VCEasy
VISUAL PHYSICS
Units 1&2
v1.3
compare the wave model and the particle model of light in terms of whether they adequately describe reflection and refraction.
explain why some atomic nuclei are stable and others are not
1. What are the three types of particles found in an atom?
2. What are nucleons?
3. What is the name of the force that holds nucleons together in a nucleus?
4. Write the nuclide notation for:
   a) carbon-13
   b) uranium-235
   c) hydrogen-2 (also called deuterium)
   d) barium-137
5. What are isotopes?
6. Explain why:
   a) Some isotopes are stable and others are not
   b) Carbon-12, carbon-13 and carbon-14 all have the same chemical properties
Half-life is the time taken for half of the radioactive nuclei in a sample to decay.

Each radioactive nucleus has a 50% chance of decaying for every half-life of time that passes.
Practice Questions for 1.1.2
Reference: Heinemann Physics 11 Chapter 1.1 & 1.2

1. Define half-life.

2. Carbon-14 has a half-life of 5740 years. What is the probability that it will still be a carbon-14 atom in 5740 years’ time?

3. Cobalt-60 has a half-life of 5.2 years. What is the probability that an atom of cobalt-60 will still be an atom of cobalt-60 in 10.4 years’ time?

4. It takes 2.6 minutes for the radioactivity of barium-137 to decrease to half its original level. What is the half-life of barium-137?

5. Describe, in terms of probability, what will likely happen to an atom after three half-lives have passed.

6. 20 billion billion radioactive atoms of a pure substance with a half-life of 2 days is in a container. How many radioactive atoms of that substance will still be in the container after 2 days’ time?
Half-life

Half-life is the time taken for half the radioactive nuclei to decay spontaneously.

\[ N = N_0 \left( \frac{1}{2} \right)^n \]

where \( n \) = no. of half-lives
\( N_0 \) = original amount
\( N \) = final amount

Becquerels

Decay is measured in Becquerels (Bq)
1 Bq = 1 disintegration per second

describe the radioactive decay of unstable nuclei in terms of half-life
Practice Questions for 1.1.3
Reference: Heinemann Physics 11 Chapter 1.4

1. A radioactive source has a half-life of 15 minutes. At a particular time the activity of the source is 16 kBq. What is the activity of the source one hour later?

2. A student in a classroom measures 450 counts on a Geiger-Muller tube in 5 minutes. What is the background radiation in the classroom?

3. A substance has a half life of 60 seconds. How long will it take for its activity to decrease from 20 kBq to 2.5 kBq?

4. Actinium-227 decays to Thorium-227 with a half-life of 22 years. If the initial sample of Ac-227 had a mass of 120 kg, how much of the actinium isotope would be left after 66 years? Show your working.

5. Barium-137 has a half-life of 2.6 minutes.
   a) If the radioactivity of a sample of barium-137 is measured at 3000 Bq at midday, what will be the radioactivity of the same sample at 12:15pm the same day?
   b) At 12:20pm, what is the probability that one of the radioactive atoms in the sample will decay within the next 2.6 minutes?

6. Alexander Litvinenko was poisoned using 10 µg of $^{210}$Po (which has a radioactivity of approximately 2 GBq) in late 2006. Use this data to calculate the half-life of $^{210}$Po. Show your working. (Some Chemistry knowledge required.)
apply a simple particle model of the atomic nucleus to the origin of α, β and γ radiation, including changes to the number of nucleons
Practice Questions for 1.1.4
Reference: Heinemann Physics 11 Chapter 1.4

1. Write the equations for the following alpha decays:
   a) $^{238}_{92}$U → $^{234}_{90}$Th
   b) $^{222}_{88}$Ra → $^{218}_{84}$Po
   c) $^{256}_{103}$Lr → $^{252}_{101}$Gd
   d) $^{231}_{91}$Pa → $^{227}_{91}$Pa
   e) $^{225}_{89}$Ac → $^{221}_{87}$Fr
   f) $^{185}_{79}$Au → $^{181}_{77}$Au
   g) $^{233}_{92}$U → $^{239}_{92}$U
   h) $^{149}_{64}$Gd → $^{149}_{66}$Gd
   i) $^{232}_{90}$Th → $^{232}_{90}$Th
   j) $^{237}_{93}$Np → $^{233}_{93}$Np

2. Write the equations for the following beta decays:
   a) $^{14}_{6}$C → $^{14}_{5}$N
   b) $^{131}_{53}$I → $^{131}_{53}$I
   c) $^{\alpha}_{4}$He → $^{\alpha}_{3}$He
   d) $^{24}_{11}$Na → $^{24}_{12}$Mg
   e) $^{201}_{79}$Au → $^{201}_{79}$Au
   f) $^{52}_{26}$Fe → $^{52}_{28}$Fe
   g) $^{42}_{19}$K → $^{42}_{19}$K
   h) $^{90}_{38}$C → $^{90}_{37}$Cl
   i) $^{239}_{93}$Np → $^{239}_{92}$Np
   j) $^{247}_{95}$Am → $^{247}_{94}$Cm
   k) $^{82}_{35}$Br → $^{82}_{35}$Br
   l) $^{99}_{43}$Tc → $^{99}_{43}$Tc
describe the detection and penetrating properties of α, β, γ radiation
1. Define ionisation.
2. Describe briefly how a Geiger-Müller counter works.
3. A radioactive sample has activity of 1450 Bq. When a piece of card is placed between the Geiger-Müller tube and the sample, the radioactivity decreases to 120 Bq. What kind of radiation is being given off from the sample?
4. A radioactive sample has activity of 300 Bq. When placed into a paper bag, the activity is still 300 Bq. When placed into a thick lead box, the activity is 30 Bq. What kind of radiation does the sample produce?
5. Explain why beta particles, not alpha particles or gamma rays, are used for detecting the thickness of aluminium sheets produced in factories.
6. What type of radiation should astronauts be most concerned about?
 Ionising radiation

5 types: α, β, γ, X-rays and UV-B

not microwaves, infra-red or visible light, etc

Radiation sources outside the body are called “external sources” of radiation.

1

**ABSORBED DOSE**

\[
\text{ABSORBED DOSE} = \frac{\text{energy absorbed}}{\text{mass of tissue}}
\]

**UNITS:** \( \frac{\text{J}}{\text{kg}} \) or Grays (Gy)

2

**DOSE EQUIVALENT**

\[
\text{DOSE EQUIVALENT} = 1 \times \text{QUALITY FACTOR}
\]

**UNITS:** Sieverts (Sv)

because α is more ionising than β and γ

3

**EFFECTIVE DOSE**

\[
\text{EFFECTIVE DOSE} = \sum (2 \times \text{weighting})
\]

**UNITS:** Sieverts (Sv)

because ionising radiation causes tumours more easily in some body parts than in others

**Unit conversion J \leftrightarrow eV**

\[1 \text{ eV} = 1.6 \times 10^{19} \text{ J}\]

**Table 1.4 Quality factors**

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Quality factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha particles</td>
<td>20</td>
</tr>
<tr>
<td>Neutrons* (&gt;10 keV)</td>
<td>10</td>
</tr>
<tr>
<td>Beta particles</td>
<td>1</td>
</tr>
<tr>
<td>Gamma rays</td>
<td>1</td>
</tr>
<tr>
<td>X rays</td>
<td>1</td>
</tr>
</tbody>
</table>
| * Radiation from neutrons is only found around nuclear reactors and neutron bomb explosions.

**Table 1.7 The ICRP weighting values, W**

<table>
<thead>
<tr>
<th>Body part</th>
<th>Weighting, W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ovaries/testes</td>
<td>0.20</td>
</tr>
<tr>
<td>Bone marrow</td>
<td>0.12</td>
</tr>
<tr>
<td>Colon</td>
<td>0.12</td>
</tr>
<tr>
<td>Lung</td>
<td>0.12</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.12</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.05</td>
</tr>
<tr>
<td>Breast</td>
<td>0.05</td>
</tr>
<tr>
<td>Liver</td>
<td>0.05</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>0.05</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.05</td>
</tr>
<tr>
<td>Rest of body</td>
<td>0.07</td>
</tr>
<tr>
<td>Total</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Background radiation**

<table>
<thead>
<tr>
<th>Location</th>
<th>Annual background radiation dose (μSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>2000</td>
</tr>
<tr>
<td>New York, USA</td>
<td>1000</td>
</tr>
<tr>
<td>Paris, France</td>
<td>1200</td>
</tr>
<tr>
<td>Aberdeen, Scotland</td>
<td>5000</td>
</tr>
<tr>
<td>Chennai, India</td>
<td>8000</td>
</tr>
</tbody>
</table>

**Sources of background radiation include:**

- Cosmic radiation (especially at high latitude or altitude)
- Rocks, air and water (varies by location)
- Manufactured radiation (e.g. coal power stations)
- Medical exposure (e.g. medical X-rays)

describe the effects of α, β and γ radiation on humans, including short- and long-term effects from low and high doses, external and internal sources, including absorbed dose (Gray), equivalent dose (Sieverts) and effective dose (Sieverts)
1. Name five types of ionising radiation and five types of non-ionising radiation.

