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Unit 2: What do experiments reveal about the physical world?

AREA OF STUDY 2

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Area of Study 2 Review

How to use this book

Heinemann Physics 11 4th edition

Heinemann Physics 11 4th edition has been written to the new VCE Physics Study Design 2016 – 2021. The book covers Units 1 and 2 in an easy-to-use resource. Explore how to use this book below.

Extension

Extension material goes beyond the core content of the Study Design. It is intended for students who wish to expand their depth of understanding.

Highlight

Focus on important information such as key definitions, formulae and summary points.

Assuming that no energy was lost as heat or noise and that all of the work is converted into kinetic energy, this equation gives us a mathematical definition for the kinetic energy of the cart in terms of its mass and velocity:

$$E_k = \frac{1}{2}mv^2$$

where E_k is kinetic energy (in J)

EXTENSION
Expressing the amount of work

Considering the scenario described in Figure 12.2.2, the work done by the force is given by the equation $W = F \cdot s$. The force causes the cart to accelerate according to Newton's second law, $F = ma$.

Rearranging the equation of motion $v^2 = u^2 + 2as$ gives:

$$s = \frac{v^2 - u^2}{2a}$$

Combining this with $F = ma$ means that the force acting on the cart can be given by the equation:

$$F = m \left(\frac{v^2 - u^2}{2s} \right)$$

This equation can be transposed to find an expression for the amount of work (W) done on the cart:

$$W = F \cdot s = m \left(\frac{v^2 - u^2}{2s} \right) \cdot s$$
$$W = \frac{1}{2}m(v^2 - u^2)$$

Since $W = F \cdot s$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

Worked example 12.2.1
CALCULATING KINETIC ENERGY

Thinking	Working
Convert the car's speed to $m \cdot s^{-1}$.	$90 \text{ km h}^{-1} = \frac{90 \text{ km}}{1 \text{ h}} = \frac{90000 \text{ m}}{3600 \text{ s}} = 25 \text{ m s}^{-1}$
Recall the equation for kinetic energy.	$E_k = \frac{1}{2}mv^2$
Substitute the values for this situation into the equation.	$E_k = \frac{1}{2} \times 1200 \times 25^2$
State the answer with appropriate units.	$E_k = 375000 \text{ J} = 375 \text{ kJ}$

Worked example: Try yourself 12.2.1
CALCULATING KINETIC ENERGY

A person crossing the street is walking at 5.0 km h^{-1} . If the person has a mass of 80 kg , calculate their kinetic energy. Give all answers correct to two significant figures.

CHAPTER 01 Heating processes

Due to increasing levels of carbon dioxide in the atmosphere, the Earth is getting warmer. The last two decades of the twentieth century were the warmest for over 400 years. In 2014, the Earth was the warmest since records began in 1890. These higher temperatures increase the severity of bushfires. The rate of evaporation from pastures also increases, drying the land and reducing the level of food production. Thermal energy is part of our everyday experience. Humans can thrive in the climatic extremes of the Earth, from the outback deserts to ski slopes in winter.

Key knowledge

By the end of this chapter, you will have covered material from the study of the thermodynamic principles related to heating processes, including concepts of temperature, energy and work, and will be able to:

- convert temperature between degrees Celsius and kelvin
- describe the zeroth law of thermodynamics as two bodies in contact with each other coming to a thermal equilibrium
- describe temperature with reference to the average kinetic energy of the atoms and molecules within a system
- investigate and apply theoretically and practically the first law of thermodynamics to simple situations: $Q = U + W$
- explain internal energy as the energy associated with random disordered motion of molecules
- distinguish between conduction, convection and radiation with reference to heat transfer within and between systems
- investigate and analyse theoretically and practically the energy required to:
 - raise the temperature of a substance: $Q = mc\Delta T$
 - change the state of a substance: $Q = mL$
- explain why cooling results from evaporation using a simple kinetic energy model.

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Chapter opener

Chapter opening pages links the Study Design to the chapter content. Key knowledge addressed in the chapter is clearly listed.

Physics in Action

Physics in Action place physics in an applied situation or relevant context. These refer to the nature and practice of physics, applications of physics and the associated issues and the historical development of concepts and ideas.

