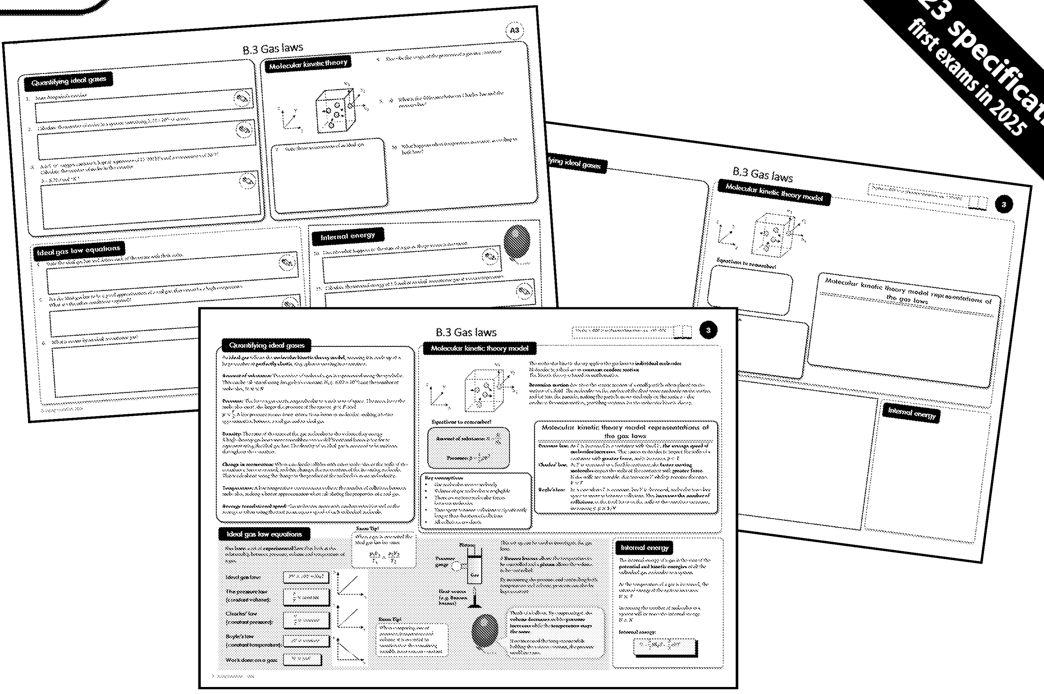
Zig Zag Education

Physics International Baccalaureate Diploma Programme

2023 specification
first exams in 2025



Topic on a Page

for IB Physics

Theme B: The Particulate Nature of Matter

zigzageducation.co.uk

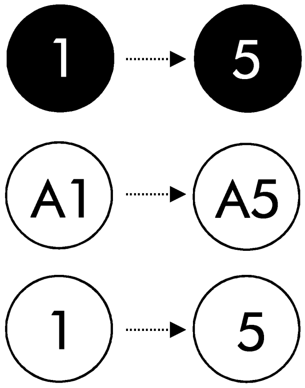
POD 12526

Contents

Teacher's Introduction

This Topic-on-a-page resource has been designed to help your students revise the key points of each topic and test their knowledge after you have taught each section of the **IB Physics Diploma Programme (Standard Level and Higher Level), Theme B – The particulate nature of matter**. Each page is closely tied to the IB specification, ensuring all aspects of the course are covered.

There are four sections to this resource, each with its own features:



1. **Summary posters**: these are the main pages which intend to clearly consolidate and recap all the key information from the IB Physics course (SL and HL).
2. **Activity worksheets**: these are identical to the summary posters, but contain a variety of tasks, from filling in missing words to performing calculations. The activity worksheets aim to ensure the student understands all the key knowledge required of them and gives them the opportunity to demonstrate how well they have remembered and understood the content of the course.
3. **Outline-only pages**: these are the summary posters, but with most of the content removed. Students can research the topics, e.g. for homework, and fill in as much information as they can.
4. **Mark scheme**: full answers for the activity worksheets.

The 'summary', 'activity' and 'outline-only' sheets are designed to be A3 size, although they are still usable at A4 with no loss of detail. When photocopying activity worksheets on A3, we suggest photocopying the relevant summary poster on the reverse. If using at A4 size, we suggest photocopying each A3 'activity worksheet' (for writing answers) as a double-sided A4 page to avoid shrinking the space available for answers.

Each page presents information in a variety of ways, including:

- **Bold key words** – essential terminology in bold, allowing students to skim and revise main points quickly.
- **Bullet-point processes** – complex processes and lists have been summarised into quick, easy-to-learn points.
- **Graphs** – sketch graphs illustrate complex points without providing unnecessary information.
- **Comparison tables** – a quick way of comparing key features of different processes or features.
- **Equation boxes** – concisely state the equations used in required calculations.
- **Exam tips** – aid memorisation, revision and exam technique in areas where students typically struggle.

We hope you find these pages useful during your teaching and your students' revision.

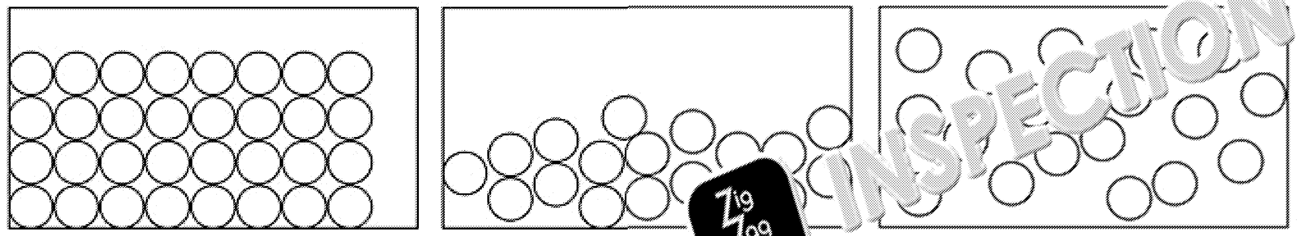
September 2024

B.1 Thermal energy transfers

Molecular theory

Density, ρ (kg m^{-3}) = $\frac{m}{V}$

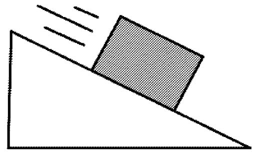
The three states of matter are:



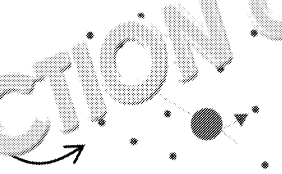
Solid
- Atoms vibrate in fixed position.
- **High density** from efficiently packed atoms.
- **Low internal energy** as particles vibrate in a fixed position (low kinetic energy).
- **High potential energy** due to strong forces.

Liquid
- Atoms slide over each other, matching the shape of the container.
- **Lower density** than for solid material.
- Exert pressure on sides of container.
- Relatively **high internal energy** due to lots of molecules interacting.

Gas
- Atoms move freely, following Brownian motion.
- **Low density** as molecules spread out to fill the container.
- **High internal energy** as molecules have lots of kinetic energy.
- **Low potential energy** as molecules rarely interact.



Internal energy: Sum of the potential and kinetic energies of the particles in a body arising from their random motion.
Brownian motion: Particles move in random directions and at varying velocities.

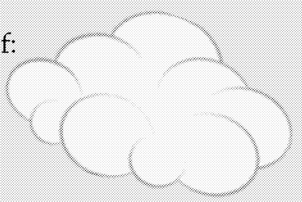


Specific heat capacity and latent hea

Thermal energy is transferred from a hotter body to a colder one (but never the other way around!). This transfer is measured using the **specific heat capacity**, c, which is the energy required to raise the temperature of 1 kg of a substance by 1 °C.

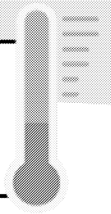
At a certain temperature, the particles overcome the **intermolecular forces** between each other and a phase change occurs. During this, the temperature remains constant as all the energy is being used to split apart the particles.

