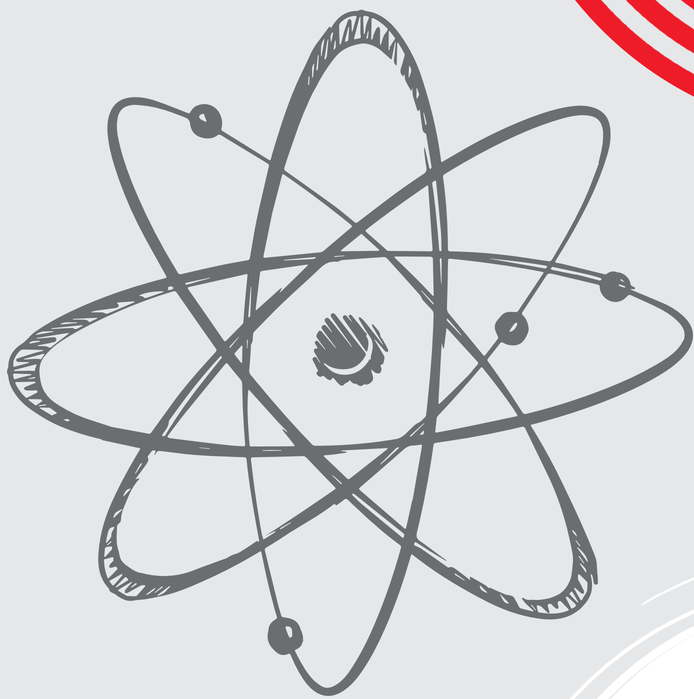
Physical Sciences

CLASS TEXT & STUDY GUIDE

Retha Louw

GRADE
11
CAPS

3-in-1



THE ANSWER SERIES *Your Key to Exam Success*

Grade 11 Physical Sciences 3-in-1 CAPS

CLASS TEXT & STUDY GUIDE

This Grade 11 Physical Sciences 3-in-1 study guide simplifies the theory of Grade 11 Physical Sciences and builds confidence through clear explanations supported by revision questions. It allows you to rapidly improve your problem-solving skills.

Key features:

- Comprehensive, explanatory notes and worked examples per topic
- Exercises and exam questions per topic
- Detailed answers with explanations and handy hints

This study guide provides reliable guidance through Grade 11, while building a solid platform for the upcoming Grade 12 curriculum.

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THIS CLASS TEXT & STUDY GUIDE INCLUDES

1. Comprehensive Notes
2. Exercises and Exam Questions
3. Detailed Memos with Explanations
   (available in a separate booklet)

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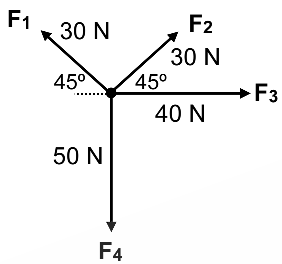
NOTES with QUESTIONS:

THE GRADE 11 NOVEMBER EXAM

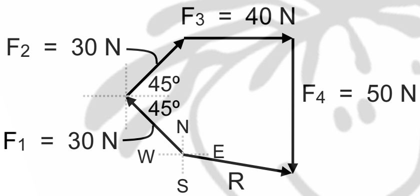
Paper	**Content**	**Marks**	**Total marks per paper**	**Duration (hours)**	**Weighting of questions across cognitive levels**			
					Level 1	**Level 2**	**Level 3**	**Level 4**
Paper 1: Physics focus	**Mechanics (Module 1)**	68	150	3	15%	35%	40%	10%
	Waves, Sound and Light (Module 3)	32						
	Electricity and Magnetism (Module 5)	50						
Paper 2: Chemistry focus	**Chemical Change (Module 4)**	70	150	3	15%	40%	35%	10%
	Chemical Systems (Module 6)	20						
	Matter and Materials (Module 2)	60						

Resultant of two or more 1-D and 2-D vectors

- Sometimes various vectors, e.g. forces in different directions, can act on a point.



