Unit 3: Principles and Applications of Physics I

Delivery guidance

The topics covered in this unit will be familiar to learners in the context of their own personal experiences. Learners will, undoubtedly, be well-versed on the use of mobile phones and other electronic devices in the home and in other activities. Similarly, learners will have significant experience and probably some detailed factual knowledge of transportation, although this knowledge may not be based on a scientific understanding of the principles involved. This can provide a valuable first introduction to the science involved in these topics.

- Use practical work and visual representations to deliver content relation to the use of waves in communication. For example:
- use a 'slinky' spring and graphs to illustrate the general features of longitudinal and transverse waves
- show diffraction patterns in water, using carefully positioned obstacles to enable learners to visualise the changes in waves travelling through a 'gap'
- demonstrate resonance in a guitar string to show how the wave shape appears 'stationary' and make links with the physical aspects of the string and its tension
- discuss uses of fibre optics and show learners how to determine critical angles for total internal reflection
- discuss the electromagnetic spectrum, its sections, frequencies, wavelengths and uses in communication.

Use visual representations and practical activities to teach aspects of physics applied to transportation and the calculations involved. For example:

- show video footage of a variety of forms of transport to illustrate aspects of speed, flight and buoyancy
- demonstrate lift in flight and make links with the design of wings
- use a water-filled basin to demonstrate the loading capacity of ships, based on volume of water displaced
- show video footage of rockets achieving orbit and reinforce this learning with a simple practical demonstration using a balloon
- set up a simple speed camera and discuss the 'real life' principles involved
- allow learners to investigate the effects of friction and changes of speed or surface, using simple model cars and ramps
- allow learners to work in groups to design a 'crumple zone' to surround a fresh egg, using simple materials – the egg can then be dropped from a height to test the efficacy of the design; make links with the principles of car design in terms of motor collisions

Approaching the unit

The topics covered in this unit are taken from two key areas of physical science:

- waves – with an emphasis on communication
- forces and motion – with an emphasis on transportation.

Scientists and technicians working in science-related organisations must have a good understanding of the core science concepts highlighted in this unit. Give learners suitable applications of this knowledge within relevant vocational contexts.

The focus of **learning aim A** is the use of waves in communications. Ensure learners appreciate how electromagnetic waves have been incorporated into fundamental and essential aspects of everyday life and consider ongoing developments in industry. Learners will need to understand how their mobile phones work – not electronically but in terms of how information is transferred around the world almost immediately and which forms of waves are used.

In **learning aim B**, learners will gain an understanding of the science of motion by looking at forces involved in land, sea and air travel and in achieving earth orbit. Learners must:

- be able to describe the main measurements and demonstrate accurate application of the calculations of motion
- understand Newton's first, second and third laws of motion
- be able to describe and analyse the main factors involved in motion on land, sea and air and in achieving orbit
- study the principles of methods used to reduce damage to vehicles during collisions.

Provide opportunities for practical work related to the motion of vehicles, and ensure learners display the results of these investigations appropriately (e.g. using graphs). Use model cars and boats to illustrate key aspects of velocity and buoyancy and enhance learners' understanding of key terms and scientific definitions.

Introduce Newton's laws of motion by defining the terms used and their units, specifically force, mass and acceleration. Consider real-life applications of these laws, such as the implications of inertia in vehicle collisions. Introduce key calculations related to the three laws in the context of relevant real-world scenarios. Investigate frictional forces using simple models, and ensure learners understand how to calculate these forces.

Use as many examples of vehicles as possible to ensure learners understand the essential principles governing ship design, aircraft principles and road collisions. Provide opportunities for meaningful research and practical investigation, for example:

- designing and testing an aircraft wing
- designing a model ship that can support a significant amount of mass
- designing a suitable 'crumple zone' for a fresh egg to be dropped from height.

Follow these practical activities with discussion and reinforcement of the key physical concepts. For example, after the crumple zone activity, discuss crumple zone design for cars in more detail, perhaps showing film footage of crash tests.

Explain that the speed of the vehicles involved is a key aspect of any collision. Guide learners to consider methods of measuring vehicle speeds on the road and the principles of speed cameras. Finally, discuss the basic principles of global positioning (GPS) using an array of satellites linked to devices in vehicles worldwide.

Assessment model

Learning aim	Key content areas	Recommended assessment approach
A Understand the main features and practical uses of waves used in communication	**A1** Working with waves **A2** Waves in communication **A3** Use of electromagnetic waves in communication	This unit is assessed through a Pearson Set Assignment.
B Explore the fundamental principles and applications of forces in transportation	**B1** Measurement and representation of motion **B2** Laws of motion **B3** Driving safely	

Assessment guidance

There are 60 guided learning hours assigned to the unit, of which 16 hours will be required for assessment.