There are three state changes to be aware of:
1. **Fusion** – solid to a liquid
2. **Vaporisation** – liquid to a gas
3. **Condensation** – gas to a liquid



These are quantified using the **specific latent heat of fusion**, L, which is the energy required for 1 kg of a substance to undergo a state change without a change in temperature. The most common example is the specific latent heat of fusion of water (ice — liquid water).

Kelvin scale: Measure of the average kinetic energy, $\overline{E}_K = \frac{3}{2}k_BT$



Specific heat capacity, c (J kg^{-1} K^{-1}) : $Q = mc\Delta T$
Specific latent heat, L (J kg^{-1}) : $Q = mL$

Exam Tip!

Remember to convert from °C to K before performing calculations:

T(K) = T(°C) + 273.15

The difference between two temperatures is the same whether it is expressed as kelvin or degrees Celsius!

Mechanisms for energy tra

There are three mechanisms for energy tr

Conduction
Occurs when two materials of different temperature are in direct contact.
The hotter material has particles with a higher kinetic energy which is then transferred to the colder material by collisions.
The rate of this transfer is: $\frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{\Delta x}$

Equations to remember!

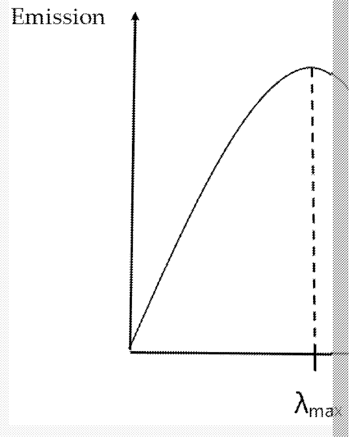
Stefan–Boltzmann law: $L = \sigma A T^4$
Luminosity: $b = \frac{L}{4\pi d^2}$
Wien's displacement law: $\lambda_{\text{max}}\, T = 2.9 \times 1$

Black body radi

A black body emits waveleng
This emission can be modell
a material is directly propor

The luminosity is related to
the distance to the body. σ i

Wien's displacement law
to the core temperature of



B.2 Greenhouse effect

Emissivity and absorption

The conservation of energy law states that:

‘Energy cannot be created or destroyed, it can only be transferred from one body to another’

In relation to solar rays this means that an incident source of radiation must either be **absorbed, reflected or re-emitted** by another body.

$$\textbf{Emissivity} = \frac{\text{power radiated per unit area}}{\sigma T^4}$$

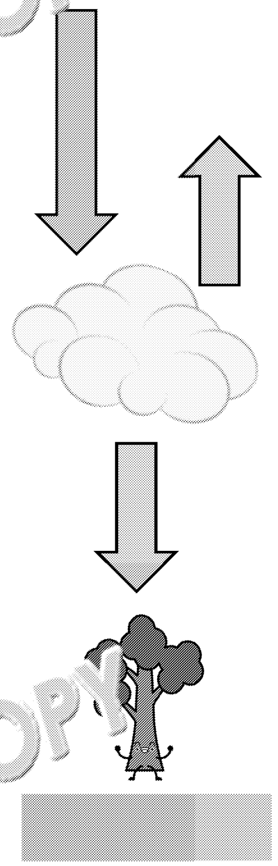
$$\textbf{Albedo} = \frac{\text{total scattered power}}{\text{total incident power}}$$

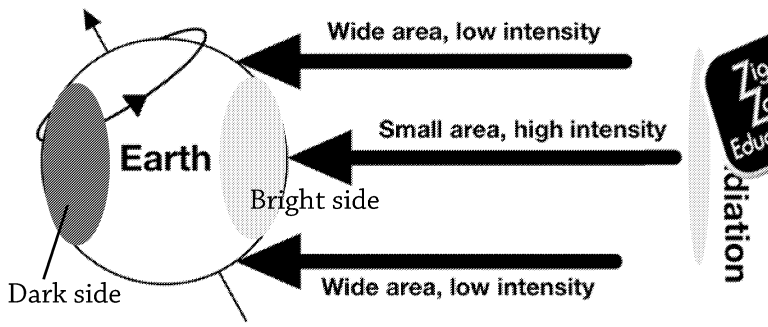
The **emissivity** of a body can be quantified as the ratio of power radiated per unit area. This is relative to a **perfect black body** where the emission would be across all wavelengths.

The **reflection** of radiation is related to the **albedo**, the average energy reflected off a macroscopic system.

The **average albedo of Earth is ~0.3** but this value depends on the **latitude and formation of clouds**. At higher latitudes, Earth's varying angular tilt causes shifts in the regions where solar radiation strikes. In general, the **greater the tilt towards the Sun, the greater the solar radiation** that reaches Earth. This is what leads to seasons.

Clouds primarily reflect solar radiation; therefore, the more clouds there are in the sky, the less solar radiation that reaches Earth’s surface.



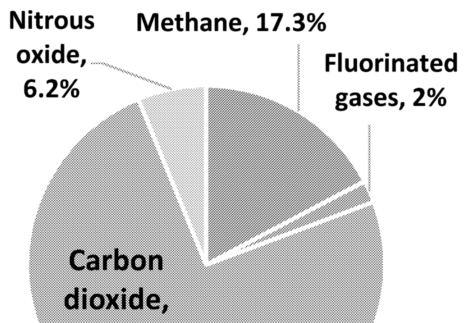


Total radiative power of sun = $S \times \pi R^2$

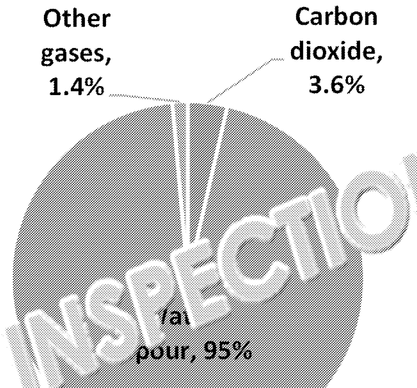
Surface area of the bright side of the Earth = $4\pi R^2$

Incoming radiative power = $\frac{S \times \pi R^2}{4\pi R^2} = \frac{S}{4}$

where S is the solar constant, and R is the radius of the disc emitting solar radiation



Man-made greenhouse gases



Natural greenhouse gases

Solar cons

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the Sun. Calculatin
S = 1400 W m^{-2}.

This radiated powe
the planet changes

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this surface woul
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Enhanced

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- Small amoun Earth’s surfa
- Generated d agricultural p

Carbo
- Present in th respiration o
- Produced fro fossil fuels.

The **enhanced greenhouse effect** de
processes. This process leads to more h

The main greenhouse gases absorb mai
radiation has energy equal to the energ
bending and vibrating motions of m

This means that when solar radiation e
greenhouse gases. This radiation can
that reaches the surface of Earth, and t

B.3 Gas laws

Quantifying ideal gases

An **ideal gas** follows the **molecular kinetic theory model**, meaning it is made up of a large number of **perfectly elastic**, tiny spheres moving in a container.

Amount of substance: The number of moles of a gas is represented using the symbol n. This can be calculated using Avogadro's constant, N_A (= 6.02×10^{23}) and the number of molecules, N. $\boldsymbol{n \propto N}$

Pressure: The force a gas exerts perpendicular to a unit area. The more force the molecules exert, the larger the pressure of the system. $\boldsymbol{p \propto F}$ $\boldsymbol{p = \frac{F}{A}}$. A low pressure means fewer interactions between molecules, making a better approximation between a real gas and an ideal gas.

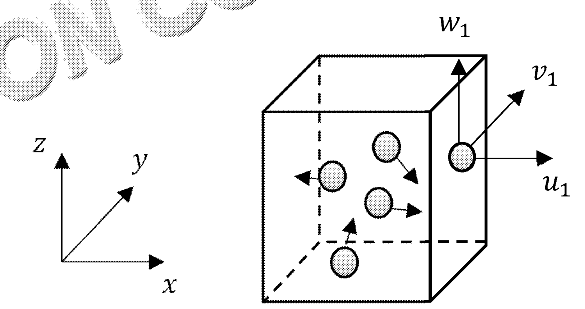
Density: The ratio of the mass of the gas molecules to the volume they occupy. A high-density gas bears more resemblance to a solid/liquid and hence is harder to represent using the ideal gas law. The density of an ideal gas is assumed to be uniform throughout the container.

