SCHOLAR Tutor Handbook

SQA CfE Higher Physics
Unit 1: Our Dynamic Universe

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SCHOLAR Tutor's Handbook Unit 1: SQA CfE Higher Physics

1. SQA CfE Higher Physics

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Contents

Topic 1

Motion: equations and graphs

1.1 Vectors

This section is an introduction to the use of vectors. By the end of the it, the student should understand the difference between scalar and vector quantities, and be able to name examples of each. The student should also be able to perform the vector addition of two vectors, and to find the orthogonal components of a vector. The theme of vectors runs through this entire unit so it is tackled at some length at the beginning of the unit. Students may find they have to refer back to this section repeatedly during their study of Unit 2.

1.1.1 Distance and displacement

Activity: Distance and displacement

This is a short activity which tests whether the student understands the difference between displacement and distance. It is based on the first diagram included in the student notes. Several points are plotted on an *x-y* graph. The student is asked to compare points with the same distance or displacement from the axis. This exercise is not suitable as a class activity.

1.1.3 Combining vectors

Activity: Adding collinear vectors

This online activity allows several collinear vectors to be added together.

The user is able to input the values of up to six collinear vectors. Once all the values have been typed in, the vectors will appear on an *x-y* axis. The vectors then rearrange themselves nose-to-tail, and the resultant vector appears, along with its value.

This simulation can be used as a class activity or by an independent learner. As a class activity, it might be useful to start by adding just two vectors, then showing how the same "nose-to-tail" technique works no matter how many vectors are being added. Once familiar with the technique, students could be shown a set of vectors and asked to calculate the resultant before the simulation is run.

Another idea for more advanced students might be to start with two or three vectors, and ask them to find what additional vector would be needed to produce a resultant of zero.

Activity: Crossing the river

A situation which is often used to illustrate vector addition is that of a boat crossing a fast-flowing river. This activity is an on-screen simulation of this situation.

The boat is initially positioned at right angles to the river bank. As it moves across the river, the flow of the river pushes the boat downstream, so that its velocity is the vector sum of the boat speed and the speed of the river. This velocity triangle is shown on the simulation. The user can alter the speeds of the boat and the river.

This simulation could be used as part of a larger calculation - for a river of a certain width, how far downstream will the boat be when it arrives at the opposite bank?

More advanced students might like to consider the question of at what initial direction should the boat set off in order to arrive at the point on the far bank directly opposite the point from which it started. To investigate this sort of problem, the initial direction of the boat can be altered by clicking-and-dragging on the "boat direction" arrow.

Activity: Addition of vectors

This activity shows how up to five vectors add together, whatever their magnitudes and direction.

This online Activity allows the user to click-and-drag a vector to whatever length and orientation is required. Once all the individual vectors are set, a nose-to-tail diagram is constructed and the resultant vector is shown. In this simulation, no numerical values are entered or displayed. The simulation is purely a visual representation of how several vectors add together.

Whilst this simulation can be used as a classroom activity, it may be more useful for a student to try out alone.

1.2 Acceleration

Students are introduced to the concept of acceleration as the rate of change of velocity.

1.3 Kinematic relationships

The ‘equations of motion’ are derived from basic relationships in kinematics. This is not the only valid way of deriving these relationships and students may find other methods of arriving at these equations in different text books or websites. Students may find different ways of deriving these relationships suit their individual learning styles better than others. It should be emphasised that no one method, as long as it is valid, is better than any other.

1.4 Measuring displacement, time, velocity and acceleration

In this section students are introduced to different pieces of laboratory equipment that can be used to measure the above quantities. There is also a brief description of motion capture techniques.

Activity: Horizontal Motion

A familiar problem is presented with an interactive simulation. A car is approaching a set of traffic lights. What is the minimum deceleration needed to ensure the car comes to a halt before it passes the lights? A worked solution is given for the particular values of initial velocity and stopping distance given when the simulation is first run. The distance can be altered by the user to allow a different calculation.

1.5 Acceleration, velocity and displacement time graphs

Activity: Acceleration

This activity allows the student to set the original velocity and acceleration of an object and then to view the graphs of acceleration against time, velocity against time and displacement time. This will help students have a better understanding of the shapes of these graphs and how they relate to each other.

Note that for some years displacement time graphs have only been examined as problem solving but in this revision of the Higher course students will once again be expected to know the shapes of these graphs.