2. A patient undergoing radiation treatment receives a whole-body 0.40 Gy effective dose of gamma radiation to a tissue of mass 3.0 g.
   a) Determine the dose equivalent.
   b) How much energy does the patient receive during the treatment?

3. In a major incident in a nuclear reactor, a 92 kg employee received a radiation dose equivalent of 5.0 Sv. The radiation was gamma rays.
   a) Calculate the amount of energy that was absorbed during this procedure. Describe some of the somatic effects that this person would experience.

4. Calculate the dose equivalent from a radiation source if the absorbed dose is 0.50 mGy and the radiation is:
   a) alpha radiation (quality factor = 20)
   b) beta radiation (quality factor = 1)
   c) gamma radiation (quality factor = 1)

5. A soft tissue tumour of mass 59 g is exposed to a radiation dose of 1.9 Gy. The dose is delivered by the implantation of small sources of caesium-137, a beta and gamma emitter.
   a) How much energy does the tumour absorb during this irradiation?
   b) Calculate the dose equivalent in sieverts.

6. First responders of the Fukushima Daiichi nuclear disaster received effective doses of up to 180 mSv. Approximately how much radiation energy did they absorb? List any assumptions you make.
Effects of Radiation on the Body

Ionising radiation causes the formation of dangerous free radicals in the body.

Important Example:

\[
\text{H}_2\text{O} + ^0\gamma \rightarrow \text{H}^- + ^0\text{O}_2
\]

Water + Gamma → Single H + Hydroxyl Radical

**Somatic effects**

1. Non-fatal
   - Only minor symptoms such as nausea
   - White blood cell level drops

2. Death unlikely
   - Radiation sickness, i.e. nausea, vomiting and diarrhoea
   - Skin rashes
   - Hair loss
   - Bone marrow damage

3. 50% likelihood of death within 2 months
   - Severe radiation sickness
   - High probability of leukaemia and tumours

4. Almost certain death within 1 or 2 weeks
   - Acute radiation sickness—convulsions, lethargy

Table 1.8 The somatic effects of radiation doses

<table>
<thead>
<tr>
<th>Whole body dose (Sv)</th>
<th>Symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>Non-fatal</td>
</tr>
<tr>
<td></td>
<td>Only minor symptoms such as nausea</td>
</tr>
<tr>
<td></td>
<td>White blood cell level drops</td>
</tr>
<tr>
<td>2</td>
<td>Death unlikely</td>
</tr>
<tr>
<td></td>
<td>Radiation sickness, i.e. nausea, vomiting and diarrhoea</td>
</tr>
<tr>
<td></td>
<td>Skin rashes</td>
</tr>
<tr>
<td></td>
<td>Hair loss</td>
</tr>
<tr>
<td></td>
<td>Bone marrow damage</td>
</tr>
<tr>
<td>4</td>
<td>50% likelihood of death within 2 months</td>
</tr>
<tr>
<td></td>
<td>Severe radiation sickness</td>
</tr>
<tr>
<td></td>
<td>High probability of leukaemia and tumours</td>
</tr>
<tr>
<td>8</td>
<td>Almost certain death within 1 or 2 weeks</td>
</tr>
<tr>
<td></td>
<td>Acute radiation sickness—convulsions, lethargy</td>
</tr>
</tbody>
</table>

describe the effects of ionising radiation on living things and the environment
Practice Questions for 1.1.7
Reference: Heinemann Physics 11 Chapter 1.5

1. Why is ionising radiation so dangerous?
2. Describe a hydroxyl radical.
3. What two effects can free radicals have on the body?
4. Antioxidants are compounds found in green tea and berries, that absorb free radicals. Explain why antioxidants are so ‘healthy’.
5. In terms of effective dose, what might be a safe legal limit for radiation exposure?
6. A 61 kg person receives a whole-body gamma radiation dose of 14 J. Will they die?
**Explaining nuclear transformations**

1. **α radiation**
   - Speed ≈ 0.1c
   - Example:
     \[
     ^{238}_{92}U \rightarrow ^{234}_{90}Th + ^4_2\alpha + \text{energy}
     \]
     - Mass number has decreased by 4; atomic number has decreased by 2
     - An alpha particle is a helium nucleus and can also be written \(^2\text{He}^{2+}\).

2. **β radiation**
   - Speed ≈ 0.9c
   - Example:
     \[
     ^{14}_6C \rightarrow ^{14}_7N + ^0_{-1}\beta + \bar{\nu} + \text{energy}
     \]
     - A beta particle is an electron that has been released from the nucleus.
     - A neutron releases an electron and leaves behind a proton in the process \(n^0 \rightarrow p^+ + e^-\)

3. **γ radiation**
   - Speed = c
   - Example:
     \[
     ^{131}_{53}I \rightarrow ^{131}_{54}Xe + ^0_{-1}\beta + ^0_0\gamma
     \]
     - Gamma radiation has no mass, no charge and is electromagnetic.
     - It therefore travels at the speed of light \((3 \times 10^8 \text{ ms}^{-1})\)

---

**Example:**
- Uranium-238 is unstable. It decays to thorium-234, releasing an alpha particle and emitting energy.
- Carbon-14 is unstable. It decays to nitrogen-14, releasing a beta particle and emitting energy.
- Iodine-131 is unstable. It decays to xenon-131, releasing a beta particle and emitting a gamma ray.

**Notes:**
- Electrostatic repulsion between protons is greater than the strong nuclear force.
- Speed of light \((3 \times 10^8 \text{ms}^{-1})\)
- Mass number has decreased by 4; atomic number has decreased by 2
1. Compare an alpha particle and a beta particle. Comment on five properties that are different.
2. Of alpha, beta and gamma radiation, which are particles and which are waves?
3. Describe what happens in the nucleus during beta decay.
4. Some people like to think of a neutron as “a proton plus an electron”. Why is this?
5. What is the difference between a valence electron and a beta particle?
6. What is an antineutrino?
There are 4 decay series. We do not need to memorise them.

Decay Series Diagrams

- **Pb** (Lead) is the last stable isotope. Decay stops here. All radioisotopes will eventually decay into lead.

Analyse decay series diagrams in terms of type of decay and stability of isotopes.
Practice Questions for 1.1.9
Reference: Heinemann Physics 11 Chapter 1.4

1. Draw a decay series for the decay of uranium-238 in the following order: αβααααββαββα
2. What is the meaning of the times written on each arrow of the decay series?
3. Why do all decay series stop at lead?
4. There are four decay series in existence, and they are called 4n, 4n+1, 4n+2 and 4n+3. What is the significance of these names?
5. Look up the CNO cycle on the internet. It is the process by which large stars make fuel. Draw a table (in the style of a decay series) for the 6 isotopes involved in the CNO cycle.
natural isotopes have < 92 protons

artificial isotopes have very short half-lives

describe natural and artificial isotopes in terms of source and stability
Practice Questions for 1.1.10
Reference: Heinemann Physics 11 Chapter 1.4

1. Compare and contrast natural and artificial isotopes.
2. Why is ununoctium less stable than bismuth?
3. Mini-assignment: choose any two artificial isotopes and write down:
   a) how they were formed (an equation)
   b) the decay series of the product
Cobalt-60 is an artificial radioisotope produced by neutron absorption.