Change in momentum: When a molecule collides with other molecules or the walls of the container a force is exerted, and this changes the momentum of the incoming molecule. This is calculated using the change in the product of the molecule's mass and velocity.

Temperature: A low temperature environment reduces the number of collisions between molecules, making a better approximation when calculating the properties of a real gas.

Average translational speed: Gas molecules move with random velocities and an average is taken using the root mean square speed of each individual molecule.

Molecular kinetic theory model



The molecul
Molecules i
The kinetic

Brownian
surface of a
and hit into
produces Br

Equations to remember!

Amount of substance: $n = \frac{N}{N_A}$

Pressure: $p = \frac{1}{3}\rho v^2$

Key assumptions

- Gas molecules move randomly
- Volume of gas molecules is negligible
- There are no intermolecular forces between molecules
- Time spent between collisions is significantly longer than duration of collisions
- All collisions are elastic

Pressu

Charle

Boyle's

Ideal gas law equations

Gas laws: a set of **experimental** laws that look at the relationship between pressure, volume and temperature of a gas**.**

Exam Tip!

When a gas is evacuated the ideal gas law becomes

$$\boldsymbol{\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}}$$

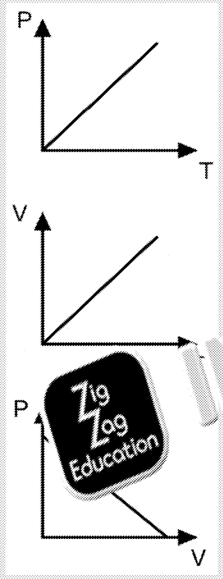
Ideal gas law: $PV = nRT = Nk_BT$

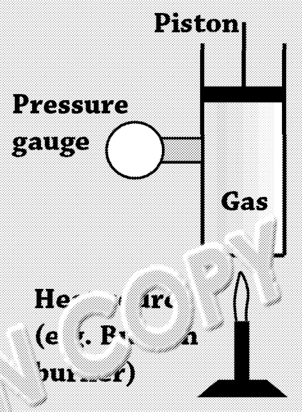
The pressure law (constant volume): $\frac{P}{T}$ = constant

Charles' law (constant pressure): $\frac{V}{T}$ = constant

Boyle's law (constant temperature): pV = constant

Work done on a gas: $W = p\Delta V$





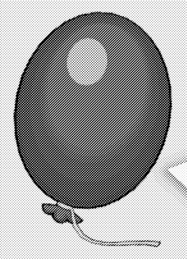
This set-up can be used to
laws.

A **Bunsen burner** allows
be controlled and a **pisto**
to be controlled.

By measuring the pressur
temperature and volume,
kept constant.

Exam Tip!

When comparing two of pressure, temperature and volume, it is essential to mention that the remaining variable must remain constant.



Think of a balloon. By
volume decreases a
increases while the **t**
the same.

If we increased the te
holding the volume co
would increase.

B.4 Thermodynamics (Additional Higher Leve

Thermal energy transfer

Internal energy: the sum of the randomly distributed kinetic energies and potential energies of particles in a system or body.

First law of thermodynamics

The change of internal energy of the object is equal to the total energy transferred due to work done and heatin

$$\boxed{\Delta U = Q - W}$$

ΔU = change in internal energy, Q = change in heat, W = work done

Internal energy is constant when:

- **no energy transfer** by heating and **no work is done**
  OR
- energy transfer by heating and work done are **equal and opposite**

$$\boxed{\Delta U = \frac{3}{2}Nk_B\Delta T = \frac{3}{2}nR\Delta T}$$

ΔU = change in internal energy, ΔT = change in temperature

Internal energy can be increased by:

- **heating** the object
  OR
- **doing work** on the object:

$$\boxed{W = P\Delta V}$$

ΔV = change in volume, P = pressure

Doing **work on a system** (e.g. compressing a gas) mean[illegible] out the work is positive (***W* > 0**) when **work is done by the system**.

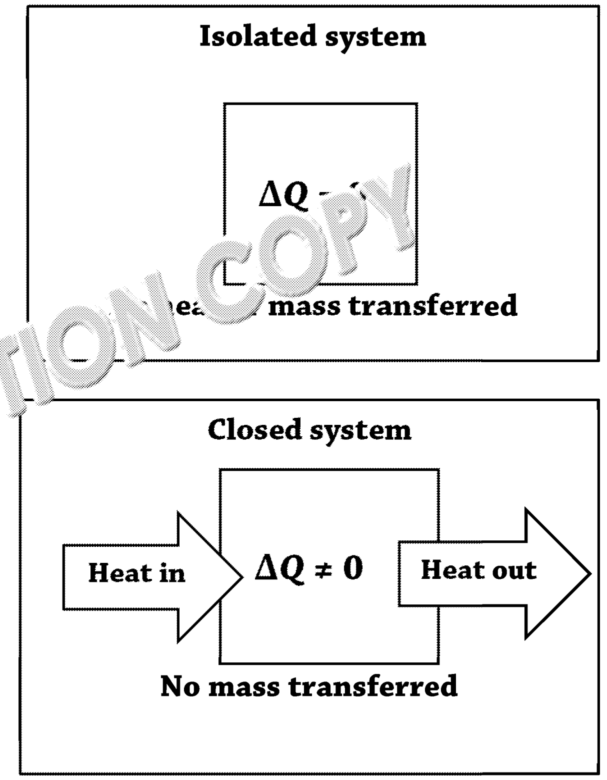
Exam Tip!

Keep track of direction of energy transfer. Heat flowing **into** an object means ΔQ is **positive** [illegible]e heat flo[illegible] o[illegible]t [illegible] ΔQ is **negative**.

Imagine an engine – as the air is compressed, it heats up. No heat is being added, but work is being done – this raises the internal energy, so temperature increases.

Key terms

Isovolumet[illegible] – [illegible]ant volume
Isob[illegible] – [illegible]nst[illegible] pressure
[illegible]therma[illegible] – constant temperature
[illegible]iabatic processes – no heat in ($\Delta Q = 0$, $PV^{\frac{5}{3}}$ = constant)
Carnot cycle – ideal thermodynamic cycle
Closed system – energy transferred as either heat or work, mass remains constant
Isolated system – no heat or mass can be transferred in or out of the system



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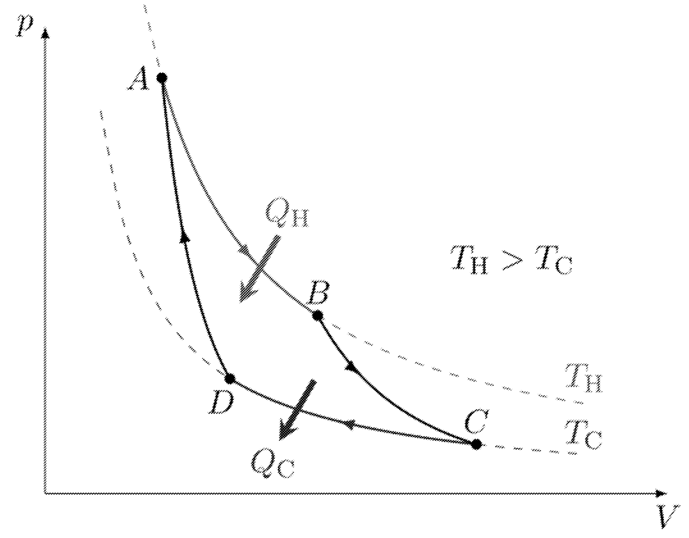


A **heat engine** converts thermal energy into m[illegible]cha[illegible]ical [illegible]. This is achieved by transferring thermal e

This process follows engine cycle[illegible] [illegible]s c[illegible]mprised of **four processes**:

1. **(D → A) Adiabatic [illegible]ress[illegible]** – work done on gas, reducing volume, and increasing temperatur
2. **(A → B) Isot[illegible] [illegible]x[illegible]sion** – Gas does work, heat taken from surroundings.
3. **(B → C) [illegible] expansion** – Gas does work, increasing volume and decreasing temperature and
4. **[illegible] → D [illegible]thermal compression** – Work done on gas, heat lost to surroundings.