- The resultant vector of **any** number of vectors in a 1-D and 2-D plane are determined by a **tail-to-head polygon** method of vector addition:
  - Draw each vector accurately to scale, pointing in the right direction.
  - Join the vectors, with the next vector's tail at the previous vector's head.
  - Once the last vector is joined, link the **first** vector's tail to the **last** vector's head. This forms the resultant vector R.

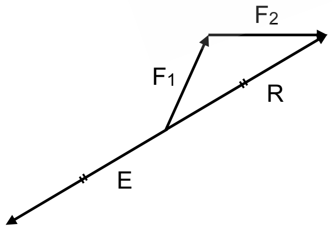


  - Determine the magnitude and direction of R by accurate measuring.

- If the vector addition using the tail-to-head method gives a **closed** polygon, the resultant vector R = 0, and the forces are in equilibrium/balanced. Such an object will remain at rest or move at a constant velocity.

- If the resultant vector (R) > 0, the forces (system) are not in equilibrium. A force that is equal to the resultant force, but acts in the opposite direction, is necessary to balance the object. This force is called the **equilibrant** (E), e.g.:

E = -R

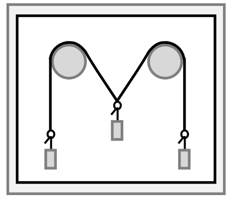


- An algebraic component method can also be used to determine the resultant of two or more 1-D and 2-D vectors (*see p. 1.5*).

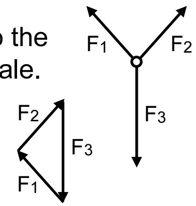
Resultant of three non-linear force vectors

Practical Investigation

Apparatus and method:



- Attach two pulleys to a board. Stick a sheet of white paper to the board behind the pulleys.
- Make loops at the ends of a light string and tie a small ring in the middle. Thread it over the pulleys.
- Suspend mass-pieces from the loops and ring so that the central ring is more or less in the middle of the paper. (Make sure that the string and mass-pieces do not touch the board.)
- Three forces now act on the central ring, counterbalancing each other. (The system is in equilibrium.)
- Mark the centre of this ring on the paper and draw a line with a pencil along the string to show the direction of the forces.
- Determine the magnitudes of the three forces according to the weight of the mass-pieces (w = mg) and draw them to scale.
- Determine the resultant of the forces, using the tail-to-head method of vector addition.



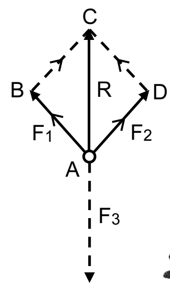
Result:

- The tail-to-head vector addition of the three forces produces a closed triangle (the head of the last vector ends at the tail of the first).
- Therefore, the resultant is zero and the forces are in equilibrium.

Conclusion:

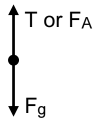
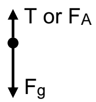
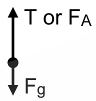
Three (or more) forces acting on a point are in equilibrium when the tail-to-head method of vector addition produces a closed triangle (or closed polygon).

*The resultant of two of the forces can be determined using the tail-to-tail method of vector addition. The diagonal (AC) of the completed polygon (parallelogram) ABCD forms the resultant of the two vectors F_1 and F_2. The resultant force is equal to the third force F_3, but in the opposite direction. Therefore, the force F_3 is the **equilibrant** and counterbalances the other two forces.*



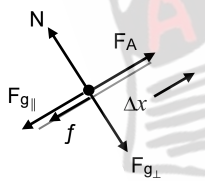
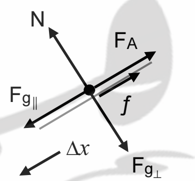
▶ **Vertical**

(object that moves vertically through the air, e.g. a spacecraft, subjected to an upward force from the burning gas (F_A), or an elevator that is suspended from a cable/rope and experiences an upward tensile force (T))