Example:

\[
\begin{array}{c}
\text{cobalt-59: stable} \\
\text{cobalt-60: radioactive}
\end{array}
\]

\[
\begin{array}{ccc}
1^0_n + & 59^{\text{Co}} & \rightarrow & 60^{\text{Co}}
\end{array}
\]

Neutron Absorption

describe neutron absorption as one means of production of artificial isotopes
1. Research: Find three isotopes that has been created by neutron absorption. For each isotope:
   a) write the equation that represents its creation
   b) draw its decay series
   c) write the uses of that isotope (if any).
Common misconceptions about radioactivity—and some rebuttals.
This list does not need to be memorised

1. People get most of their yearly radiation dose from nuclear power plants. Only 0.005% of the average American's radiation dose comes from nuclear power.
2. A nuclear reactor can explode like a nuclear bomb. Impossible.
3. Nuclear energy is bad for the environment. It's one of the cleanest forms of electricity generation.
4. Nuclear energy is not safe. Nobody has ever been killed by nuclear power generation in the United States.
5. There is no solution for huge amounts of nuclear waste being generated. It's stored underground.
6. Most Americans don’t support nuclear power. Most Americans support nuclear power.
7. An American “Chernobyl” would kill thousands of people. A Chernobyl-type disaster could only have happened in the Soviet Union
8. Nuclear waste cannot be safely transported. Yes, it can. By truck, train and ship.
9. Used nuclear fuel is deadly for 10,000 years. 99% of nuclear waste only needs to be stored for 300 years.
10. Nuclear energy can’t reduce our dependence on foreign oil. Yes it can, especially for small islands who import all their fuel.
Practice Questions for 1.1.12
Reference: TED Nuclear Energy Debate

1. Summarise ten common concerns about nuclear technology and ten rebuttals in a table.
2. Using the internet, research the sequence of events at Chernobyl in 1986. What were some of the predictions for consequences of exposure at that time? What has happened since then?
In 1986, a nuclear reactor melted down in Chernobyl in the Soviet Union.

Nuclear fallout was blown into the air, which settled into the soil in the surrounding area. The soil is still slightly radioactive.

Even in 2014, there is strong evidence of a significant increase in thyroid cancers among children living in the vicinity.
1. Written assignment: write a 5-paragraph, 250-word essay that answers the following question: “Some vital technologies rely on radioactivity for their operation. However, radioactive sources can be extremely dangerous if misused. Should the possession of artificial radioactive sources of any quantity be made illegal?” Take a stance. (Marked Excellent, Good, or Satisfactory)

2. Written assignment. Write an essay either supporting or opposing the use of nuclear power. You must use at least two real-life examples of nuclear power (or nuclear disasters) in your essay. Your essay must be hand-written and drawings are not necessary. Maximum length is 500 words.

Rubric:
- [4 marks for CLEAR HANDWRITING]
- [3 marks for SPELLING AND GRAMMAR]
- [2 marks for A CLEAR THESIS STATEMENT]
- [2 marks for CLEAR TOPIC SENTENCES]
- [3 marks for LOGICAL PARAGRAPH STRUCTURE]
- [4 marks for TWO REAL-LIFE EXAMPLES]
- [2 marks for AN INTERESTING CONCLUSION]
Electricity

**Electric Field Lines** show the direction that a positive charge would move in that electric field.

**Electric Field Lines**

- **+ + REPULSION**
- **− − REPULSION**
- **+ − ATTRACTION**

**Objects become positively charged when they lose electrons.**

**Electrostatic induction**

In this example, negatively-charged rod A induces a static charge in neutral rod B.

**Rod B was initially neutral.**

**Electrostatic induction**

In this example, negatively-charged rod A induces a static charge in neutral rod B.

**Repulsion**

- **+ +**
- **− −**

**Attraction**

- **+ −**

**Potential Difference**

concentration of charge (volts, V)

**Potential Difference**

- **V**
- **E**
- **J**
- **q**
- **C**

**Electrical potential between two points**

**Electric Current**

flow of electric charge over time (amperes, A)

**Electric Current**

- **I**
- **q**
- **C**
- **t**
- **s**

the amount of charge that flows in 1 second

**Power**

rate of energy use (watts, W)

**Power**

- **P**
- **E**
- **J**
- **t**
- **s**

the amount of energy that flows in 1 second

**Electric Field Strength at a given point**

force felt by 1C (newtons per coulomb N C⁻¹)

**Electric Field Strength at a given point**

- **F**
- **q**
- **N C⁻¹**
- **C**

Coulomb’s Law

- **F**
- **kq₁q₂**
- **r²**
- **N**
- **C²**
- **m²**

**Charge**

measured in coulombs (C)

**Charge**

- **q**
- **C**

charge of one electron = \(1.6 \times 10^{-19} \text{ C}\)

1 C = the charge of \(6.242 \times 10^{18}\) electrons

**VOLTAGE**

\[ V = \frac{E}{q} \]

**ENERGY**

\[ E = \frac{V}{q} \]

**CHARGE**

\[ q = \frac{E}{V} \]

**TIME**

\[ t = \frac{q}{I} \]

**POWER**

\[ P = \frac{E}{t} \]

**CURRENT**

\[ I = \frac{q}{t} \]

**ENERGY**

\[ E = \frac{P}{t} \]

**FORCE**

\[ F = \frac{kq₁q₂}{r²} \]

**CHARGES**

\[ q₁, q₂ \]

**DISTANCE**

\[ r \]

**.apply the concepts of charge (Q), electric current (I), potential difference (V), energy (E) and power (P) in electric circuits**
1. Questions about q
   a) Two Van de Graaff machines are placed 30 cm apart and switched on. If they both attain a charge of \( +3 \, \mu\text{C} \), what will be the electrostatic force between them?
   b) Two metal plates are placed 1 millimetre apart. One has a charge of \( +10 \, \mu\text{C} \) and the other has a charge of \( -10 \, \mu\text{C} \). What is the force between the plates? Attraction or repulsion?
   c) Two Van de Graaff machines are placed at opposite ends of Australia. If they both attain a charge of \( +3 \, \mu\text{C} \), what will be the electrostatic force between them? (Australia is 4100 km wide).

2. Questions about E
   a) A negative charge moves to the left in an electric field. What is the direction of the electric field?
   b) An electron feels a force of \( 8.0 \times 10^{-14} \, \text{N} \) upwards. What is the strength of the electric field?
   c) A charge of \( +7 \, \mu\text{C} \) feels a force of 200 N to the left. What is the strength and direction of the field?

3. Questions about I
   a) If 360 C flows through a torch in 20 minutes, what is the current?
   b) Teach current and conventional current

4. Questions about V
   a) A particular electric circuit carries 2.9 kJ of energy per coulomb of charge. What is the voltage of the circuit?
   b) How many joules of energy does each electron carry in a 240 V household electrical circuit?

5. Questions about P
   a) A particular family uses 4.12 kW h of electricity in one day. Convert this to an average power consumption in watts.
   b) A person ate 9320 kJ of food in one day. What is the equivalent power input of their diet?
analyse electrical circuits using the relationships \( I = \frac{q}{t} \), \( V = \frac{E}{q} \), \( P = \frac{E}{t} = VI \), \( E = VIt \)

**3 Useful Formulae**

\[ E = VIt \quad P = VI \quad P = I^2R \]

**Device** | **Symbol** | **Device** | **Symbol**
---|---|---|---
wraps crossed not joined |  | cell (DC supply) |  
wraps joined, junction of conductor |  | battery of cells (DC supply) |  
resistor or other load |  | AC supply |  
fixed resistor |  | ammeter |  
filament lamp |  | voltmeter |  
diode |  | fuse |  
earth or ground |  | switch |  

**Kirchhoff’s Two Laws**

- Sum of all currents flowing into a point = sum of all currents flowing out of it
- Voltage is conserved in parallel circuits

Current is split in parallel circuits

Voltage is conserved in parallel circuits

Sum of voltage drops across all components in a circuit = voltage provided by the battery
1. Write the official definitions of Kirchhoff’s two laws.

2. What is the purpose/function of the following electronic devices?
   a) fuse
   b) switch
   c) resistor
   d) diode
   e) voltmeter
   f) ammeter

3. Draw circuits for the following appliances:
   a) a torch (DC)
   b) a heater (AC)
   c) a set of 5 Christmas tree lights in series (AC)
   d) a set of 5 LED lights in series (DC) — you will need to look up the symbol for an LED

4. What is the power of consumption of a device that requires a 10 A current at 240 V?

5. What is the power consumption of an electrical component that uses 10 mA at 3 V?

6. How much energy is used by a heater that uses 2000 W of power for three hours?

7. How long will it take an 800 W microwave to consume 1 kJ of energy?

8. Draw a circuit containing a battery of cells, a switch, a filament lamp, a voltmeter and an ammeter.
Series Circuits

Example
(no branches)

\[ R = \frac{V}{I} \]

for ‘ohmic’ devices

Resistors in series

\[ R_r = R_1 + R_2 + \ldots + R_n \]

Parallel Circuits

Example
(has branches!)

\[ R = \frac{V}{I} \]

for ‘ohmic’ devices

Resistors in parallel

\[ \frac{1}{R_r} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n} \]

model resistance in series and parallel circuits using - potential difference versus current (V-I) graphs; resistance as the potential difference-to-current ratio, including V/IR=constant for ohmic devices; equivalent effective resistance in arrangements in series and parallel
Practice Questions for 1.2.3
Reference: Heinemann Physics 11 Chapter 3.1 & 3.2

1. Define the following:
   a) Series
   b) Parallel

2. Define an “ohmic” device.

3. Calculate the resistances of the following combinations:
   a) Three resistors in series: 30 Ω, 20 Ω and 10 Ω
   b) Two resistors in series: 100 Ω and 10 Ω
   c) Three resistors in parallel: 30 Ω, 20 Ω and 10 Ω
   d) Two resistors in parallel: 100 Ω and 10 Ω
   e) Parts (c) and (d) connected in series by a single wire.