[illegible]iency of a heat engine is the ratio of the useful work transferred to the total energy input. Most
Th[illegible] efficiency can increase but only up to a limit set by the **Carnot cycle**. This is set by the temperature surrounding the heat engine.

B.5 Current and circuits

Basics of electricity

Cells provide a **source of electromotive force** (emf), ε, driving the flow of electrons around a circuit. For example, a cell with an emf of 1 V can provide a **maximum potential difference** of 1 V. Cells can be classified by their emf as well as their **internal resistance**, ***r***.

$$\boxed{\varepsilon = I(R + r)}$$

S[illegible]ght for *I* and *R*

The electrical **potential difference**, ***V***, is the **work done**, ***W***, [illegible] a **unit positive charge**, ***q***, between two points along a circuit.

$$\boxed{V = \frac{W}{q}}$$

Direct current, ***I***, is defined as the **number of charge carriers**, **Δq**, that pass a given point **in unit time**, **Δt**.

$$\boxed{I = \frac{\Delta q}{\Delta t}}$$

There are **two types of energy sources** (cells) to be aware of: chemical and solar. **Chemical cells** involve chemical reactions between a set of **electrodes** and an **electrolyte** that produces a voltage. **Solar cells** involve solar radiation being transferred into electrical energy via the electron-hole pair migration. This generates an excess of free electrons by the **photovoltaic effect**.

Energy source	Examples	Advantages	Disadvantages
Chemical cell	Li-ion batteries, hydrogen fuel cell	• Small and compact • Cheap, readily available, and large emf	• Requires constant supply of reactants
Solar cell	Photovoltaic cell, silicon solar panels	• Renewable source of energy • Requires no fuel or chemical reactions	• Requires a constant, intense source of light

Resistance

Electrical re
as the ratio
passing thro
position, m

Because electrons encounter resistance
in a resistor is the amount of energy tr

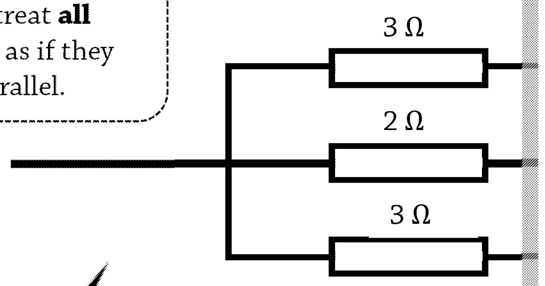
Resistivity, ***ρ***, is the measure of a mat
material is proportional to its **length**,

There are three types of **variable resis**
1. **Thermistors** – resistance decreas
2. **Light-dependant resistors** (**LD**
3. **Potentiometers** – split up the vo

Exam Tip!

In any parallel branch, treat **all** resistors as if they are in parallel.

Exa



Conductors and insulators

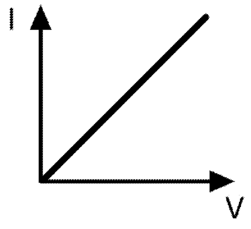
In order for an electrical **current** to pass through a material, the **electrons** must be able to travel through the material:
- **Conductors** – electrons are not tightly bound to any nuclei and so are highly mobile.
- **Insulators** – electrons are tightly bound to the nucleus and so are unable to move around to carry current.

Ohm's law states

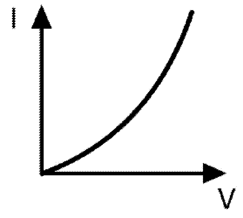
> **'The current through an Ohmic conductor is directly proportional to the potential difference across it, given that the temperature is constant.'**

For an **Ohmic conductor**, the I–V characteristics can be illustrated using a **straight-line graph**. From this, the gradient can be calculated and interpreted as the resistance of the component.

In a **non-Ohmic conductor**, the I–V characteristic will follow a **non-linear curve** and therefore the resistance changes as the quantities are changed. It is then necessary to estimate the resistance at individual points along the curve.



Ohmic Conductor

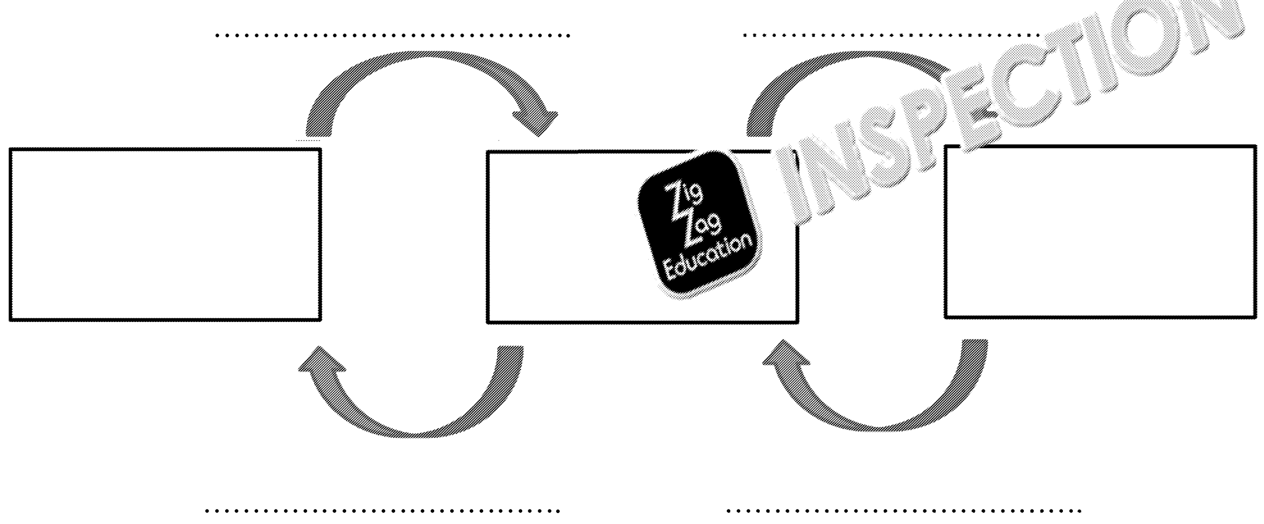


Non-Ohmic Conductor

B.1 Thermal energy transfers

Molecular theory

1. Complete the diagram to show the three states of matter and the different state changes.



2. Calculate the density of a square block with a mass of 3 kg and length 3 cm, including the units.

3. Complete the following:

Internal energy is the sum of the .... and .... energies of the particles in a body arising from their .... motion and velocities.

Brownian motion: Particles move in random directions with varying velocities.

Specific heat capacity and latent heat

Specific heat capacity, c (J kg^{-1} K^{-1}) : $Q = mc\Delta T$
Specific latent heat, L (J kg^{-1}) : $Q = mL$

6. A pot of water of mass 5 kg is heated to its boiling point. What is the energy required for the water to evaporate?

Specific latent heat of fusion of water = 3340 J kg^{-1}

7. A pot of water is heated from 20 °C to its boiling point. The heat energy required to heat the unknown mass of water is 5.0×10^5 J. Calculate the mass of water in the pot.