1.5.1 Interpreting graphs

Activity: Extra Help: Interpretation of graphs

This section offers additional support to students in understanding graphs of the motion of objects. It can be used as a remedial loop or as a revision exercise.

1.5.2 Motion of a bouncing ball

Activity: Motion of a bouncing ball

Graphs of acceleration, velocity and displacement against time are plotted for a ball dropped from a window. As well as plotting the graphs, several questions relating to the motion of the ball are given, which can be solved using the kinematic relationships.

This Activity could be referred to in the next Topic, when kinetic and potential energy is being discussed. Students could work out how much energy is lost each time the ball bounces.

1.5.3 Motion on a slope

Activity: Motion of toy car moving down a slope and hitting a stretched elastic band

A car is allowed to accelerate down a slope and rebound from an elastic band. The car then moves up and back down the slope several times. As the car moves a velocity time graph is produced. Questions are designed to highlight that when the velocity changes sign the car changes direction. In addition, there are questions requiring the calculation of displacement at various time intervals.

1.6 Motion of objects

1.6.1 Freefall

Activity: Freefall

This activity displays the graph for an object falling freely under the influence of Gravity. This is not meant to replace practical work but to supplement it. Students should carry this activity out as individuals.

1.7 An object projected vertically upwards

In this section students are introduced to the variation of vertical velocity by considering a ball projected vertically.

1.8 An object accelerating down a slope

Activity: Acceleration on a slope

This simulation allows students to change the angle of a slope and measure the acceleration of a trolley running down the slope. The student can then alter the angle of the slope and measure the effect this has on the acceleration. Students should gain an appreciation that increasing the angle of the slope increases the acceleration of the trolley but the acceleration is not in fact directly proportional to the angle of the slope. This activity can be carried out by individuals or by students working in a larger group. Once again this is not meant to replace practical work but to supplement it.

Topic 2

Forces, energy and power

Mechanical energy is introduced and discussed via work done, kinetic and potential energies. The equivalence of solving problem s using kinematic relationships and by consideration of energy is demonstrated.

2.1 Balanced and unbalanced forces

The concept of balanced and unbalanced forces and their effects is introduced. This leads to the section on Newton's Laws that follows.

2.1.1 Newton's laws of motion

All three of Newton's laws are introduced and discussed with the emphasis on the first and second laws. The third law is mentioned briefly with a fuller discussion to follow once students have studied momentum and impulse.

Activity: Newton's second law

This activity allows the student to vary the accelerating force acting on an object and measure the acceleration produced. The activity will produce a graph of the acceleration against the accelerating force. Students should see that the two quantities are directly proportional and this should lead them to the conclusion that increasing the unbalanced force on an object causes a proportional increase in the acceleration of the object. This activity is suitable for both individual students and groups of students working together.

2.2 Friction

In previous Higher Physics courses the effect of friction was usually taken to be negligible but in this course there is a discussion on friction. In particular the terminal velocity of objects such as raindrops is discussed. This may help overcome some student's objections to idea that all objects that start from rest, in the absence of air friction, fall through the same distance in the same time.

2.3 Resolving forces into rectangular components

This is a brief vector treatment of force. this is intended to reinforce what the student has learned in topic 1 therefore students may wish to refer back to the section on vectors in topic 1. In this section students learn about resolving a force vector into vertical and horizontal forces to allow the motion of objects to analysed.

2.4 Using free body diagrams

Students are introduced to the use of free body diagram s through a series of examples that become increasingly more complex. The idea of tension is also introduced and the component of weight down a slope is discussed.

2.5 Objects undergoing acceleration

2.5.1 Acceleration of an object

Activity: Mass on a slope

The "mass on a slope" scenario is often used as an exercise in which free body diagram s are needed to solve a problem. This simulation enables the user to vary the different parameters in a "mass on a slope" situation to see how they affect the motion.

Activity: World's strongest man

In this simulation, three strongmen are competing in a truck-pulling contest. The simulation presents the force and angle used by each strongman. The student is then asked to predict who will win the competition.

The simulation is suitable for a class activity - perhaps a vote could be taken on which strongman will win. Students could also work through the simulation alone. Full calculations are included to show why the winner won.

2.6 Energy

Activity: Projectile motion

This allows students to examine how the potential and kinetic energies of a projectile vary during its flight. Students should be aware that the total energy of the projectile will not vary only the relative proportions of kinetic and gravitational potential energy.