4. Combine a 3 Ω resistor, a 2 Ω resistor and two 1 Ω resistors so that the total resistance is 2 Ω.

5. In a simple circuit, only a 1.5 V cell, a filament bulb and a resistor are connected in series.
   a) Draw the circuit.
   b) If the voltage across the resistor is 1.0 V, what is the voltage across the filament bulb?
   c) A student measured the resistance across the filament bulb and found it to be a little bit less than your answer in part (b). Suggest a reason for this.

6. In a simple circuit, only a battery of six 1.5 V cells, two filament bulbs and an ammeter are connected in series.
   a) Draw the circuit.
   b) Draw the circuit with the ammeter in a new location in the circuit.
   c) In the new location, is the reading on the ammeter the same as different? Why?
   d) A student measured the resistance across the filament bulb and found it to be a little bit less than your answer in part (b). Suggest a reason for this.

7. Two identical resistors are placed in parallel in a circuit containing a 9.0 V battery. How much current passes through each resistor?

8. A 10 Ω resistor and a 5.0 Ω resistor are placed in parallel in a circuit with a 9.0 V battery. How much current passes through each resistor? How much energy will be transmitted through each resistor in 5 minutes?

9. Why is “electromotive force” (an alternative term for ‘voltage’) technically an incorrect term?
AC is alternating current
 electrons oscillate back and forth

DC is direct current
 electrons travel in one direction

AC voltage is calculated like this:

\[ V_{AC} = \frac{V_{peak}}{\sqrt{2}} \]

For example:

\[ 240 \text{ V DC} \]

\[ 240 \text{ V AC} \]

(We can't just take the average AC voltage because the average will always be zero volts.)

For example:

\[ \frac{340}{\sqrt{2}} = 240 \]

model simple electrical circuits such as car and household (AC) electrical systems as simple direct (DC) circuits.
1. Define alternating current and give three examples
2. Define direct current and give three examples
3. Calculate the peak voltage for a 240 V alternating current
4. Calculate the peak voltage for a 120 V alternating current
5. If you use a high-speed camera, you can see that electric lights in our houses and schools actually flicker about 100 times per second. Why is this?
240 V AC is the standard household electrical voltage in Australia. The voltage oscillates rapidly between –340 V and +340 V, and the energy output is equivalent to that of a 240 V direct current.

model household electricity connections as a simple circuit comprising fuses, switches, circuit breakers, loads and earth

VERY IMPORTANT SAFETY INFORMATION:
the switch should always be placed in the active wire or the appliance will be live even when turned off!
Practice Questions for 1.2.5
Reference: Heinemann Physics 11 pages 97

1. Components in DC circuits make connections to two wires, one of which is positive, and the other of which is negative. Why don’t AC circuits have positive and negative wires?

2. Wires in an AC circuit can be abbreviated as A, N and E. What do those letters stand for?

3. Why should the on/off switch always be wired into the active wire?

4. What would happen if the on/off switch was wired into the neutral wire? Would the device still work?

5. Create a table with the following column headings: component, image, function; and the following rows: fuses, loads, earth. Fill in the table.
**Severity of an electric shock depends on the current and the duration of the shock.**

### Table 3.1 The likely effect of a half-second electric shock. The actual current that flows will depend on the voltage and skin resistance

<table>
<thead>
<tr>
<th>Current (mA)</th>
<th>Effect on the body</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Able to be felt</td>
</tr>
<tr>
<td>3</td>
<td>Easily felt</td>
</tr>
<tr>
<td>10</td>
<td>Painful</td>
</tr>
<tr>
<td>20</td>
<td>Muscles paralysed—cannot let go</td>
</tr>
<tr>
<td>50</td>
<td>Severe shock</td>
</tr>
<tr>
<td>90</td>
<td>Breathing upset</td>
</tr>
<tr>
<td>150</td>
<td>Breathing very difficult</td>
</tr>
<tr>
<td>200</td>
<td>Death likely</td>
</tr>
<tr>
<td>500</td>
<td>Serious burning, breathing stops, death inevitable</td>
</tr>
</tbody>
</table>

### Table 3.2 The likely effect on the human body of a 50 mA shock for various times

<table>
<thead>
<tr>
<th>Time of 50 mA current</th>
<th>Likely effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 0.2 s</td>
<td>Noticeable but usually not dangerous</td>
</tr>
<tr>
<td>0.2–4 s</td>
<td>Significant shock, possibly dangerous</td>
</tr>
<tr>
<td>Over 4 s</td>
<td>Severe shock, possible death</td>
</tr>
</tbody>
</table>

**What causes more current to travel through your body?**

**Wet floors**

**Wet skin**

Standing on a wet floor carries more current than standing on an insulator, e.g. carpet.

Wet skin carries 100× more current than dry skin because it has 100× less resistance.

Identify causes, effects and treatment of electric shock in homes, relating these to approximate danger thresholds for current and time.
Practice Questions for 1.2.6
Reference: Heinemann Physics 11 pages 100

1. A person has been shocked by touching the outer casing of an incorrectly-wired metal toaster. Suggest how the wiring might have been incorrect.

2. The person receives a 8 mA current. Describe how they feel.

3. Another person has just come out of the shower with wet hands and also touches the broken toaster. They receive a 50 mA current. Describe how they feel.

4. Explain mathematically why the person in question 3 experienced a greater shock than the person in question 2.
investigate practically the operation of simple circuits containing resistors, variable resistors, diodes and other non-ohmic devices

**Ohmic**

**CONSTANT RESISTANCE** (straight line V-I graph)

- **Resistor**

**Non-ohmic**

**RESISTANCE VARIES WITH VOLTAGE OR CURRENT** (curved V-I graph)

- **Light bulb**
- **Diode**

Ohmic

Non-ohmic
Practice Questions for 1.2.7
Reference: Heinemann Physics 11 Chapters 3.1 & 3.2

1. Define “ohmic”.

2. Draw an V/I graph containing the light bulb and the diode on the next page.
   a) Sketch the resistance of these two components are combined in parallel
   b) Sketch the resistance of these two components are combined in series

3. Draw an V/I graph containing the light bulb and the resistor on the next page.
   a) Sketch the resistance of these two components are combined in parallel
   b) Sketch the resistance of these two components are combined in series

4. The next questions refer to the V/I graphs you have drawn.
   a) Calculate the resistance of the resistor
   b) Calculate the resistance of the diode at 1.0 V
   c) Calculate the resistance of the light bulb at 6.0 V
KWh Conversions

\[ J \times 3.6 \times 10^6 \]

\[ \div 3.6 \times 10^6 \]

Do not confuse kW h (energy) with kW (power)!

Convert energy values to kilowatt-hour (kWh)
A family uses 4.98 kW h of electricity in 24 hours.
   a) Convert this value to megajoules
   b) Convert this average level of energy consumption into watts

Another family uses 19 MJ of electricity in 36 hours.
   a) Convert this value to kilowatt-hours
   b) Convert this average level of energy consumption into watts

If electricity costs $0.37 per kilowatt-hour, how much does it cost to heat a plate of food for 60 seconds at 800 W in the microwave?

At night, electricity is a little cheaper. Assuming a night-time electricity cost of $0.32 per kilowatt-hour, calculate the cost of charging an iPad Air. The charger says “5.4 V, 2.4 A” on the back, and the iPad takes about 5 hours to charge from 0% to 100%.
identify and apply safe and responsible practices when conducting investigations involving electrical equipment and power supplies.