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}

8. Calculate the average kinetic energy of a system of nitrogen molecules at 32 °C.

Mechanisms for energy t

4. Complete the table to briefly explain h

Conduction

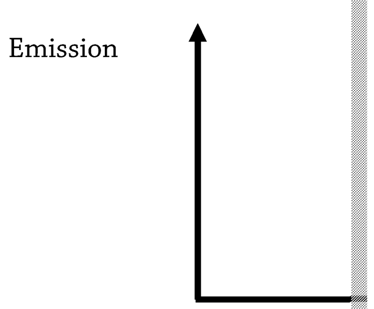
5. The rate of thermal energy transfer of temperature changes by 2 °C every 0.2 Calculate the constant of proportional

9. Convert 213 °C to kelvin.

10. Define a perfect black body.

11. Explain what is meant by a bod

12. Calculate the peak wavelength emission spectrum.



B.2 Greenhouse effect

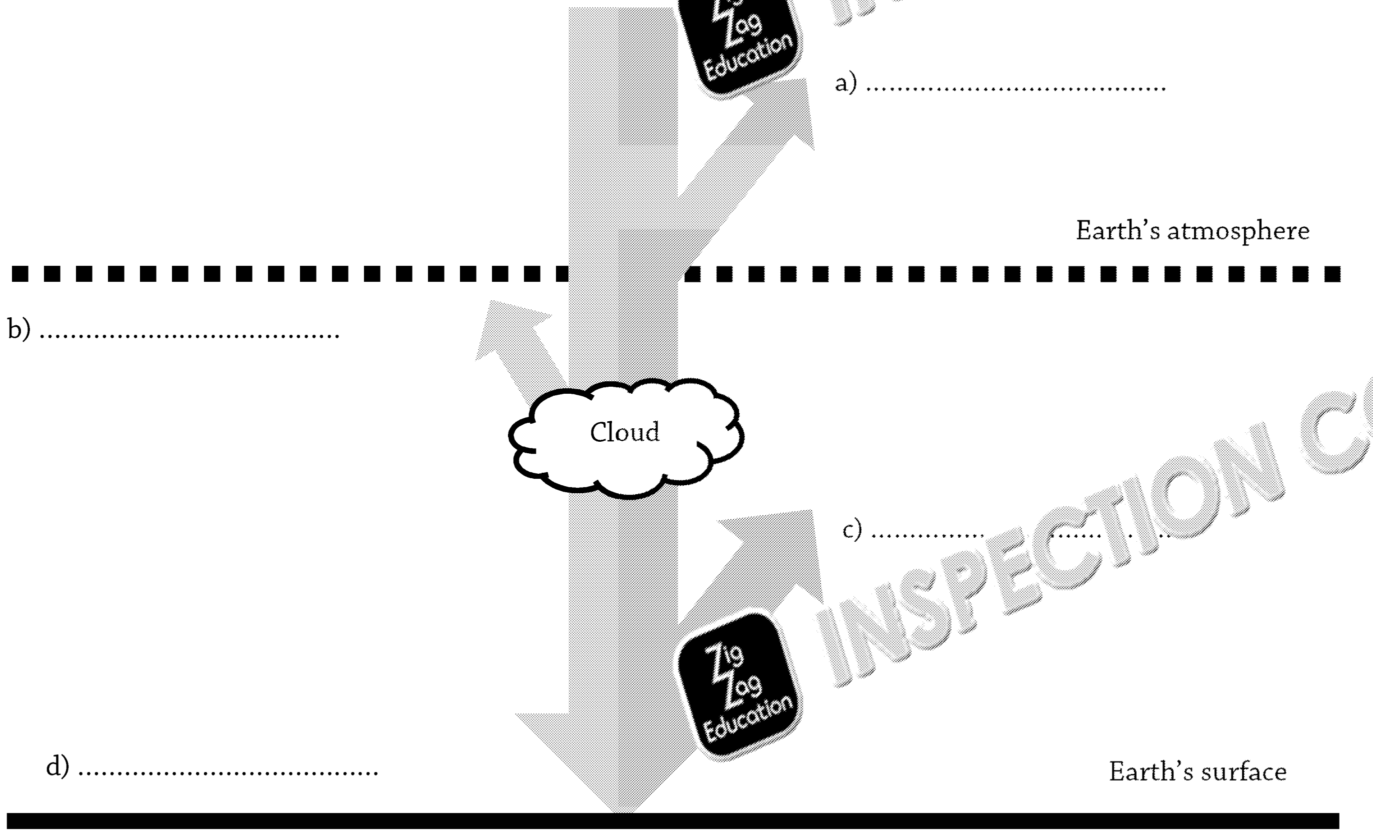
Emission and absorption

1. Calculate the core temperature of a body where the emissivity is 0.8 and the power radiated is 1.3 [illegible] W.

2. Solar radiation of 1.8×10^{12} W is incident on Ea[illegible] × 1[illegible] W is scattered by Earth's atmosphere, what is the albedo of Earth?

3. Explain how Earth's albedo contributes to the seasons.

4. Label the diagram to show the energy balance of solar radiation reach[illegible] incident radiation is 1400 W m^{-2}. 10 % is reflected by Earth's atmosph[illegible] $^{-2}$ [illegible] reflected by the clouds, and 50 % of the remaining radiation is ads[illegible] Ea[illegible]ce.



5. State the definition of the solar

6. Why is it that the average radiati

7. It turns out the radiation emitte
Explain this observation.

Enhanced greenhouse ef

8. Why is it that burning fossil fuels co

9. The resonance model describes the
molecule of carbon dioxide.

10. Many misunderstand that greenhou
Why is this the case?

B.3 Gas laws

Quantifying ideal gases

1. State Avogadro's number.

2. Calculate the number of moles in a system containing [illegible]^3 of [illegible]ms.

3. A 6.5 m^3 oxygen canister is kept at a pressure of 15 200 kPa and a temperature of 20 °C.
   Calculate the number of moles in the canister.

   $R = 8.31\ J\ mol^{-1}\ K^{-1}$

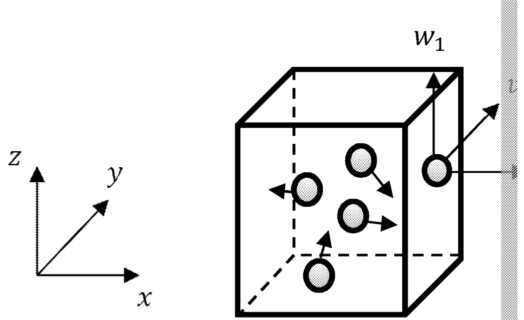
Ideal gas law equations

4. State the ideal gas law and define each of the terms with [illegible]ts.

5. For the ideal gas law to be a good approximation of a real gas, there must be a high temperature.
   What are the other conditions required?

6. What is meant by an ideal monatomic gas?

Molecular kinetic theory



7. State three assumptions of an ideal gas.

Internal energy

10. Describe what happens t

11. Calculate the internal en

12. Why is it that a high tem

B.4 Thermodynamics (Additional Higher Lev

Thermal energy transfer

1. State the first law of thermodynamics.

First law of thermodynamics

2. 100 J of heat is taken out of an isolated system. If the work done by the gas is 50 J, what is the change in internal energy?

3. An isolated system is comprised of 1.5 mol of oxygen molecules contained in a container at a pressure of 100 kPa. The gas is compressed from 20 cm^3 to 10 cm^3, increasing the temperature by 20 K.
Calculate the transfer of energy as heat.