2.7 Power

Students often struggle at first to distinguish between power and energy. It should be emphasised that power is the rate at which work is done. In other words the power of a device is how much energy it converts every second. There follows a series of examples on energy conversion and power.

Topic 3

Collisions, explosions and impulse

The idea of momentum is introduced as a method of examining what happens when two objects interact in a collision or in an explosion.

3.2 Types of collisions

Activity: Newton's cradle

If you have this piece of equipment available, then that is clearly preferable to using this simulation. If not, then this simulation could be used as a class introduction to momentum and collisions. When the conservation of energy in elastic collisions is discussed later in the Topic, this simulation could be used again.

Activity: Collision between two spheres

This is a short paper-based exercise, involving a simple collision between two objects. Students are encouraged to make a sketch diagram showing velocity vectors before attempting any calculations.

3.2.1 Inelastic collisions

Activity: Inelastic collisions

This simulation allows students to investigate the affects of altering mass and velocity during a collision and should be regarded as a supplement to practical work. During this simulation students should observe that total momentum in the system is always conserved. This activity is best carry out by students working individually but could be used with larger groups.

Activity: Ballistic pendulum

This activity shows a ballistic pendulum, in which a bullet is fired into a block of wood. Given the masses of the bullet and the block, and the height to which the block rises, the student is asked to calculate the initial speed of the bullet.

The activity is most suitable for an individual student or a small group of students, rather than a classroom activity.

3.2.2 Elastic collisions

Activity: Elastic collisions

This is a very similar activity to that used for inelastic collisions except that the total kinetic energy in the system is also now conserved.

3.3 Explosions

The idea of explosions and momentum is explored in this topic. The conservation of momentum in explosions is discussed and there is a worked example of a collision.

3.4 Newton's third law of motion

This animation shows the forces acting on a rocket while it is in motion. Students often struggle with the idea that rockets are propelled forwards due to the reaction force to the gasses being expelled backwards from the rocket. This animation helps with this idea. This activity is best suited to students working individually.

Activity: Rocket

This simulation is similar to the two simulations for collisions in the topic above but this examines the forces involved in a collision. The student should realise when they have completed the simulation that the force of one trolley is the same in size but opposite in direction to the force on the other. Again this simulation is designed to be used by individual students but could be used with a larger group.

3.5 Impulse

The impulse on a body is discussed and the equivalence of impulse and change in momentum is shown.

Two examples of impulse are now discussed; car safety and pile drivers. For car safety there is an example of a car crash test leading to the ideas of safety devices such as air bags. Students should be aware that air bags increase the time of the collision and hence reduce the force on the passenger. The pile driver example is taken from a previous Higher exam paper.

Activity: Test your strength contest

To illustrate impulse and conservation of momentum, this Activity is a simulation of the old fairground "Test your strength" contest. A strongman smashes down a hammer as hard as he can, causing a metal block to be sent up a pole. If the impulse applied at the bottom of the pole is large enough, the metal block rings a bell at the top of the pole.

This Activity works best for a student working alone. The student is asked to calculate the minimum speed that the hammer must be travelling at in order for the bell to be struck. Full worked calculations are given.

3.6 Force time graphs

Force time graphs are discussed. the area bounded by the line on the graph is the impulse and is equivalent to the change in momentum on the object.

Topic 4

Gravitation

4.1 Projectiles

The notes contain diagram showing how image capture or video capture can be used to show that vertical motion of a projectile is identical to that of an object falling through the same vertical height. This may aid students with what is to many a difficult concept.

Activity: Projectile motion

This simulation allows the student to make a thorough investigation of projectile motion. A projectile is launched, with the user able to specify the initial speed, the angle of projection, the initial height, the mass of the projectile and even the value of *g*. The user can view the *x* and *y* co-ordinates, the velocity, the acceleration or the kinetic and potential energies of the projectile whilst it is in motion.

As a classroom demonstration, the simulation could be initially set up to show purely vertical motion. The angle of projection could then be changed to show motion in two dimensions.

This simulation has a lot of parameters which could be varied, and it is important to guide users through. A good place to start is by looking at acceleration, to explain that it is constant and has no horizontal component. Velocity could then be studied, and explained in terms of what has just been learnt about acceleration.