5 Safe Electrical Practices

- **Fuses**: burns out safely at high current, preventing fires in the other components
- **Earth wire**: current passes into the earth wire
- **Earth leakage system**: switches off the power if a difference in active and neutral currents is detected
- **Double-insulation**
- **Switches**
Practice Questions for 1.2.10
Reference: Heinemann Physics 11 pages 98-99

1. Explain in detail how each of the five “FEEDS” devices make our household electrical circuits much safer.
identify parameters of motion as vectors or scalars

### Scalars

- **have no direction**

- **S**
  - e.g. speed

  \[
  \text{speed} = \frac{\text{distance travelled}}{\text{time}}
  \]

  \[
  \text{Algebraically:} \quad v_{av} = \frac{d}{\Delta t}
  \]

### Vectors

- **have direction**

- \( \vec{V} \)
  - e.g. velocity

  \[
  \text{velocity} = \frac{\text{displacement}}{\text{time}}
  \]

  \[
  \text{Algebraically:} \quad \vec{v}_{av} = \frac{\vec{x}}{\Delta t}
  \]

final position – initial position (straight-line distance)
Practice Questions for 2.1.1
Reference: Heinemann Physics 11 Chapter 4.1

1. Explain the difference between scalar and vector quantities.
2. Give five examples of scalar quantities and list their units.
3. Give five examples of vector quantities and list their units.
4. Describe an example of a car that has travelled with high speed but low velocity.
5. Describe an example of a car that has travelled with high speed but zero velocity.
6. Some objects have negative velocity. Is it possible to have negative speed? If so, how?
3 Ways to Analyse Linear Motion

**Graphically** 3 sub-types

- **Position-Time Graph**
- **Velocity-Time Graph**
- **Acceleration-Time Graph**

**Numerically**

**Example**

- Velocity at 20 s is 2 m s\(^{-1}\)
- Velocity between 25 s and 35 s is 0 m s\(^{-1}\)
- Velocity at 55 s is –1 m s\(^{-1}\) or 1 m s\(^{-1}\) in the opposite direction

**Get numbers from the above graphs**

**Example**

- Velocity at 1 s is 3 m s\(^{-1}\)
- Velocity at 5 s is 1.5 m s\(^{-1}\)
- Acceleration at 4.5 s is 1.5 m s\(^{-2}\) backwards
- Between 6 s and 7 s, the object is stationary
- After 4 s, the object is 12 m from its starting point.

**Algebraically**

- \( t \) time
- \( a \) acceleration
- \( x \) displacement
- \( u \) initial velocity
- \( v \) final velocity

- \( v_{\text{avg}} = \frac{(u + v)}{2} \)
- \( x = ut + \frac{1}{2}at^2 \)
- \( v = u + at \)
- \( x = vt - \frac{1}{2}at^2 \)
- \( x = \frac{(u + v)}{2}t \)
- \( v^2 = u^2 + 2ax \)

**Know how to use these 5 formulae**

- Analyse straight-line motion under constant acceleration graphically, numerically and algebraically
Practice Questions for 2.1.2
Reference: Heinemann Physics 11 Chapter 4.2 & 4.3

1. A cat climbs up a tree. It takes 5 seconds for the cat to reach a branch 3 metres high.
   a) Draw a position-time graph for the cat from 0 to 5 seconds.
   b) Draw a velocity-time graph for the cat from 0 to 5 seconds.

2. A cyclist is waiting at a red traffic light. One second after the traffic light turns green, he accelerates at 3 m s\(^{-2}\) for 2 seconds, then at 2 m s\(^{-2}\) for 5 seconds. He then brakes very hard in order to avoid an accident, and his velocity decreases to just 3 m s\(^{-1}\) within 2 seconds.
   a) Draw a position-time graph for the cyclist from 0 to 10 seconds.
   b) Draw a velocity-time graph for the cyclist from 0 to 10 seconds.
   c) Draw an acceleration-time graph for the cyclist from 0 to 10 seconds.

3. Find \(t, a, x, u, v\) for all of the following situations:
   a) A bird is flying at 10 m s\(^{-1}\), then decelerates (uniformly) for 5 seconds before coming to a complete stop so it can land on a branch.
   b) A car takes 20 m to stop from 60 km h\(^{-1}\).
   c) An apple falls from a tree from a height of 3 m.
   d) A McLaren P1 accelerates from 0 to 100 km h\(^{-1}\) in 2.8 seconds.
   e) A McLaren P1 accelerates from 0 to 300 km h\(^{-1}\) in 16.5 seconds.
   f) A McLaren P1 accelerates from 0 to 300 km h\(^{-1}\) in 16.5 seconds.
   g) A space shuttle accelerates at 9 m s\(^{-2}\) for 55 seconds after launch.
In reality, the lines are curved...

Find the gradient at point A by measuring the gradient of the tangent at point A.

analyse graphically non-uniform motion in a straight line
1. This picture is from http://www.russellwestbrook.com/Acceleration.htm
   a) Draw a full-page velocity-time graph from this data
Aristotle

- Four elements theory
- All objects are combinations of fire, earth, wind and water.
- Earth objects want to return to “earth” (so they fall downwards)
- Fire wants to return to the sun (so it rises)
- Forces keep things moving
- Heavy objects fall faster due to gravity

Galileo

- All objects fall at the same rate regardless of their mass
- All objects fall with constant acceleration due to gravity
- Objects keep moving until a force is applied (inertia)

Newtown

- Forces make objects change velocity
- Newton’s Three Laws (see Unit 2.1.8)
- Objects keep moving until a force is applied (inertia)

compare the effect of a force as defined by Aristotle, Galileo and Newton
Practice Questions for 2.1.4
Reference: Heinemann Physics 11 Chapter 4.4 & 5.2

1. According to Aristotle, what would happen if you rolled a football and a bowling ball down a ski slope? (Ignore friction.)

2. According to Galileo, what would happen if you rolled a football and a bowling ball down a ski slope? (Ignore friction.)

3. In a hypothetical situation, what would happen if you rolled a bowling ball down an infinitely long bowling alley:
   a) according to Aristotle’s theory of motion?
   b) according to Galileo’s theory of motion?
model weight, \( w \), as the force of gravity acting at the centre of mass point (approximated as the geometric centre) of a body, \( w = mg \)

\[
\text{Weight} \quad = \quad \text{Mass} \times \text{Acceleration due to gravity}
\]

\[
w = mg
\]

\[
g = 9.8 \text{ m s}^{-2} \quad \text{(on Earth)}
\]

\[
\text{Example} \quad 490 \text{ N} = 50 \text{ kg} \times 9.8 \text{ m s}^{-2}
\]

We can assume that gravity acts on the centre of mass of every object.
Assume all these objects are near the surface of the Earth unless otherwise stated.

1. Calculate the masses of the following objects. The forces due to gravity acting upon these objects is shown beside each object.
   a) a bottle of water (4.9 N)
   b) a bird (1.8 N)
   c) a $100 note (9.8 mN)
   d) an elephant (25.48 kN)
   e) a book (2.45 N)

2. Calculate the force due to gravity (in N) acting on the following objects.
   a) a 1 kg gold bar
   b) a 4 g gold ring
   c) 4 g of feathers
   d) 420 g of potatoes
   e) 7 tonnes of coal

3. A student has mass of 58 kg. What is the force due to gravity if the student is standing:
   a) on Earth (g = 9.8 m s\(^{-2}\))
   b) on the Moon (g\(_{\text{moon}}\) = 1.6 m s\(^{-2}\))
   c) on Neptune (g\(_{\text{neptune}}\) = 11.2 m s\(^{-2}\))
   d) on Mars (g\(_{\text{mars}}\) = 3.7 m s\(^{-2}\))

4. A monkey has jumped out of a tree. Immediately after it jumped, the monkey and the Earth are attracting each other with a force of 89 N. Assuming the tree is not very tall, what is the mass of the monkey?
Force, \( F \) is measured in newtons (N) and is a vector quantity. It requires a magnitude and a direction to describe it fully.

**Describe forces as “force of \( X \) on \( Y \)”**

- Force of air resistance on the football
- Force of gravity on the car
- Force of lift on the aeroplane

**Add forces up like vectors in one dimension**

![Diagram of forces in one dimension](image)

Net force = 75 N

Net force = 320 N

**Add forces up like vectors in two dimensions**

![Diagram of forces in two dimensions](image)

All of these objects are travelling at constant velocity because the net force acting on them equals zero.