PHYSICS IN ACTION
Wind chill

Convective effects are the main means of heat transfer that lead to the 'wind chill' factor. The wind blows away the thin layer of relatively still air near the skin that would normally act as a partial insulator in still air. Cooler air comes in close contact with the skin and heat loss increases. It feels as if the 'effective' temperature of the surrounding air has decreased. Skiers can experience similar effects simply from the wind created by their own motion.

In cold climates the wind chill factor can become an important factor to consider. The chilling effect is even more dramatic when the body or clothing is wet, increasing evaporative cooling. Bushwalkers look for clothing that dries rapidly after rain and which carries moisture from the perspiration of heavy exertion away from the skin.

PHYSICS FILE
Paragliders

Paragliders fly by sitting in a harness suspended beneath a fabric wing. They gain altitude by catching thermals. Thermals are columns of rising hot air created by dark regions on the ground that have been heated up by the Sun. Roads, rock faces and ploughed fields are good at creating thermals.

In 2007, Polish paraglider Ewa Wisniewska was practicing in NSW for a competition when she was caught in an intense thermal updraft during a storm. She reached an altitude of almost 10 km. Fortunately, she lost altitude, and landed about 60 km from where she started, where her crew found and rescued her. Ewa is now a paragliding instructor in Germany.

FIGURE 12.6 Paragliders can gain altitude by riding a thermal. These are areas of rising hot air created by hot regions on the ground. These paragliders are flying near Bright, Victoria.

CHAPTER 1 | HEATING PROCESSES 23

PhysicsFile

PhysicsFiles include a range of interesting information and real world examples.

Worked examples

Worked examples are set out in steps that show both thinking and working. This enhances student understanding by linking underlying logic to the relevant calculations.

Each Worked example is followed by a Try Yourself: Worked example. This mirror problem allows students to immediately test their understanding.

Fully worked solutions to all Try Yourself: Worked examples are available on *Heinemann Physics 11 4th edition ProductLink*.

Section summary

Each section includes a summary to assist students consolidate key points and concepts.

Section review

Each section finishes with questions to test students' understanding and ability to recall the key concepts of the section.

6.4 Review

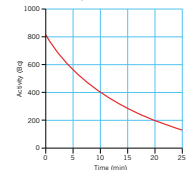
SUMMARY

- The rate of decay of a radioisotope is measured by its half-life ($t_{1/2}$). This is the time that it takes for half of the radioisotope to decay.
- The activity of a sample indicates the number of emissions per second. Activity is measured in becquerels (Bq), where 1 Bq = 1 emission per second.
- The number of atoms of a radioisotope will decrease over time. Over one half-life, the number of atoms of a radioisotope will halve.
- The half-life equation can be used to calculate the number (N) or activity (A) of a radioisotope remaining after a number of half-lives (n) has passed:

$$N = N_0 \left(\frac{1}{2}\right)^n \quad A = A_0 \left(\frac{1}{2}\right)^n$$
- When a radionuclide decays, its daughter nucleus is usually itself radioactive. This daughter will then decay to a grand-daughter nucleus, which may also be radioactive, and so on. This is called a decay series.

KEY QUESTIONS

- What is meant by the 'activity' of a radioisotope?
- Technetium-99m has a half-life of 6.0 hours. A sample of the radioisotope originally contains 8.0×10^{10} atoms. How many technetium-99m nuclei remain after 6.0 hours?
- Iodine-131 has a half-life of 8 days. A sample of the radioisotope initially contains 2.4×10^{14} iodine-131 nuclei. How many iodine-131 nuclei remain after 24 days?
- Radioactive materials are considered to be relatively safe when their activity has fallen below 0.1% of the initial value.
 - How many half-lives does this take?
 - Plutonium-239 is a by-product of nuclear reactors. Its half-life is 24000 years. How long does the plutonium-239 have to be stored as nuclear waste before it is considered safe to handle?
- If a particular atom in a radioactive sample has not decayed during the previous half-life, what is the percentage chance that it will decay in the next half-life?
- A hospital in Alice Springs needs 12 μg of the radioisotope technetium-99m. The specimen has to be ordered from Sydney. The half-life of technetium-99m is 6 hours and the delivery takes 24 hours. How much must be produced in Sydney to satisfy the Alice Springs order?
- The activity of a radioisotope changes from 6000 Bq to 375 Bq over a period of 60 minutes. Calculate the half-life of this radioisotope.
- A Geiger counter is used to measure the radioactive emissions from a certain radioisotope. The activity of the sample is shown in the graph.
 - What is the half-life of the radioisotope according to the graph?
 - What would the activity of the sample be after 40 minutes have elapsed?
- According to Figure 6.4.4 on page 220, what type of decay does lead-210 undergo and what is its half-life?
- The uranium decay series shown in Figure 6.4.4, ^{238}U decays to eventually produce stable ^{206}Pb . How many alpha and beta-minus decays have occurred?



