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Oxford Cambridge and RSA

AS and A LEVEL

Delivery Guide

PHYSICS B (ADVANCING PHYSICS)

H157/H557
For first teaching in 2015

Space, time and motion

Version 2

Introduction

AS and A LEVEL
PHYSICS B

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resources.feedback@ocr.org.uk

Curriculum content

This section develops classical mechanics, including vectors. The conservation of momentum, the kinematics of uniformly accelerated motion and the dynamics of motion in two dimensions under a constant force are covered. IT skills may be developed through a variety of data capture techniques and simple mathematical modelling (HSW3).

(a) Describe and explain:

- (i) the use of vectors to represent displacement, velocity and acceleration
- (ii) the trajectory of a body moving under constant acceleration, in one or two dimensions
- (iii) the independent effect of perpendicular components of a force
- (iv) calculation of work done, including cases where the force is not parallel to the displacement
- (v) the principle of conservation of energy
- (vi) power as rate of transfer of energy
- (vii) measurement of displacement, velocity and acceleration
- (viii) Newton's laws of motion
- (ix) the principle of conservation of momentum; Newton's Third Law as a consequence.

(b) Make appropriate use of:

- (i) the terms: displacement, speed, velocity, acceleration, force, mass, vector, scalar, work, energy, power, momentum, impulse

  by sketching and interpreting:
- (ii) graphs of accelerated motion; slope of displacement–time and velocity–time graphs; area underneath the line of a velocity–time graph
- (iii) graphical representation of addition of vectors and changes in vector magnitude and direction.

(c) Make calculations and estimates involving:

- (i) the resolution of a vector into two components at right angles to each other
- (ii) the addition of two vectors, graphically and algebraically
- (iii) the kinematic equations for constant acceleration derivable from:

  $a = \frac{v - u}{t}$ and average velocity $= \frac{v + u}{2}$:

  $v = u + at$, $s = ut + ½at^2$, $v^2 = u^2 + 2as$
- (iv) momentum $p = mv$
- (v) the equation $F = ma = \frac{\Delta(mv)}{\Delta t}$ where the mass is constant
- (vi) the principle of conservation of momentum
- (vii) work done $\Delta E = F\Delta s$
- (viii) kinetic energy $= ½mv^2$
- (ix) gravitational potential energy $= mgh$
- (x) force, energy and power:

  power $= \frac{\Delta E}{t}$, power $= Fv$
- (xi) modelling changes of displacement and velocity in small discrete time steps, using a computational model or graphical representation of displacement and velocity vectors.

Learner Activity 1

Definitions – Learner Resource 1 and Teacher Resource 1

A matching exercise to consolidate the meanings of key words.

Learner Activity 2

Deriving equations of motion

Derivations and examples from IsaacPhysics.

https://isaacphysics.org/concepts/cp_eq_of_motion

Learner Activity 3

Vector addition (PhET)

https://phet.colorado.edu/en/simulation/vector-addition

Applet which lets you grab and position vectors then show the resultant.

Thinking conceptually

Approaches to teaching the content

This is a very traditional forces and motion topic. There are plenty of practicals that can be done but they need to be backed up with some solid practice of the calculations. Whenever possible the results of an experiment should be predicted and any difference accounted for. This will reinforce the scientific method as well as giving additional practice at the calculations.

An historical introduction can be valuable. Examine how Galileo and Newton changed the scientific understanding of motion through experiment. Comparing the original wording of their work (translated into English) with a more modern interpretation can give students additional perspectives on the core content, such as Newton's Laws of Motion.

Common misconceptions or difficulties students may have

The most common misconception about Newton's Laws of Motion comes with the Third Law. Students often pair up the wrong forces, for example the weight of a person with the normal reaction of the floor on that person. It should be stressed that Third Law pairs are always the same type of force and always act on different objects. In the above example the weight of the person (in the Earth's gravitational field) is correctly paired with the weight of the earth (in the person's gravitational field).

Many students find it difficult to decide which kinematic equation to use. A way to help is to get them into the habit of always writing S U V A T. They should then put the values they know underneath. Next they should put a question mark under the one for which the question is asking. They can then look through the list of formulae and select the correct one using only those four terms.

One common problem is being consistent with the sign when doing the kinematic equations. One way to help is to enforce a rule that upwards and forwards are always positive. Another is not spotting 'hidden' values, for example "from rest" means "u=0".