**Use trigonometry if needed**

\[
c = \sqrt{a^2 + b^2}
\]

- **Example 1:** Net force = 50 N
  - \( c = \sqrt{30^2 + 40^2} = 50 \)
  - \( 50 = \sqrt{30^2 + 40^2} \)

- **Example 2:** Net force = 141 N
  - \( c = \sqrt{100^2 + 100^2} = 141 \)
  - \( 141 = \sqrt{100^2 + 100^2} \)

Model forces as vectors acting at the point of application (with magnitude and direction), labelling these forces using the convention ‘force of ... on ...’
Practice Questions for 2.1.7
Reference: Heinemann Physics 11 Chapters 5.1 & 5.2

1. What does it mean when we say that force is a “vector”?

2. What is the effect of:
   a) Non-zero net force?
   b) Zero net force?

3. Draw, with all the individual forces and the net force labelled as arrows (no numbers required):
   a) a bowling ball rolling down a bowling lane
   b) a tennis ball just after it has been hit by a tennis racket
   c) a person who has just jumped off a cliff
   d) an asteroid travelling through outer space

4. Calculate the magnitude and direction of the net force of:
   a) 2 N west and 1 N east
   b) 4 N north and 3 N north
   c) 9 N east and 2 N west
   d) 5 N north, 19 N north and 9 N south
   e) 4 N south and 3 N west

5. Calculate the magnitude of the net force of:
   a) 2 N north and 3 N east
   b) 4 N south and 9 N south
   c) 8 N east and 77 N south
   d) 65 N at 090° and 10 N at 000°
   e) 10 N 010° and 10 N at 100°
   f) 20 N at 000° and 10 N at 270°
   g) 41 N north-west, 22 N north-east, 31 N south-west, 4 N south-east
Newton’s 3 Laws

**First Law**

"an object will maintain constant velocity unless a non-zero net force acts upon it"

Cyclist travels at constant speed because zero net force is acting on the bike

\[ \sum F = F_{\text{applied}} + F_{\text{drag}} = 60 - 60 = 0 \]

If the Force vectors all add up to zero, then the velocity isn’t changing

**Second Law**

\[ F = ma \]

After you’ve found acceleration \((a)\) using the formulae in Unit 2.1.2, use \(F = ma\) to calculate the size and direction of the force in newtons.

\[ a = \frac{F}{m} = \frac{1\, \text{N}}{1\, \text{kg}} = 1\, \text{m/s}^2 \]

Rearrange to find acceleration

**Third Law**

Every action has an equal and opposite reaction

Newton’s Third Law takes into account an entire system, not just a single object (e.g. a bike or a weight). The above arrows represent forces and are all of equal size. However, the pairs of objects in each picture have different masses and therefore have different accelerations.

apply Newton’s three laws of motion to a body on which a resultant vector force acts
1. State Newton’s Three Laws.
2. Describe the motion of objects that have zero net force acting upon them.
3. A tennis player accelerates a tennis ball from 0 m s\(^{-1}\) to 25 m s\(^{-1}\) in just 5 ms. What is the force acting on the ball during this time?
4. A 4.20 g bullet is fired from a pistol with barrel length 125 mm. The pistol’s muzzle velocity is 381 metres per second. Assuming constant acceleration, calculate:
   a) the acceleration of the bullet
   b) the force acting on the bullet
   c) the time taken for the bullet to reach the end of the muzzle
   d) the force of the recoil acting on the pistol
   e) if the pistol weighs 952 g, what with what acceleration does the pistol recoil?
Example: a 1.2-tonne car accelerates

\[ \sum F = 1800 \text{ N forwards} \]
If \( m_{\text{car}} = 1200 \text{ kg} \), then:

\[ a = \frac{1800 \text{ N}}{1200 \text{ kg}} \]
\[ a = 1.5 \text{ m/s}^2 \]

In free-fall

\[ a = g \]
\[ a = 9.8 \text{ m/s}^2 \]

Moving down a slope

\[ a = g \sin \theta \]
\[ a = 9.8 \times 0.5 \]
\[ a = 4.9 \text{ m/s}^2 \]

apply the vector model of forces, including vector addition and components of forces, to readily observable forces including weight, friction and reaction forces
1. Draw the forces acting on a 680-gram remote-controlled aeroplane that is travelling at constant velocity in the air. Air resistance on the plane is 0.46 N.

2. Draw the forces acting on a 1.5-tonne car that is accelerating at 1.0 m s\(^{-2}\) if the force of friction on the car is 1000 N.

3. Calculate the rate of acceleration due to gravity of a truck rolling down a hill at the following angles:
   a) 0°
   b) 1°
   c) 2°
   d) 8.9°
   e) 10°
   f) 1 in 5 slope
   g) 30°
   h) 1 in 2 slope tan
   i) 45°
   j) 89°

4. A 162-gram pool ball that is travelling at 0.42 m s\(^{-1}\). The force of friction between the pool ball and the pool table is 1.3 \(\times\) 10\(^{-2}\) N.
   a) Draw the ball and the forces acting on it as vectors (arrows).
   b) Calculate the rate of deceleration of the ball.
   c) Calculate the distance that the ball travels before stopping.
   d) Calculate the time taken for the ball to come to a complete stop.
   e) Are these figures realistic?
apply the concept of work done by a constant force: work done = constant force x distance moved in direction of force; work done = area under force-distance graph
1. Calculate the work done when:
   a) a helicopter weighing 1400 kg ascends vertically to a height of 1000 metres.
   b) a rocket weighing 500 grams ascends to a height of 2900 metres.
   c) a 65-kg student climbs a 4-metre flight of stairs.
   d) a person pulls a suitcase at an angle of 55° with a force of 85 N a distance of 100 metres.
   e) a parasailing holiday-maker is pulled by a parachute, which is flying at 25 metres above sea-level on a 42-metre-long rope. If the force of the wind hitting the parachute pulls it at 800 N away from the holiday-maker, how much work is done after the holiday-maker has travelled 300 horizontal metres?
**Hooke’s Law for Ideal Springs**

**Equation:**

\[ F = -k \Delta x \]

- **Force** (in newtons, N)
- **Spring constant** \( k \) (in N m\(^{-1}\))
- **Extension or compression** in metres (m)

**Graph:**

A graph shows the linear relationship between applied force and extension, with a red line indicating direct proportionality.

**Text:**

Only ideal materials obey Hooke’s Law, which states:

“The force applied by a spring is directly proportional, but opposite in direction, to the spring’s extension or compression.”

**Analysis:**

Analyse Hooke’s Law for an ideal spring, \( F = -k \Delta x \)
1. What is an ideal spring?

2. What is Hooke’s Law?

3. Draw a Force-extension graph (force on the y axis and Δx on the x axis) showing the following information. (Draw the x axis from zero to 0.5 metres.)
   a) an ideal spring with spring constant = 400 N m\(^{-1}\)
   b) an ideal spring with spring constant = 800 N m\(^{-1}\)
   c) find the force required to extend each of the springs from zero to 0.5 metres.
   d) find the work done in extending each of the springs from zero to 0.5 metres.
2.1.12

Analyse energy transfers and transformations using an energy conservation model including transfers between gravitational potential energy near Earth’s surface, \( mgh \), and kinetic energy, \( \frac{1}{2}mv^2 \); and between potential energy in ideal springs, \( \frac{1}{2}k\Delta x^2 \), and kinetic energy, \( \frac{1}{2}mv^2 \).

For a spring being stretched

\[
\text{Total Energy in the Spring} = E_k + U_s = \frac{1}{2}mv^2 + \frac{1}{2}k\Delta x^2
\]

= constant for ideal springs

Kinetic energy

Elastic Potential Energy

Total Mechanical Energy

= \( E_k + U_g \) = \( \frac{1}{2}mv^2 + mgh \)

= constant for each jump or fall

Falling or jumping

Initially the jumper has only horizontal kinetic energy (at take-off) which is all converted into gravitational potential energy (at peak height)

Substituting the values from the question:

\[
\frac{1}{2}u^2 \quad \text{and} \quad u \cdot 2 = 15.42
\]

5.6 m s\(^{-1}\).

In reality the take-off speed will need to be a little greater since there will be some losses to friction.

Figure 6.32

During each airborne stage of a gymnast’s trampoline routine (indicated on the graph by shading), mechanical energy is conserved.

The graph shows the relationship between total energy and gravitational potential energy and kinetic energy.

Each time the gymnast lands, energy is transferred to the trampoline. The energy returning from the springs after each landing allows the routine to continue.
Practice Questions for 2.1.12
Reference: Heinemann Physics 11 pages 203-205

1. Define the following terms:
   a) $E_k$
   b) $U_g$
   c) $U_s$

2. Describe the changes in $E_k$ and $U_g$ as a gymnast jumps and lands on the ground again.

3. Describe the changes in $E_k$ and $U_s$ as a spring is stretched and slowly relaxed again.

4. Have a look at the graph you drew for Unit 2.1.11 question 3. If a 50-gram mass is hung from each of those springs, what would be the elastic potential energy stored in each of the springs?
apply rate of energy transfer, power, \( P = \frac{E}{t} \)

Power

Energy

watts, W

joules, J

time

seconds, s

You may also use this alternative formula because both \( W \) and \( E \) are measured in joules
1. Calculate the energy required to maintain a 50 W lamp switched on for 8 hours.