Chapter review

Each chapter finishes with a set of higher order questions to test students' ability to apply the knowledge gained from the chapter.

Chapter review

KEY TERMS

- activity
 - alpha particle
 - antimatter
 - atomic number
 - beta particle
 - daughter nucleus
 - decay series
 - electron
 - electrostatic force
 - gamma ray
 - Geiger counter
 - half-life
 - isotope
 - mass number
 - neutron
 - neutrino
 - nuclear transmutation
 - nucleon
 - nucleus
 - parent nucleus
 - penetrating ability
 - positron
 - radiation
 - radioactive
 - radioisotope
- How many protons and neutrons are in the ^{92}Ca nucleus?
 - Use the periodic table in Figure 6.1.7 on page 203 to determine the number of protons, neutrons and nucleons in cobalt-60.
 - Determine the nature of the unknown, X, for the following transmutation:

$$^{90}\text{Sr} \rightarrow ^{90}\text{Zr} + X$$
 (60Sr means the nuclide is metastable and has a higher level of stability than very short-lived isotopes. The mass number is 88.602.)
 - What type of radiation does potassium-48 (atomic number 19) emit? Use Figure 6.2.6 on page 208 to answer this question.
 - Identify each of these radiation types:
 - IA
 - IB
 - IC
 - II
 - III
 - IV
 - V
 - VI
 - VII
 - VIII
 - IX
 - X
 - Some nuclei can be made unstable by firing neutrons into them. The neutron is captured and the nucleus becomes unstable. The nuclear equation when the stable isotope boron-10 transmutes by neutron capture into a different element, X, by emitting alpha particles is:

$$^{10}\text{B} + n \rightarrow X + \alpha$$
 Identify the unknown element, X, and its mass and atomic numbers.
 - Identify each of the unknown particles X and Y in the following nuclear transmutations.
 - $^{19}\text{F} + n \rightarrow ^{19}\text{O} + X$
 - $^{235}\text{U} + n \rightarrow ^{141}\text{Ba} + Y + 3n$
 - Find the values of x and y in each of these radioactive decay equations.
 - $^{210}\text{Po} \rightarrow ^{206}\text{Pb} + \alpha$
 - $^{238}\text{U} \rightarrow ^{214}\text{Pb} + \alpha$
 - Fluorine-18 is a radioisotope that is used for detecting tumours. It is formed when radioactive neon-18 decays by positron emission. Fluorine-18 in turn also decays by positron emission. The equations are as follows:

$$\text{Ne} \rightarrow \text{F} + \beta^+$$

$$\text{F} \rightarrow \text{O} + \beta^+$$
 Determine the values of a, b, c, d and identify X and Y, which are the daughter nuclei that result from this process.
 - The radioisotope nitrogen-12 decays by emitting a positron and a neutrino. The decay equation for nitrogen-12 is:

$$^{12}\text{N} \rightarrow X + \beta^+ + \nu$$
 Identify particle X.
 - A stable isotope of neon has 10 protons and 10 neutrons in each nucleus. Every proton is repelling all the other protons. Why is the nucleus stable?
 - Which type of radiation out of alpha, beta and gamma:
 - is the fastest?
 - has the greatest penetrating power?
 - Health workers who deal with radiation to treat cancer often have to wear a lead vest to protect their vital organs from exposure. Which types of radiation is the lead apron shielding them from?
 - A nuclear physicist was bombarding a sample of beryllium-7 with a beam of electrons in an effort to smash the electrons into the beryllium nuclei. Why would it be quite difficult for a collision between the electrons and the nuclei to occur?
 - A radioactive isotope X has a half-life of 20 minutes. A sample starts with 6.0×10^{14} atoms of the isotope. What amount of the original isotope will remain after 20 minutes?
 - Radioisotope Y has a half-life of 3.0 hours. A sample starts with 5.6×10^{14} atoms of the radioisotope. How many atoms of Y remain after 9.0 hours?

Area of Study review

Each Area of Study finishes with a comprehensive set of exam-style questions, including multiple choice and extended response, that assist students draw together their knowledge and understanding and apply it to this style of questions.