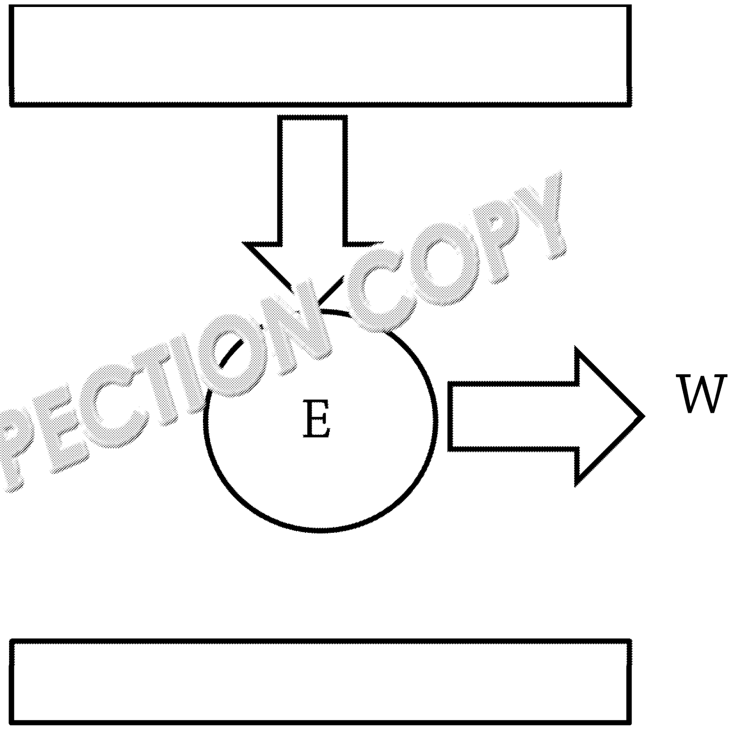
Key terms

4. State the meaning of the terms.

Isobaric

Closed system

5. Complete the diagram below to illustrate an engine working between two bodies of different temperatures.



Entro

6. State t

7. State t

8. What l
system

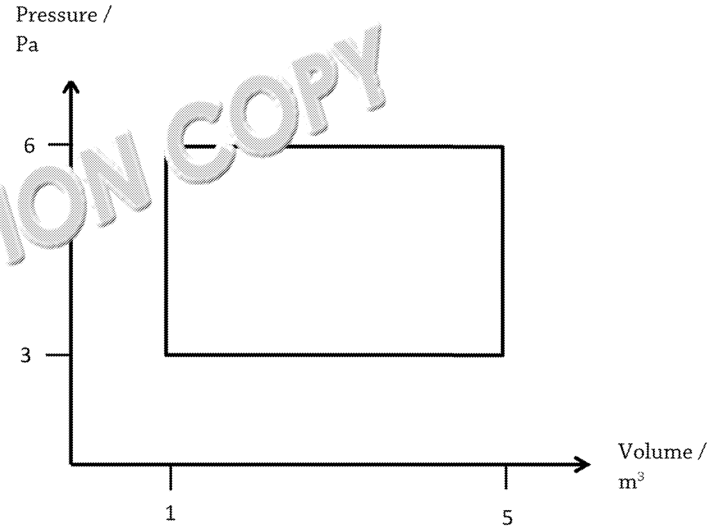
9. Explai
a non-

Heat engines

10. State the word equation for efficiency.

11. Give one way of increasing the efficiency of an engine.

12. What would happen to the efficiency if two heat engin ated between the bodies?



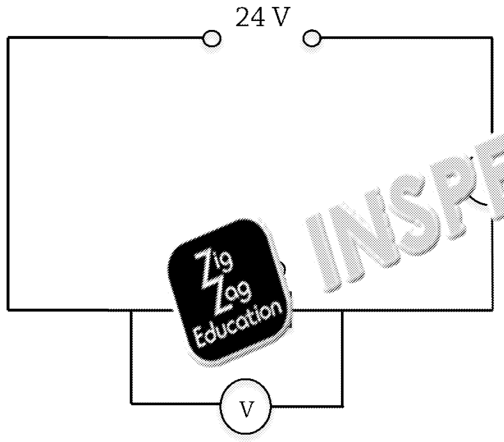
13.

14.

15.

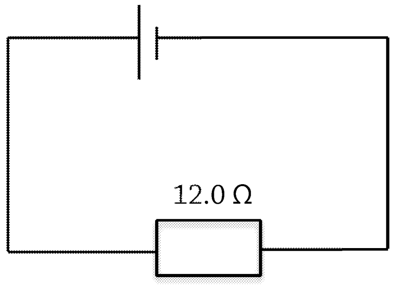
B.5 Current and circuits

Basics of electricity



1. The emf of the source of the circuit is 24 V and it is connected in series to a 11.4 Ω resistor. The reading on the ammeter is 1.9 A.
   a) Calculate the internal resistance of the power source.
   b) Calculate the reading on the voltmeter.
   c) Explain why the reading on the voltmeter is less than the emf of the power source.

Resistance



2. 1.20 A is pr
   a) Calcula
   b) Determ

3. A variable resistor circuit is set up with a th
the fridge door has been left open too long

   The voltage output is connected to an alarm
the voltage reaches a sufficiently high value

   a) Explain how the alarm rings as the tem

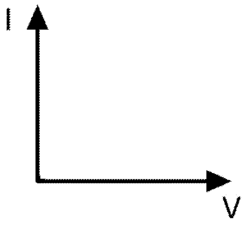
   At a certain temperature, the resistance of t
measured to be 6.4 Ω.

   b) Calculate the voltage output when the

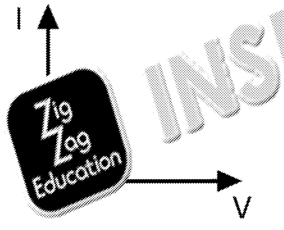
Conductors and insulators

4. State Ohm's law.

5. Complete the axes to show the I–V characteristics of an Ohmic and a non-Ohmic conduct



Ohmic Conductor



Non-Ohmic Conductor

Circuit laws

6. Co

Quantity
Current
Potential difference
Resistance

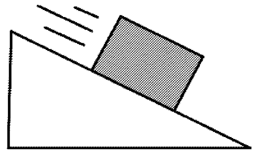
B.1 Thermal energy transfers

Molecular theory

Density

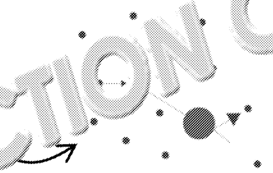
Mechanisms for energy tra

Equations to remember!

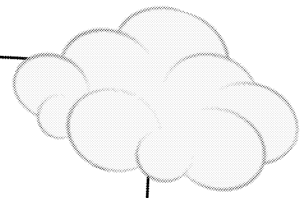


Internal energy:

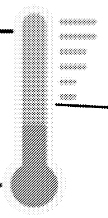
Brownian motion:



Specific heat capacity and latent he



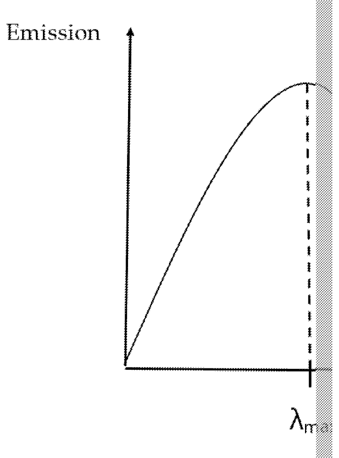
Kelvin scale:



Specific heat capacity

Specific latent heat

Black body radi

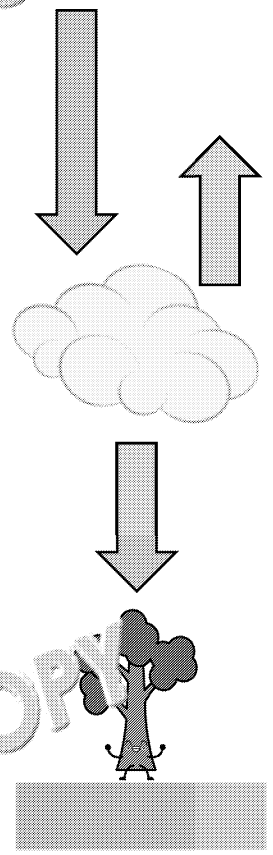


B.2 Greenhouse effect

Emissivity and absorption

Emissivity

Albedo



Solar con

Enhanced

There are **four mai**

Earth

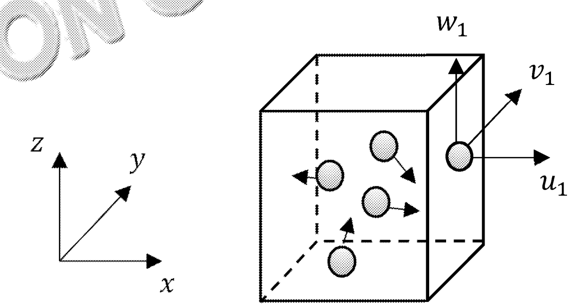
Man-made greenhouse gases

Natural greenhouse gases

B.3 Gas laws

Quantifying ideal gases

Molecular kinetic theory model



Equations to remember!