The unit is assessed by a Pearson Set Assignment. The assessment is set by Pearson and must be taken under controlled conditions before it is marked by tutors.

Set assignment units are subject to external standards verification processes common to all BTEC units. By setting an assignment for some units, Pearson can ensure all learners take the same assessment for a specific unit.

Learners are permitted to re-sit set assignment units during their programme.

Set assignments are available from September each year and are valid for one year only.

Delivery must cover all the unit content and prepare learners to produce evidence to meet the assessment criteria and assessment guidance in preparation for taking the Pearson Set Assignment.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 3: Principles and Applications of Physics I
Introduction This unit is focused on two important areas of physical science: communication, and forces in transportation. Both areas provide excellent opportunities to reinforce the scientific principles involved in practical investigation, enhancing learners' knowledge and ability to apply the subject material. Areas of study for ***Learning Aim A*** could be introduced by asking learners to identify in groups, 'what exactly **is** communication and what aspects to everyday life **use** communication?' – this can lead to a general discussion and key points displayed on screen.
Learning aim A – Understand the main features and practical uses of waves used in communication
● Introduce this learning aim by asking learners answer the following questions in groups: ○ What is communication? ○ What areas of everyday life rely on communication? ● Follow up with a class discussion and summarise the key points on the board. **A1** ● Use practical demonstrations and independent investigation to enhance this content for learners. For example: ○ calculate the speed of waves in different media ○ discuss principles of optical fibres and make links with the medical industry and other areas of science ○ demonstrate diffraction of light using glass blocks, protractors and a light box, and make links with real-life applications (e.g. detection of raindrops on a vehicle windscreen) ● Discuss everyday uses of the electromagnetic spectrum – for example, Bluetooth devices or television remote controls. These items will be familiar to learners, helping them to understand the content in context. ● Explain the main features of waves (longitudinal and transverse) and demonstrate these features using a slinky spring. ● Introduce the main definitions and units related to waves (periodic time, speed, wavelength, frequency, amplitude and oscillation), showing labelled diagrams of transverse and longitudinal waveforms. ● Demonstrate diffraction in waves using a water trough and blocks. Adjust the gap between the blocks so learners can observe and record the resulting patterns. ● Make links between water waves and light waves. Set up a wire on a stand, with a screen behind it, and shine a laser at the wire and screen. Explain to learners that light is a wave, which bends around both sides of the wire creating bright spots (constructive interference) and dark spots (destructive interference).

- Ask learners to research the uses of diffraction gratings for:
  - emission spectra
  - identifying gases.
- Introduce the wave equation ($v = f\lambda$) and state that the speed of light in a vacuum is 3×10^8 m/s. For each type of electromagnetic wave, give learners two of the three values (e.g. speed and wavelength) and ask them to calculate the third (in this case, frequency).
- Ask learners to research the main uses of the different types of electromagnetic wave in science and medicine.
- Set up apparatus to demonstrate a standing wave on a string.
  - You will need a 1.5 m length of string or wire, a selection of masses, a wave generator and a way of attaching the string or wire.
  - Ask learners to discuss what happens to the 'pitch' of the wave when masses are added or removed, and if the mass of the string is changed.
- Introduce the equation $v = \sqrt{\frac{T}{\mu}}$

A2

- Allow learners to find the refractive index and critical angle of a material such as glass or Perspex:
  - Set up a rectangular glass block and a light box.
  - Show the path of the light through the glass block when changing the angle of incidence of the light ray.
  - Explain how to calculate the refractive index of the block: $n = \frac{c}{v} = \frac{\sin i}{\sin r}$.
  - Now use a semi-circular glass block. Approach the point where the ray runs parallel to the flat edge of the glass block.
  - Move beyond this point to show total internal reflection of the light ray within the block.
  - Explain how to calculate the critical angle: $\sin c = \frac{1}{n}$
- Discuss the application of total internal reflection in optical fibres and ask learners to research uses of fibre optics in medicine and in communication.

A3

- Introduce the equation for intensity of a wave: $I = \frac{k}{r^2}$ (inverse square law relating to the intensity of a wave).
- Ask learners to research and produce a report on uses of waves in communication, making links with the frequency ranges of different types of wave. The report should focus on satellites, mobile phones, Bluetooth, infra-red and Wi-Fi. This work will allow learners to demonstrate sound research techniques and an understanding of frequency ranges.