2. What is the power consumption of a toy that uses 1 MJ of energy in 2.5 hours?

3. A 1000-kg helicopter ascends from a height of 200 metres to a height of 500 metres in 1 minute.
   a) How much gravitational potential energy has the helicopter gained?
   b) Calculate the work done by the helicopter.
   c) What is the average power output of the helicopter during this manoeuvre?

4. Tour de France cyclists burn over 40 MJ of energy each day during the competition.
   a) What is their average power output?
   b) How many times higher is this than a non-athlete?
apply the concept of momentum, $p = mv$
1. Calculate the momentum of the following objects:
   a) a 3-ton elephant running at 10 km h\(^{-1}\)
   b) a 600-kg Smart car driving at 80 km h\(^{-1}\)
   c) an 80-ton train driving at 180 km h\(^{-1}\)
   d) a 150-gram ping pong ball travelling horizontally through the air at 8.0 m s\(^{-1}\)
   e) a 5-gram coin that has fallen straight down from a height of 4.9 m
   f) a paperweight of mass 800 g that has been lifted with a velocity of 0.1 m s\(^{-1}\)
   g) a paper aeroplane of mass 9 grams that is flying with a velocity of 2.1 m s\(^{-1}\)
If $F \neq 0$, the object is accelerating. Therefore $v$ is changing.

$$p = mv$$

If $m$ remains constant... Then $p$ must also change.
Practice Questions for 2.1.15
Reference: Heinemann Physics 11 Chapter 6.2

(Describe how net force causes changes in momentum)
Impulse = change in momentum

\[ I = \Delta p \]

Impulse = average Force during impact \times time

\[ I = F_{\text{average}} \Delta t \]

Ns = N \times s

The same impulse applied over a longer time results in a smaller (and less painful) Force being acted upon the object.

analyse impulse (momentum transfer) in an isolated system, for elastic collisions between objects moving in a straight line.
1. Calculate the Impulse in N s of the tennis ball in Unit 2.1.8 question 3.
2. Calculate the Impulse in N s of the bullet fired in Unit 2.1.8 question 4.
3. Explain why it doesn’t hurt to fall over onto soft snow, even though the same fall would be painful on concrete.
describe transverse waves in terms of amplitude, wavelength period and frequency
Practice Questions for 2.2.1
Reference: Heinemann Physics 11 Chapters 7.1 & 7.2

1. Describe the two types of waves.

2. Give five examples of:
   a) transverse waves
   b) longitudinal waves

3. Draw a sinusoidal transverse wave.
   a) Draw another wave superimposed with double the amplitude of the first wave.
   b) Draw another wave superimposed with double the wavelength of the first wave.
   c) Draw another wave superimposed with double the frequency of the first wave.

4. Make a half-page drawing of two randomly-shaped waves and label them A and B.
   a) Graphically sketch the wave that results from the superimposition of A + B.
2 Very Important Wave Formulae

\[ v = f \lambda \]

\[ f = \frac{1}{T} \]

calculate wavelength, frequency, period and speed of travel of light waves, \( v = f \lambda = \frac{\lambda}{T} \)
Practice Questions for 2.2.2
Reference: Heinemann Physics 11 Chapter 7.2 & 7.3

1. Fill in the following table.

<table>
<thead>
<tr>
<th>$v$ (m/s)</th>
<th>$\lambda$ (m)</th>
<th>$f$ (Hz)</th>
<th>$T$ (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3.0 \times 10$</td>
<td>$5.9 \times 10$</td>
<td>$3.0 \times 10$</td>
<td>$4000$</td>
</tr>
<tr>
<td>$2.0 \times 10$</td>
<td>$3.0 \times 10$</td>
<td>$5.9 \times 10$</td>
<td>$30$</td>
</tr>
<tr>
<td>$1.3 \times 10$</td>
<td>$1.0 \times 10$</td>
<td>$1.008 \times 10$</td>
<td>$1 \times 10$</td>
</tr>
<tr>
<td>$9.1 \times 10$</td>
<td>$4.1 \times 10$</td>
<td>$1.0 \times 10$</td>
<td>$5.5 \times 10$</td>
</tr>
<tr>
<td>$1.0 \times 10$</td>
<td>$4.1 \times 10$</td>
<td>$1.0 \times 10$</td>
<td>$9.1 \times 10$</td>
</tr>
</tbody>
</table>
investigate and analyse the behaviour of light using ray diagrams including reflection, $i = r$, refraction, Snell’s Law, total internal reflection, critical angle (any form of image location is not required)
Practice Questions for 2.2.3
Reference: Heinemann Physics 11 Chapter 8.1, 8.2 & 8.3

1. What is the speed of light in a vacuum?
2. What is the Law of Reflection?
3. What is Snell’s Law?
4. Define the following words:
   a) normal
   b) parallel
   c) incident
   d) reflected
   e) transmitted
   f) absorbed
   g) refracted
   h) theta
   i) diffuse reflection
   j) refractive index
   k) relative refractive index
   l) total internal reflection
   m) critical angle
5. Draw a mirror with incident rays hitting the mirror at the following angles. Also draw the reflected rays.
6. Describe why we can’t see our reflection on a sunlit beach.
7. Explain, with a diagram, why objects in water appear to be higher up in the water than they actually are.
8. Explain why light rays are not refracted when light travels from one medium to another medium when it is travelling perpendicular to the interface between the two materials.
9. Draw light rays travelling at 30° from air into the following materials:
   a) water \((n = 1.33)\)
   b) diamond \((n = 2.42)\)
   c) ice \((n = 1.31)\)
10. Calculate the speed of light travelling through each of the materials in question 9.
11. Calculate the critical angle \(i_{\text{critical}}\) for the interface between water and diamond.
12. Calculate the critical angle \(i_{\text{critical}}\) for the interface between water and ice.
describe light using a wave model and a particle model

Light is a Particle

Explains why light travels in straight lines

Light is a Wave

Explains why light refracts, diffracts and polarises
Practice Questions for 2.2.4
Reference: Heinemann Physics 11 Chapter 8

1. In what ways/situations can light be described as a particle?
2. In what ways/situations can light be described as a wave?
Explain polarisation of visible light and its relation to a transverse wave model.
1. What is polarised light?

2. What happens when you look through two pairs of polarised sunglasses, one behind the other:
   a) at the same angle?
   b) at 45° to each other?
   c) at 90° to each other?
   d) at 180° to each other?
compare the wave model and the particle model of light in terms of whether they adequately describe reflection and refraction

Light can be drawn two ways

**Light is a Particle**
- Drawn as ‘rays’, or straight lines
- Explains why light travels in straight lines
- Good for modelling REFLECTION

**Light is a Wave**
- Drawn as wavefronts
- Explains why light refracts and diffracts
- Good for modelling REFRACTION
Practice Questions for 2.2.6
Reference: Heinemann Physics 11 Chapter 8.1 (pages 250-253)

1. Describe two reasons why it is useful to model light as a particle.
2. Describe two reasons why it is useful to model light as a wave.
identify visible light as a particular region of the spectrum of electromagnetic radiation and that all light travels at the speed of light in a vacuum, $c$.
Practice Questions for 2.2.7
Reference: Heinemann Physics 11 Chapter 8.3 (page 273) & the electromagnetic spectrum song

1. List seven types of electromagnetic radiation and give one use for each of them.
explain the colour components of white light as different frequencies of light combining to appear white
Practice Questions for 2.2.8
Reference: Heinemann Physics 11 Chapter 8.3 (page 278)

1. Name the colours produced when the following lights are combined:
   a) red and green
   b) red and blue
   c) red, blue and green
   d) blue and green
   e) red and yellow
   f) blue and yellow

2. Name the colours seen when the following light passes through a red filter:
   a) red
   b) blue
   c) white
   d) cyan (mixture of blue + green)
   e) magenta (mixture of red + blue)
   f) green

3. Name the colours seen when the following light passes through a green filter:
   a) red
   b) blue
   c) white
   d) cyan (mixture of blue + green)
   e) magenta (mixture of red + blue)
   f) green

4. Name the colours seen when the following light passes through a blue filter:
   a) red
   b) blue
   c) white
   d) cyan (mixture of blue + green)
   e) magenta (mixture of red + blue)
   f) green

5. Name the colours seen when white light is passed through the following filter combinations:
   a) red and blue
   b) blue and green
   c) red, blue and green
explain colour dispersion in prisms and lenses in terms of refraction of the components of white light as they pass from one medium to another

Violet light is refracted the most because it has the shortest wavelength.