Vertical forces	Object hanging still or moving at constant velocity	Object accelerating downwards	Object accelerating upwards
Free-body diagram (use a 1-D frame of reference, e.g. ↓ **+** or ↑ **+**)			
Magnitude of forces	$F_g = T$	$F_g > T$	$F_g < T$
Resultant force in y-direction *	$F_{net} = F_g + T$ $= 0$ N	$F_{net} = F_g + T$ downwards	$F_{net} = T + F_g$ upwards
Resultant force in *x*-direction *	$F_{net} = 0$ (no horizontal forces)		

▶ **On an inclined plane**

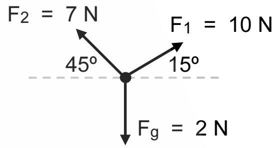
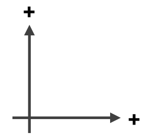
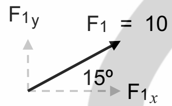
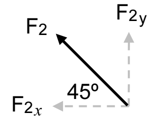
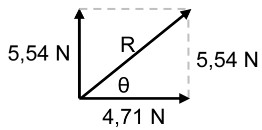
(object on a slope at rest or moving)

Forces on inclined plane	Applied force upwards plus frictional force; object moves upwards	Applied force upwards plus frictional force; object moves downwards
Free-body diagram (use a 1-D frame of reference e.g. ↗ **+** or ↙ **+**)		
F_{net} ∥ plane *	$F_{net} = F_A + F_{g_\parallel} + f$	$F_{net} = F_A + f + F_{g_\parallel}$
F_{net} ⊥ plane *	$F_{net} = F_{g_\perp} + N = 0$ N	

NB:

- *$F_{g_{/\!/}}$ is always present and is directed at an angle down the slope.*
- *F_A/T and f may be present if specified as such.*
- *A frictional force f is always parallel to the slope but in the opposite direction to the direction of motion (Δx).*

Forces in two directions on an object

	Two or more forces in different directions
Free-body diagram (use a 2-D frame of reference)	
Resultant force in *x*-direction *	$F_{1x} = F_1 \cos\theta_1$ $= 10 \cos 15º$ $= 9,66$ N right $F_{2x} = F_2 \cos\theta_2$ $= 7 \cos 45º$ $= 4,95$ N left $F_{net}(x) = 9,66 + (-4,95) = 4,71$ N right **+ →**
Resultant force in y-direction *	$F_{1y} = F_1 \sin\theta_1$ $= 10 \sin 15º$ $= 2,59$ N upwards $F_{2y} = F_2 \sin\theta_2$ $= 7 \sin 45º$ $= 4,95$ N upwards $F_{net}(y) = 2,59\text{ N} + 4,95\text{ N} + (-2\text{ N})$ $= 5,54$ N upwards **+ ↑**
Resultant vector R	$\tan\theta = \frac{y}{x}$ $= \frac{5,54}{4,71}$ $\theta = 49,63º$ $\therefore \sin\theta = \frac{y}{r}$ $\sin 49,63º = \frac{5,54}{R}$ $\therefore R = \frac{5,54}{\sin 49,63º}$ $= 7,27$ N 49,63º above the positive x-axis **OR** $R = \sqrt{5,54^2 + 4,71^2}$ $= 7,27$ N

NEWTON'S FIRST LAW OF MOTION

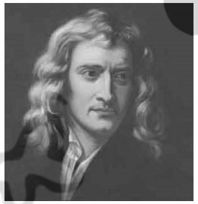
- Before about the middle of the 16th century, scholars believed that a force was needed to make an object move continuously.

  (In practice, you find that you move an object by pushing or pulling it, but it comes to a standstill soon after you stop pushing or pulling.)

- The scientist Galileo Galilei was the first person to realise that friction resists the motion of an object:
  - He did practical investigations and proved that if friction is reduced between an object and the surface on which it moves, the object takes increasingly longer to come to a stop.
  - He came to the conclusion that if it were possible to eliminate friction completely, a moving object would continue to move unrestricted at a constant velocity in a straight line (without the influence of forces).