Learning aim B – Explore the fundamental principles and applications of forces in transportation

B1

- When considering forces in transportation, make links with real-life scenarios wherever possible. Place particular emphasis on road traffic, sea and air travel, and refer to factors needed to achieve orbit. Introduce the mathematical formulae for motion using examples which can be clearly understood and represented using graphs.
- Start by introducing the SI units of speed and explaining how to calculate speed using the equation $v = \frac{d}{t}$
- Show distance/time and velocity/time graphs for familiar scenarios and demonstrate calculations using the appropriate formulae. Emphasise the importance of accuracy when producing graphs so that, for example, acceleration can be determined correctly.
- Allow learners to practise calculating unknown quantities in motion.

B2

- Set up a demonstration using light gates to introduce the general principles of the 'Gatso' speed camera. Follow up with a more detailed explanation of the actual method used to calculate the speed of a passing vehicle, making links with the 'Doppler shift' of wavelengths of light.
- Reinforce learners' understanding of the Doppler effect with other real-life examples – for example, the observed changes in pitch of an ambulance siren as it approaches and then recedes from a fixed observer. Learners should be able to explain this accurately.
- Introduce Newton's three laws of motion together, then take time to explain each law in more detail.
- Introduce Newton's first law as the law which deals with inertia, and illustrate the key concepts with relevant examples linked to transport. For example, the damage to cars and their passengers in a collision is a result of the resistance of the passenger's body to the change in velocity.
- Introduce Newton's second law using $F = m \times a$ and compare the forces of vehicles with low mass travelling at high speed, and vehicles with high mass travelling at low speed. Provide a definition and a number of example calculations in relevant contexts.
- Introduce Newton's third law with the general definition: 'For every action there is an equal and opposite reaction', then explain that other definitions may be used. Provide simple examples, such as releasing an inflated untied balloon, and make links with the launch of a rocket to the ISS.
- Introduce flight and buoyancy by discussing key aspects of design. Then explain the main features of wing design and identify the forces involved during various aspects of flight (take-off, climbing, level flight and descent).
- Explain the Archimedes Principle, using the legend of this discovery to develop a suitable context.
- Allow learners to design and build from simple materials:
    - an aircraft wing
    - a ship (or a container to resemble a ship).

- Test learners' designs:
    - For an aircraft wing, develop a simulation or simple wind tunnel to show air flow directions.
    - For a ship, test an open model to link the volume of the vessel with the amount of water displaced. Then test the boat's capacity to float by adding weights.

B3

- Introduce this content by showing video footage of vehicle collisions and asking learners to identify common characteristics in the way the vehicles are driven and the road conditions. (Make sure you review all footage carefully, in advance, to ensure it is appropriate.)
- Next, ask learners to identify the areas of the vehicles that suffered the most damage. Lead on to discuss the design aspects of modern vehicles (motor cars in particular) which aim to reduce harm to passengers.
- Use a practical activity to put this work in context.
    - Divide learners into small groups and give each group one fresh egg and some plastic straws and clear tape. (Ensure all groups have the same resources).
    - Ask learners to design and create an effective crumple zone 'cage' to protect their egg when it is dropped.
    - End the activity by dropping all the eggs from a set height to test learners' designs.
    - Make links with crumple zones on vehicles and ensure learners understand the key concepts.
- Ensure learners understand that stopping distances is a combination of thinking distance and braking distance. Then lead a class discussion to identify factors affecting stopping distance. Ask learners to research and make notes on these factors: vehicle mass, road surface conditions, tyre condition, brake condition, speed of the vehicle, state of the driver (concentration, alcohol, drugs, eyesight, tiredness, distractions, etc.).
- Explain the essential principles of GPS. Then ask learners to research:
    - the minimum number of satellites required to locate a vehicle
    - the accepted precision of GP factors which may result in wrong directions being given to the driver.

Issue 1 – April 2020 © Pearson Education Limited 2020

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 18: Astronomy and Space Science*
- *Unit 23: Materials Science.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Internationals in Applied Science. Check the Pearson website at http://qualifications.pearson.com/endorsed-resources for more information as titles achieve endorsement.

Textbooks

Milner, G. *Pinpoint: How GPS is changing technology, culture and our minds*, W. W. Norton & Company, 2016, ISBN 978-0-393-08912-7 – This is a useful resource which explains the principles of GPS to an audience with minimal knowledge of the processes involved

Videos

- You may wish to search for the following titles or channels on YouTube:
- Bozeman Science has produced various videos outlining the basic principles of diffraction and Newton's laws of motion.

Websites

- The Physics Classroom – Search for 'Lesson-3' for a detailed explanation (with diagrams) of the conditions required for total internal reflection.
- Stratos Jets – This site makes links between Newton's laws of motion and flight.

Pearson is not responsible for the content of any external internet sites. It is essential for tutors to preview each website before using it in class so as to ensure that the URL is still accurate, relevant and appropriate. We suggest that tutors bookmark useful websites and consider enabling learners to access them through the school/college intranet.