Red light is refracted the least because it has the longest wavelength.
Practice Questions for 2.2.9
Reference: Heinemann Physics 11 Chapter 8.4 (page 280)

1. Draw white light being refracted through a triangular prism.
2. How many times is light refracted when it travels through a triangular prism?
3. Regarding question 2, is the light refracted towards the normal or away from the normal in each instance?
4. Why is red light refracted less than violet light?
5. Draw white sunlight being refracted through a raindrop to produce a rainbow. (Hint: both refraction and total internal reflection are involved.)
explain the structure of the atom in terms of location of protons, neutrons and electrons, electrostatic forces, strong nuclear forces in the nucleus, the stability of nuclei of different size
Practice Questions for 2.3.3.1
Reference: Heinemann Physics 11 Chapters 1.1 & 1.2

1. Explain why some isotopes are radioactive and others are not
2. Why are isotopes with atomic numbers of 83 or greater all radioisotopes?
3. What is the line of stability?
4. What is the “island of stability” that some scientists hope might exist?
Fission is the splitting of atoms

Example:

Fission is the splitting of atoms

Fission products are about slightly lighter than the reactants. The mass lost is converted into energy as $E = mc^2$.

Energy is given off during fission

Energy, J

mass, kg

$E = mc^2$

Electron-volts

$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$

describe fission and fusion reactions in terms of balance of energy, $E = mc^2$
Practice Questions for 2.3.3.2
Reference: Heinemann Physics 11 Chapter 12.1

1. Describe what happens during nuclear fission
2. Give three examples of nuclear fission and write their formulae (find these yourselves on the internet)
3. Define the following words:
   a) fission
   b) fissile
   c) daughter nuclei
4. Why is energy given off during fission?
5. Convert the following mass defects into energy (in joules)
   a) $2.0 \times 10^{-25}$ kg
   b) $3.4 \times 10^{-26}$ kg
   c) $6.67 \times 10^{-27}$ kg
   d) $1.00 \times 10^{-29}$ kg
   e) $3.14 \times 10^{-28}$ kg
   f) $3.92 \times 10^{-28}$ kg
6. Convert the following values into electron-volts:
   a) $1.5 \times 10^{-14}$ J
   b) $4.55 \times 10^{-16}$ J
   c) $1.0 \times 10^{-11}$ J
   d) $1.9 \times 10^{-12}$ J
   e) $1.6 \times 10^{-19}$ J
   f) $2.4 \times 10^{-15}$ J
   g) $9.995 \times 10^{-18}$ J
   h) $5.1088 \times 10^{-13}$ J
7. For each of the following reactions, calculate the mass defect, and the amount of energy released in joules and in electron-volts. You will need to look up the masses of each particle online.
   a) $^{228}_{90}\text{Th} \rightarrow ^{224}_{88}\text{Ra} + ^{4}_2\alpha$
   b) $^{144}_{60}\text{Kr} \rightarrow ^{140}_{58}\text{Ce} + ^{4}_2\alpha$
   c) $^{14}_6\text{C} \rightarrow ^{14}_7\text{N} + ^{0}_{-1}\beta$
Only neutrons with the correct energy level will cause fission.

U-235 requires slow neutrons; and Pu-239 requires fast neutrons for fission to occur.

**SLOW NEUTRONS**

Example:

\[
\text{slow neutron} + ^{235}_{92}\text{U} \rightarrow \text{neutron absorbed} + ^{236}_{92}\text{U} \rightarrow \text{fission!}
\]

**FAST NEUTRONS**

Example:

\[
\text{fast neutron} + ^{239}_{94}\text{Pu} \rightarrow \text{Pu-240} \rightarrow \text{fission!}
\]

If Pu-239 absorbs a slow neutron, it forms Pu-240 but no fission occurs:

explain nuclear fission reactions of \(^{235}\text{U}\) and \(^{239}\text{Pu}\) in terms of: fission initiation by slow and fast neutrons respectively; products of fission including typical unstable fission fragments and energy; radiation produced by unstable fission fragments
1. Which isotope of uranium undergoes fission when its nucleus is hit by a slow, or ‘thermal’ neutron?

2. Write an equation to represent what happens if Pu-239 absorbs a slow neutron.

3. Write an equation to represent what happens if Pu-239 absorbs a fast neutron.
**U-235 undergoes FISSION**

This can trigger a chain reaction if U-235 atoms are present in a high enough concentration.

**U-238 just absorbs a neutron**

The fuel in standard nuclear reactors is a mixture of 4% $^{235}\text{U}$ and 96% $^{238}\text{U}$.

The concentration of fissile $^{235}\text{U}$ needs to be high enough to allow a chain reaction, but not so high that the fuel explodes rather than slowly generates heat.

The role of $^{238}\text{U}$ in nuclear power plants is to absorb some of the neutrons from $^{235}\text{U}$ fission, and slow down the chain reaction.

Removing the $^{239}\text{Pu}$ from a standard nuclear reactor and putting it into a Fast Breeder Nuclear Reactor is one way to reuse spent nuclear fuel.

In a Fast Breeder Nuclear Reactor, $^{239}\text{Pu}$ undergoes fission, producing more energy for electricity generation.

$^{239}\text{Pu}$ releases fast neutrons during its fission chain reaction.

**Examples**

- fission bombs
- nuclear power plants

**HALF-LIFE OF PRODUCT**

- $^{239}\text{U} \rightarrow ^{239}\text{Np} + ^0\beta + \bar{\nu}$: 2.35 days
- $^{239}\text{Np} \rightarrow ^{239}\text{Pu} + ^0\beta + \bar{\nu}$: 24,400 years

nuclear waste; produces fast neutrons

**Standard Nuclear Reactors**

**Fast Breeder Nuclear Reactors**

describe neutron absorption in $^{238}\text{U}$, including formation of $^{239}\text{Pu}$
1. Draw a small decay series diagram to represent what happens when U-238 absorbs a neutron.
   a) Write all the types of decay on the arrows
   b) Write all the half-lives on the arrows
2. State the isotopes of uranium that are used in nuclear reactors and state their roles
3. What is a fast breeder reactor?
4. $^{235}\text{U}$ is fissile. $^{238}\text{U}$ isn’t fissile. How do they differ when they absorb neutrons?
5. State the concentration of $^{235}\text{U}$ required to make:
   a) fuel for a nuclear reactor
   b) a bomb (look this up online) around
6. Give one use for $^{239}\text{Pu}$, a form of nuclear waste

EXTENSION (Find relevant information online.)

7. In addition to $^{235}\text{U}$ and $^{239}\text{Pu}$, there is also a third type of nuclear reactor called a “thorium-based reactor”. Give one reason why scientists and governments worldwide are showing increasing interest in thorium-based reactors.
8. Does Australia have any nuclear power plants? If so, where are they? Are they fast breeders?
A fissile material will only sustain a chain reaction:

1. **when there is sufficient mass**
   - The minimum mass at which a spherical sample of pure fissile material will sustain a chain reaction.
   - The critical mass.

2. **when concentration is sufficiently high**
   - Most neutrons are absorbed by the non-fissile isotopes because fissile isotopes are in higher concentration.

3. **when surface area is sufficiently low**
   - With a large surface area, too many of the neutrons escape into the surroundings to sustain a chain reaction.
   - Large surface area.

**Critical Mass**

Critical Mass refers to the minimum mass of fissile material required to sustain a chain reaction. This mass depends on the shape and size of the material. In a spherical sample, the surface area is the lowest, allowing more neutrons to remain within the material and sustain the reaction. In contrast, a large flat piece of material has too much surface area, causing many neutrons to escape and preventing the reaction from sustaining itself.

**Explain Fission Chain Reactions**

Including:

- Effect of mass and shape on criticality.
- Neutron absorption and moderation.
Practice Questions for 2.3.3.6
Reference: Heinemann Physics 11 Chapter 12.2

1. Define “chain reaction”.
2. Define “critical mass”.
3. Find a definition for the word “moderation” and add this to your notes.
4. What are the three factors that affect whether a sample of fissile material will undergo a fission chain-reaction?
5. What are the reasons for the factors you wrote in question 1?
describe the energy transfers and transformations in the systems that convert nuclear energy into thermal energy for subsequent power generation
1. What would happen in a pressurised water reactor (PWC):
   a) if there were too few fuel rods?
   b) if there were too few control rods?
   c) if the pump were to break?

2. Describe the six main stages of electricity generation in a pressurised water reactor (PWC) and include the types of energy transfer that are taking place (if any) at each stage.

   For example:

   “Nuclear energy in the fuel rods is converted into heat energy in the coolant...”
evaluate the risks and benefits for society of using nuclear energy as a power source.
Practice Questions for 2.3.3.8
Reference: TED Nuclear Energy debate

1. Make a list of the risks and benefits.
2. Choose the three most important risks and benefits.
3. Would you support nuclear power in Victoria?