, Champaign, IL: Human Kinetics.
- Blazevich, A. (2016) *Sports Biomechanics: The Basics: Optimising Human Performance*, London: A&C Black Publishers (2nd edition)
- Hay, J. (1993) *The Biomechanics of Sports Techniques (Fourth Edition)*, Upper Saddle River, NJ: Prentice Hall
- Wesson, K., et al. (2005) *Sport and PE: A Complete Guide to Advanced Level Study (Third Edition)*, London: Hodder Education

Useful websites

Levers:

- www.sciencelearn.org.nz/Contexts/Sporting-Edge/Looking-closer/What-levers-does-your-body-use
- www.humankinetics.com/excerpts/excerpts/levers-work-to-create-movement-in-the-human-body
- www.brainmac.co.uk/levers

Newton's Laws of Motion:

- www.explainthatstuff.com/motion.html
- www.proteacher.org/c/972_laws_of_motion.html

Linear motion:

- www.physicsclassroom.com/class/1DKin/Lesson-1/Speed-and-Velocity
- www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/forces/represmotionrev4.shtml
- https://www.pearsonschoolsandfecolleges.co.uk/FEAndVocational/Sport/ALevel/OCRALevelPE2008/Samples/A2PEStudentBookSamplePages/PEforOCR(A2)SBCH11.pdf

Angular motion:

- www.saburchill.com/physics/chapters/0022.html
- www.wired.com/2012/08/diving-and-the-moment-of-inertia/ (background reading for tutors)

Projectile motion:

- www.study.com/academy/lesson/projectile-motion-definition-and-examples.html
- www.physicstutorials.org/home/mechanics/1d-kinematics/projectile-motion

Fluid mechanics:

- http://www.slideshare.net/klharrison/biomechanics-4