Modelling is a concept that the majority of students find challenging. Partly this is because they can't see why it is needed as they know the formulae. It should be stressed that computer simulation is needed in more complicated situations.

The use of a spreadsheet to carry out a simulation is a good tool. Before starting to set it up it is worth running though a few iterations manually so the students get a good feel for what is happening.

Conceptual links to other areas of the specification – useful ways to approach this topic to set students up for topics later in the course

Forces come up again and again throughout physics. In particular the link between force and acceleration is frequently needed.

The incremental modelling methods will be useful when studying exponential decay (5.1.1).

Work done, KE and GPE will be met again and extended to situations where *g* is not constant (5.1.2). It would help if it were stressed that *mgh* is only valid close to the planet's surface.

Impulse will be introduced later in the context of particle collisions (5.2.1). When teaching momentum and Newton's Second Law it would be good to drop in a mention of impulse as change in momentum and force as impulse per unit time.

Learner Activity 1

Newton's Laws of Motion

https://www.youtube.com/watch?v=tL8ugCAz07g

A useful introductory video to Newton's laws.

Learner Activity 2

Freefall trajectories

https://www.walter-fendt.de/html5/phen/projectile_en.htm

A simple simulation to investigate the motion of objects in freefall.

Learner Activity 3

Parachute simulation

A spreadsheet for analysing the effects of mass and parachute size on the terminal velocity of a parachutist. A good discussion point for simulation vs experiment – why not just test a new parachute experimentally and why not trust simulation without experiment?

www.ocr.org.uk/Images/258216-space-time-and-motion-delivery-guide-support-resource-.xlsx

Thinking contextually

Pretty much any context in which something happens can be explained in terms of energy or forces. You could start off with simplified situations like an object falling in a vacuum or sliding down ramps.

Analysing car safety is a good way to cover the momentum and energy sections. Students should already be familiar with braking distances; understanding the link to speed, through the kinetic energy and work done formulae, is a good next step. The effect of crash safety systems, such as seatbelts, air bags and crumple zones, could be explained in terms of work done and in terms of change in momentum.

A classic example of a force acting in a direction that is not parallel to displacement is a sailing boat. Here the wind generates the force but usually blows across the boat. An object sliding down a ramp is another example; this time it is the weight of the object causing the motion.

Learner Activity 1

Crumple zones (Volvo)

https://www.youtube.com/watch?v=zS_Gk7vjmOg

Crash tests and safety features explained.

Learner Activity 2

Applied kinematic equations – Learner Resource 2 and Teacher Resource 2

A selection of questions using the kinematic equations in real-life situations.

Definitions

Match the word to its definition.

displacement	The rate of doing work.
speed	Change in momentum.
velocity	How fast something is travelling.
acceleration	The rate at which the velocity is changing.
force	Product of force applied and distance moved in direction of force.
mass	The distance and direction, in a straight line, between start and finish.
vector	A quantity with a magnitude and direction.
scalar	mass × velocity
work	An action that changes the motion of something.
power	How fast something is travelling in a particular direction.
momentum	A quantity with a magnitude but no direction.
impulse	The amount of matter in something.

Learner Resource 2

Equations of motion

1. A well-streamlined 500kg dragster fired its rocket motor for 3 seconds along a flat track and reached a top speed of 180m/s.
   a. What was the force produced by the motor?
   b. How far did it travel?
2. A sailboat sets a straight course at 10 m/s but a crosswind produces a perpendicular acceleration of 0.05m/s^2. If the sideways velocity reaches 4m/s the boat is likely to capsize. What is the total distance travelled from when the wind fetches up to when the sideways velocity becomes too dangerous?
3. A rocket had a mass of 10 tonnes and a thrust of 500kN. How long did it take to reach 1km altitude, assuming the loss of fuel to be negligible?
4. An ice skater spotted a hole 10m ahead. He managed to stop right on the edge after applying a deceleration of 31.25ms^{-2}. How fast was he travelling at the start?
5. A daredevil was determined to jump five London buses. Her motorbike could produce an acceleration of 20ms^{-2} from a rolling start of 15m/s. To make the jump safely she needed to be travelling at 40m/s. How far back did she need to start accelerating?
6. A probe falls towards an alien planet. It deploys its 'chute 30km above the surface at 400m/s. At what speed does it impact 2.38 minutes later, assuming the atmosphere is too thin for terminal velocity to be reached?
7. An F-16 jet travelling at 200m/s at sea-level looses a 78kg Sidewinder missile that reaches Mach 2.5 in 2.2 seconds. What is the force on the missile?
8. A high-jumper just cleared the bar at 2.38m. How fast did she hit the ground?
9. A marathon runner cruising at 2.7m/s decides to sprint for the line from 200m out. He can sustain an acceleration of 0.02ms^{-2} for that distance. How much time will he save?
10. A train is travelling at 10m/s when it is thrown into reverse. It takes 2 minutes to return to its initial speed.
    a. What is the acceleration?
    b. How far does it travel?
    c. What is the total displacement?
11. A leopard is jogging along at 2m/s when an antelope darts past in the opposite direction at its top speed of 6m/s. The leopard brings down the antelope ten seconds later.
    a. How far had the antelope travelled in that time?
    b. What was the acceleration of the leopard?
    c. How long did it take the leopard to stop moving in its initial direction?
    d. How far had the leopard travelled by the time it reached the antelope?
    e. What was the relative speed of the two animals on impact?