Key assumptions:

Ideal gas law equations

B.4 Thermodynamics (Additional Higher Leve

Thermal energy transfer

First law of thermodynamics

$$\Delta U = \Delta Q + \Delta W$$

Imagine an engine –

Key terms

Isolated system

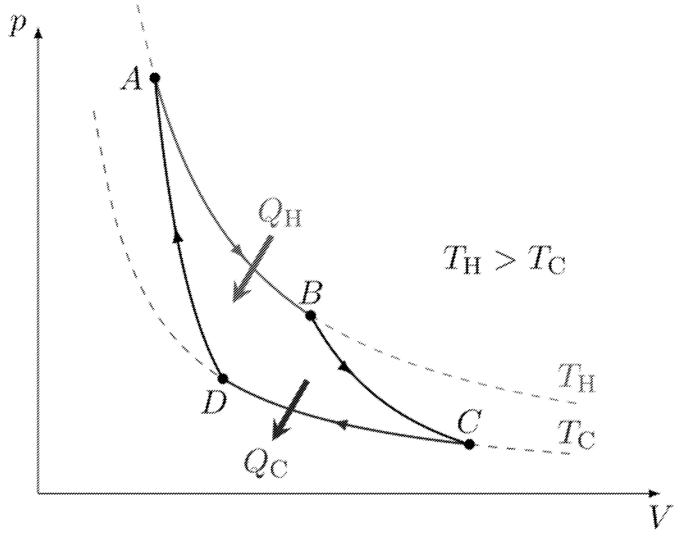
Closed system

Entr

Alternati
of therm

Consider the uni

Heat engines

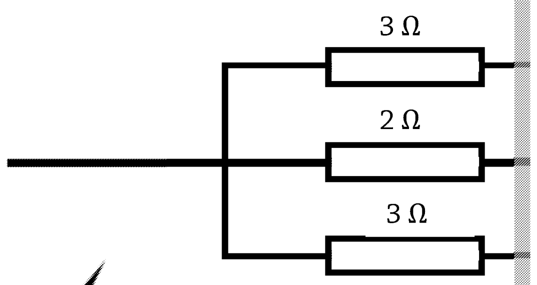


B.5 Current and circuits

Basics of electricity

Resistance

Exa

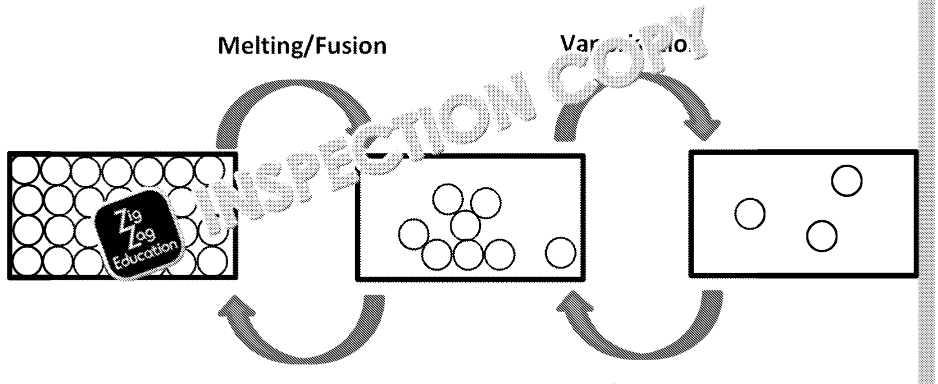


Conductors and insulators

IB Topic on a Page, Theme B: Mark

B.1 Thermal energy transfers

1.



2. $v = (3 \times 10^{-2}\ \mathrm{m})^3 = 2.7 \times 10^{-5}\ \mathrm{m}^3$

   Density = $m \div v = 3 \div (2.7 \times 10^{-5}) = 1.11 \times 10^5$ kg m^{-3}

3. Internal energy is the sum of the ***kinetic*** and ***potential*** energies of the parti ***random*** motion and velocities.

4.

Conduction	Convection	
Transfer of kinetic energy from a hotter body to a colder one	Differences in density (due to differences in temperature) across a fluid, generating convection currents	Tr wi be el in

5. $k = \frac{3}{20\ \text{[illegible]}} = 1.5$ J s^{-1}m^{-1}k^{-1}.

   Describes the amount of energy transferred per second in one metre of ma raised by one kelvin.

6. $\Delta Q = \Delta mL$

   $\Delta Q = 5 \times 3340 = 1.67 \times 10^4$ J

7. $Q = mc\Delta T$ rearranges to $m = Q / (m\Delta T)$

   $Q = 5.0 \times 10^5$ J, $\Delta T = 80$ K, $c = 4200$ J kg^{-1} K^{-1}

   $m = (5.0 \times 10^5) / (4200 \times 80) = 1.488$ kg ~ 1.5 kg

8. KE = $\frac{3}{2} k_B T$

   KE = $\frac{3}{2} \times 1.38 \times 10^{-23} \times (32 + 273)$

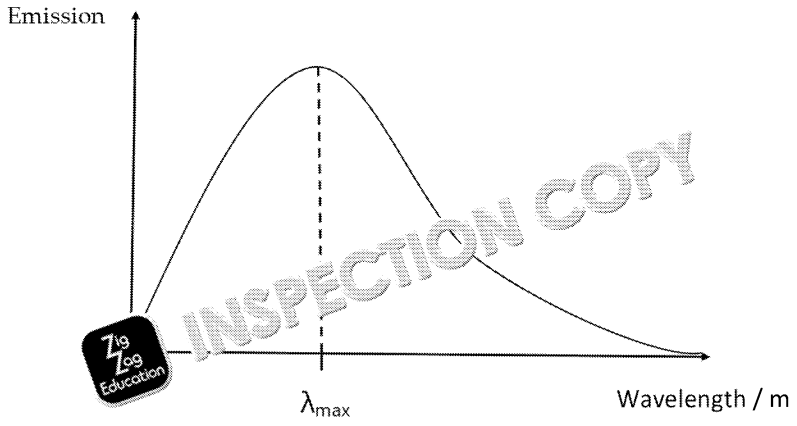
   KE = 6.31×10^{-23} J

9. 213 + 273 = 486 K

10. A perfect black body emits radiation across the whole electromagnetic spec radiati[illegible]t.

11. Three watts of power are transferred in one metre square of area.

12. $\lambda_{\max} = \frac{2.9 \times 10^{-3}}{3500 \text{ K}} = 8.28 \times 10^{-7}\text{m}$



B.2 Greenhouse effect

1. $T^4 = \frac{\text{power radiated per unit area}}{\sigma \times \text{emissivity}}$

   $= \frac{1.3 \times 10^{9}}{5.67 \times 10^{-8} \times 0.8}$

   $= 2.87 \times 10^{16}\ \text{K}^4$

   $T = 1.30 \times 10^4\ \text{K}$

2. albedo $= \frac{1.3 \times 10^{11}}{1.8 \times 10^{12}}$

   $= 0.072$

3. Earth's albedo varies with the proportion of clouds and the latitude. Therefo and/or a lower latitude means that more radiation is scattered, leading to co extrem[illegible] th[illegible]

4. a) 14 W m^{-2}
   b) 100 W m^{-2}
   c) 580 W m^{-2}
   d) 580 W m^{-2}

5. The solar constant is the power radiated by the Sun in a one square metre a

6. The average radiation absorbed changes with the surface of Earth.

7. Radiation is absorbed by the clouds, Earth's atmosphere and any other obje in its absorption spectrum.

8. The atmosphere absorbs in the infrared region and infrared radiation is wha combusting fossil fuels. This radiation is emitted in all directions so a large p Earth's surface.