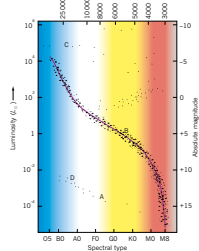
UNIT 2 • Area of Study 2

REVIEW QUESTIONS

Options

Stars

The following information relates to questions 1 to 3. Consider the Hertzsprung–Russell diagram shown below.



- Which letter corresponds to a Sun-like star?
 - A
 - B
 - C
 - D
- Which letter corresponds to a blue supergiant?
 - A
 - B
 - C
 - D
- Which letter corresponds to an old star that once was a Sun-like, main sequence star?
 - A
 - B
 - C
 - D

- Which of the following best outlines the life cycle for a massive star, a star with a mass much greater than that of the Sun?
 - main sequence star → planetary nebula → red supergiant → supernova → black hole
 - main sequence star → planetary nebula → supernova → red supergiant → black hole
 - planetary nebula → main sequence star → supernova → red supergiant → black hole
 - planetary nebula → main sequence star → red supergiant → supernova → black hole
- If star A and star B are the same luminosity, but star A is 4 times farther than star B, how do their apparent brightness compare?
 - Star A's apparent brightness is 4 times greater than that of star A.
 - Star B's apparent brightness is 4 times greater than that of star A.
 - Star A's apparent brightness is 16 times greater than that of star B.
 - Star B's apparent brightness is 16 times greater than that of star B.
- The following diagram depicts the concept of parallax.
 - parallax
 - AU
- The event horizon, the space around a black hole, has a radius described by Schwarzschild's equation:

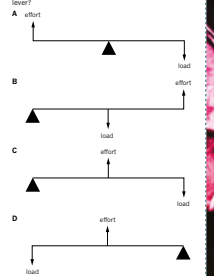
$$r_s = \frac{2GM}{c^2}$$
 - Explain what is meant by the 'event horizon'.
 - The mass of our Sun is 2.0×10^{30} kg. The mass of the star Betelgeuse is not known exactly, but is thought to fall somewhere between 7.7 solar masses and 20 solar masses. Determine the range of distances (radii) in km that the Schwarzschild radius would be for Betelgeuse.

- Outline the main ideas presented in this chapter regarding Einstein's idea of 'spacetime'.
- Define absolute magnitude in terms of a star's brightness. Explain how absolute magnitude and apparent magnitude are related.
- The luminosity, L , of a star can be determined by the Stefan-Boltzmann law:

$$L = 4\pi r^2 \sigma T^4$$
 where σ is the Stefan-Boltzmann constant, $5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$, and T is the surface temperature of the star. Remember that the surface area of a sphere is $4\pi r^2$. The surface temperature, T , of the Sun is 5800 K and its radius is 6.96×10^8 m.
 - Calculate the luminosity of the Sun.
- Explain what change would be observed in the luminosity of the Sun if its radius was twice its current value.
- Explain what change would be observed from the original luminosity of the Sun if the surface temperature was halved.

Forces in the human body

- Which of the following statements best describes the situation for an object in translational equilibrium.
 - The net force on the object is zero.
 - The object experiences no acceleration.
 - The object is at constant velocity.
 - All of the above are correct.
- The maximum compressive stress for bone is given as approximately 170 MPa. What information does this value provide about the strength of bone?
 - 170 N per m^2 of compressive force is required to 'break' a bone sample.
 - 170×10^6 N of compressive force is required to 'break' a bone sample.
 - 170×10^6 N per cm^2 of compressive force is required to 'break' a bone sample.
 - 170×10^6 N per m^2 of compressive force is required to 'break' a bone sample.
- Bone sample A is loaded with a force of F newtons. A second sample B, with twice the diameter of the first, is also loaded with a force of F newtons. What is the ratio of stress on bone sample A to stress on bone sample B?
 - 1:2
 - 2:1
 - 4:1
 - 1:4



Answers

Numerical answers and key short response answers are included at the back of the book. Comprehensive answers and fully worked solutions for all section review questions, Try Yourself: Worked examples, chapter review questions and Area of Study review questions are provided via *Heinemann Physics 11 4th edition ProductLink*.

Glossary

Key terms are shown in bold and listed at the end of each chapter. A comprehensive glossary at the end of the book includes and defines all key terms.