4.2 Satellites

Activity: Newton’s thought experiment

This is a simulation of Newton's well known thought experiment into satellite orbits. Students have to try to discover the correct speed for their projectile so that it just completes an orbit. Most will achieve this by trial and error. This is designed to be used by individual students but could be used as part of a class discussion.

Topic 5

Gravity and mass

This topic opens with a discussion on the force of gravity and its effects. There is a brief description of how gravity acts in the formation of the solar system and how it can bring about star collapse. There is also a brief description of how gravity can be used to assist space travel using the example of the Galileo mission to Jupiter that used gravity assist from Venus to gain the energy required to travel such a large distance.

5.2 Mass, weight and gravitational field strength

The relationship between mass and weight is introduced. The effect of changing the gravitational field strength on weight is discussed more fully later.

5.3 Newton's universal law of gravitation

- Students need to be able to state and use, but not derive, the inverse square law of gravitation.

5.4 Weight

- It is worth spending some time making sure that students are clear about what is meant by 'big G' and 'little g' and that they understand how these quantities are different but related.

Activity: Acceleration due to gravity

This simulation allows student to study the motion of an object falling from a height of 100 m on different planets in the solar system. This should help students with an understanding of weight and gravitational acceleration. The simulation is designed to be used by students as individuals but could be used for illustrate purposes with a class group.

Topic 6

Special relativity

This topic acts as an introduction to Einstein's theory of special relativity. The topic is not dealt with in any great mathematical depth but rather in a way that is intended to give the student an appreciation of the ideas involved in this revolutionary area of modern physics.

6.1 Frames of reference

The animation introduces the idea of frames of reference through a person walking along a train. The different possible frames of reference that could be used to measure their speed are discussed. Again this is designed to be used by students as individuals but could be used with a class group to introduce this topic.

6.2 Opinions on Newton's ideas

This deals briefly with the historical context that gave rise to Einstein's special theory of relativity.

6.3 Special relativity

6.3.1 Time dilation

Activity: Time dilation

This simulation allows students to examine the time dilation of a vehicle travelling from the Earth to Pluto at different velocities. The student should notice that the time dilation for low velocities is very small but increases rapidly once 10 % of c is reached. This activity is designed to be used by individuals but if a group of students are struggling with this concept it may help them to work on it together.

The idea of length contraction for objects with high velocities is also discussed.

Topic 7

The expanding universe

7.2 The Doppler effect with moving source

Activity: Doppler effect

The activity shows the physical process which means the frequency of the waves is shifted. The students should be able to relate this animation to Equation 7.3, and to state whether this means the pitch of the sound heard by the observer is higher or lower than the emitted sound.

Topic 8

Hubble's Law

8.1 Measuring large distances in space

The difficulties of measuring large distances in space is discussed. Parallax is discussed followed by the use of standard candles. This subtopic ends with a discussion of the different units that are used to measure such large distances.

8.2 Hubble's law

This is a brief discussion of Hubble's law based around the red shift of distant galaxies. In brief Hubble discovered that the more distant an object the more its spectrum is red shifted therefore the faster it is travelling away from us. This leads to the conclusion that space is expanding.

Topic 9

Expansion of the universe

9.1 Evidence for the expanding universe

This subtopic looks at evidence for an expanding universe and discusses the eventual fate of the universe. It also contains a reference to the recent revival of interest in Einstein's cosmological constant. Brief reference is made to the suggested existence of dark matter and dark energy.

Topic 10

The Big Bang theory

10.1 Measuring temperature

Different methods of measuring temperature are discussed including using colour to gauge temperature. The example of the colour of steel at different temperatures is used in this context.

10.2 The temperature of stellar objects

The use of the wavelength of light to determine the temperature of a star is discussed. The use of colour and temperature to classify stars is introduced with a brief description of different star types.

10.3 Evidence for the Big Bang

Obler's paradox is introduced and the measurement of the temperature of the microwave background radiation is used as good evidence for the Big Bang theory for the beginning of the universe.

Topic 11

End of unit test

11.1 Open ended and skill based questions

This End of Unit assessment contains Course level questions and a variety of open ended and skills based questions.

11.3 End of unit assessment

An online assessment, covering all of the work of this Unit. The questions are set at the same level as the questions in the NAB tests, covering all the areas that it is possible to cover for a Unit test. There are no 'Course-type' questions covering more than one Unit of work.