9. Bending, stretching and rotating.

10. Many people are not aware of the difference between the greenhouse effect effect and so are not aware that only man-made gases, such as fluorinated ga

B.3 Gas laws

1. $N_A = 6.02 \times 10^{23}$
2. $n = \frac{7.23 \times 10^{23}}{6.02 \times 10^{23}}$
   $= 1.20$ mol
3. $n = \frac{pV}{RT} = \frac{15,200 \times 10^3 \times 6.5}{8.31 \times 298}$
   $= 4.0 \times 10^4$ mol
4. $pV = nRT$
   p – Pre[illegible]f contained gas, Pa
   V – Vol[illegible] of container, m^3
   n – Number of moles of gas, mol
   R – Gas constant, J mol^{-1} K^{-1}
   T – Temperature of gas, K
5. Low density and pressure.
6. A gas that contains only one atom and obeys the ideal gas law.
7.
   - Gas molecules move randomly
   - Volume the gas occupies is negligible compared to size of container
   - No intermolecular forces between molecules

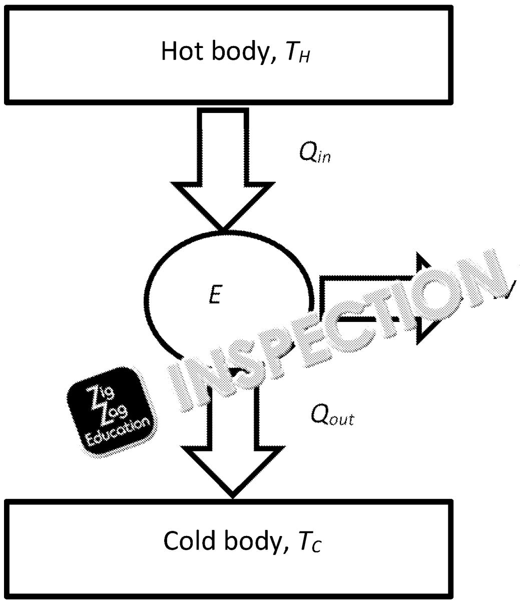
   OR any other key assumptions
8. Molecules collide with each other and the sides of the container. These mol
   area and therefore a pressure exists.
9. a) In Charles' law, pressure is consta[illegible] wh[illegible]as in the pressure law, volu
   b) In Charles' law, when te[illegible] [illegible]ncreases in a flexible container, the
   moving molecu[illegible] the walls with greater force, but pressure re

   In[illegible] law, when temperature increases, the average speed o
   vo[illegible] fixed, the pressure increases as they impact the walls with gr
10. The gas particles are brought closer together, increasing the internal energy
    compressed into a condensed vapour.
11. $U = 1.5 \times 1.5 \times 8.31 \times 298 = 5.57 \times 10^3$ J
12. At a higher temperature, there are fewer intermolecular forces between mo
    assumptions of the ideal gas law.

B.4 Thermodynamics (Additional Higher Level)

1. The first law of thermodynamics states that the tran[illegible] of energy as heat is
   and the work done on the system.
2. -100 – 50 = -150 J
3. $W = 100 \times 10^3 \times (1$[illegible] J
   $\Delta U = 1$[illegible]$5 \times$ [illegible]$1 \times 20 = 374$ J
   $Q = 1 +$ [illegible] 375 J
4. Isobaric – constant pressure
   Closed system – mass remains constant, while energy is transferred as heat

5.



6. J K^{-1}

7. Clausius – It is impossible to produce a device which will transfer heat energ energy being transferred.
Kelvin – It is impossible to produce a device which will only transfer thermal

8. There is more disorder so the number of microstates increases with the tem

9. A negative sign indicates a process is non-spontaneous and must be accomp by the surroundings. A positive sign indicates an increase in entropy and the be spontaneous.

10. Efficiency = $\frac{\text{Useful work output}}{\text{Total energy input}}$

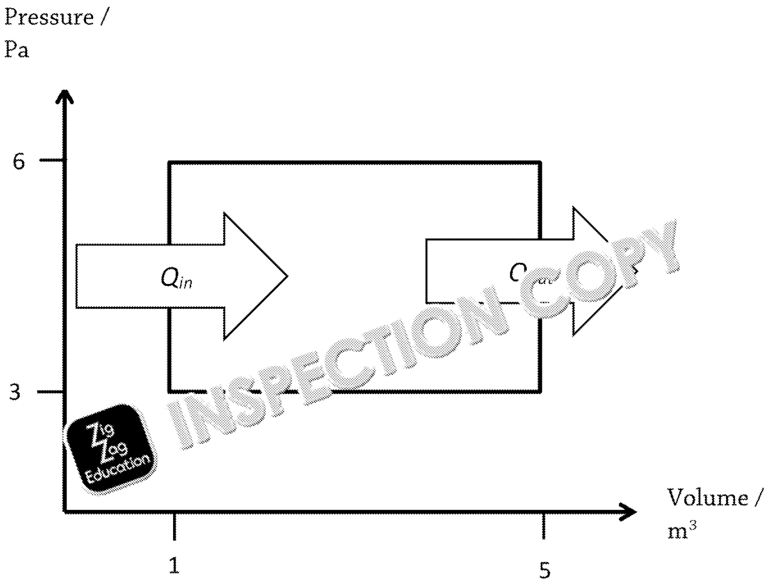
11. Insulate the apparatus to reduce heat loss to the surroundings.

12. The efficiency would increase as the heat lost by one engine becomes the he

13. 4 × 3 = 12 J of work

14. $\eta = 1 - \frac{123\text{ K}}{398\text{ K}} = 0.69$

15.



B.5 Circuits, electromotive force and internal resistance

1. a) $\varepsilon = IR + Ir$

$r = \dfrac{\varepsilon - IR}{I}$

$r = \dfrac{24-(1.9\times 11.4)}{1.9}$

$r = 1.2\,\Omega$

b) $V = IR$

$V = 1.9\times 11.4$

V [illegible] V

c) When there is current in the cell, work has to be done by the charge ca
cell. This results in an energy loss, as some energy is transferred into h
energy supplied by the emf is supplied to the rest of the circuit – some

Therefore, the terminal potential difference supplied to the circuit will be

2. a) $V = IR$

$V = 1.2\times 12$

$V = 14.4\ V$

b) $P = IV$

$P = 1.2\times 14.4$

$V = 17.28$ W

$V = 17.3$ W

c) $E = Pt$

$E = 17.28\times 500$

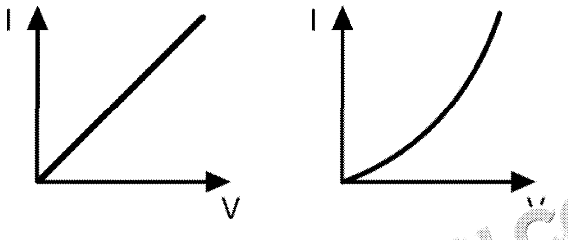
$E = 8640$ J

3. a) As the temperature increases, the resistance of the thermistor decreas
potential difference across the thermistor (V = IR). As the potential diff
decreases, the potential difference across the fixed resistor increases u
the alarm.

b) $V_{out} = \dfrac{8.5}{8.5+6.4}\times 12 = 6.8\ \text{V}$

4. The current through an Ohmic conductor is directly proportional to the pote
that the temperature is constant.

5.



Ohmic Conductor   Non-Ohmic Conductor

6.

Quantity	Series circuits
Current	$I = I_1 = I_2 = \Omega$
Potential difference	$V = V_1 + V_2 + \Omega$
Resistance	$R_T = R_1 + R_2 + \Omega$