Definitions

Match the word to its definition.

displacement **1**	The rate of doing work. **10**
speed **2**	Change in momentum. **12**
velocity **3**	How fast something is travelling. **2**
acceleration **4**	The rate at which the velocity is changing. **4**
force **5**	Product of force applied and distance moved in direction of force. **9**
mass **6**	The distance and direction, in a straight line, between start and finish. **1**
vector **7**	A quantity with a magnitude and direction. **7**
scalar **8**	mass × velocity **11**
work **9**	An action that changes the motion of something. **5**
power **10**	How fast something is travelling in a particular direction. **3**
momentum **11**	A quantity with a magnitude but no direction. **8**
impulse **12**	The amount of matter in something. **6**

Equations of motion

1. A well-streamlined 500kg dragster fired its rocket motor for 3 seconds along a flat track and reached a top speed of 180m/s.
   a. What was the force produced by the motor?
   30kN
   b. How far did it travel?
   270m
2. A sailboat sets a straight course at 10 m/s but a crosswind produces a perpendicular acceleration of 0.05m/s^2. If the sideways velocity reaches 4m/s the boat is likely to capsize. What is the total distance travelled from when the wind fetches up to when the sideways velocity becomes too dangerous?
   $s_{forward}$=800m $s_{sideways}$=160m s=820m
3. A rocket had a mass of 10 tonnes and a thrust of 500kN. How long did it take to reach 1km altitude, assuming the loss of fuel to be negligible?
   7s
4. An ice skater spotted a hole 10m ahead. He managed to stop right on the edge after applying a deceleration of 31.25ms^{-2}. How fast was he travelling at the start?
   25ms^{-1}
5. A daredevil was determined to jump five London buses. Her motorbike could produce an acceleration of 20ms^{-2} from a rolling start of 15m/s. To make the jump safely she needed to be travelling at 40m/s. How far back did she need to start accelerating?
   35m (34.4m but rounding down would be unsafe)
6. A probe falls towards an alien planet. It deploys its 'chute 30km above the surface at 400m/s. At what speed does it impact 2.38 minutes later, assuming the atmosphere is too thin for terminal velocity to be reached?
   20m/s
7. An F-16 jet travelling at 200m/s at sea-level looses a 78kg Sidewinder missile that reaches Mach 2.5 in 2.2 seconds. What is the force on the missile?
   22kN
8. A high-jumper just cleared the bar at 2.38m. How fast did she hit the ground?
   6.8ms^{-1}
9. A marathon runner cruising at 2.7m/s decides to sprint for the line from 200m out. He can sustain an acceleration of 0.02ms^{-2} for that distance. How much time will he save?
   14s
10. A train is travelling at 10m/s when it is thrown into reverse. It takes 2 minutes to return to its initial speed.
    a. What is the acceleration?
    0.17ms^{-2}
    b. How far does it travel?
    600m
    c. What is the total displacement?
    0m
11. A leopard is jogging along at 2m/s when an antelope darts past in the opposite direction at its top speed of 6m/s. The leopard brings down the antelope ten seconds later.
    a. How far had the antelope travelled in that time?
    60m
    b. What was the acceleration of the leopard?
    1.6ms^{-2}
    c. How long did it take the leopard to stop moving in its initial direction?
    1.3s
    d. How far had the leopard travelled by the time it reached the antelope?
    62.6m
    e. What was the relative speed of the two animals on impact?
    8ms^{-1}

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