- Isaac Newton (1642 - 1727) expanded on Galilei's work and did a further study on forces and motion.

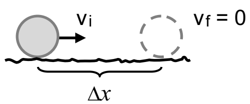
- Newton stated his first **law of motion**, summarising this theory:



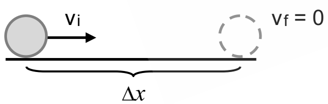
Isaac Newton

> **Newton I:** A body will remain in its state of rest or motion at constant velocity, unless a non-zero resultant/net force acts on it.

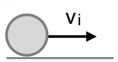
- Suppose the same initial velocity is given to a ball in the following situations:



Ball rolls over a carpet: the ball covers a displacement Δx and comes to a stop



Ball rolls over a wooden floor: the ball has a greater displacement before it comes to a stop



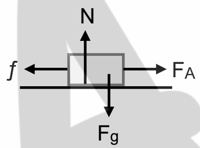
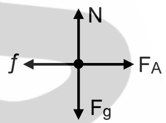
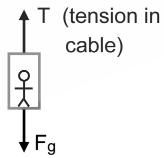
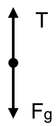
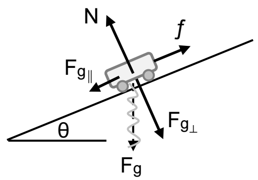
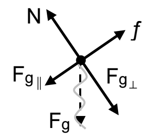
Ball rolls over a floor of smoothly polished marble tiles (seen as frictionless): the ball continues moving at a uniform velocity

In practice, frictional force is always present and cannot be eliminated.

Resultant/net force of forces in equilibrium

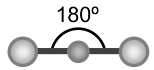
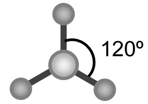
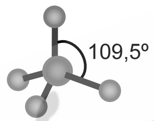
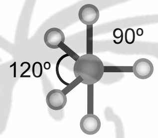
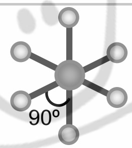
When the resultant/net force equals zero (F_{net} = 0 N), the forces are in equilibrium or counterbalance each other. The object then maintains its state of rest or motion.

Some representations of forces in equilibrium

	Force diagram	Free-body diagram	F_{net}
Horizontal			*** x-direction:** $F_{net} = F_A + f$ $= 0$ N *** y-direction:** $F_{net} = F_g + N$ $= 0$ N
	applied force (F_A) = frictional force (f)		
Vertical			**x-direction:** No forces *** y-direction:** $F_{net} = F_g + T$ $= 0$ N
	T = F_g		
Inclined plane			*** ∥ to inclined plane:** $F_{net} = F_{g\parallel} + f$ $= 0$ N *** ⊥ to inclined plane:** $F_{net} = F_{g\perp} + N$ $= 0$ N
	frictional force (f) = $F_{g\parallel}$		

***NB:** Use negative values for the relevant forces when required by the reference framework.*

Take A = central atom and X = terminal atom:

General formula	Number of electron pairs	Geometry	Illustration	Examples
AX_2	2 bond pairs	linear		CO_2 ; $BeC\ell_2$
AX_3	3 bond pairs	trigonal planar		BF_3
AX_4	4 bond pairs	tetrahedral		CH_4
AX_5	5 bond pairs	trigonal bipyramidal		PF_5
AX_6	6 bond pairs	octahedral		SF_6

Molecular shapes of molecules with single covalent bonds

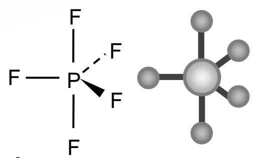
Bond pairs are arranged in a 3-D, symmetrical manner at a maximum distance from each other. *(See forms AX_2 to AX_6 as indicated in the table.)*

Molecules with more than four bond pairs

Phosphor pentafluoride (PF_5):

- There are five bond pairs around the central P atom.
- The molecular shape is trigonal bipyramidal (three F—P—F angles = 120º and two F—P—F angles = 90º).

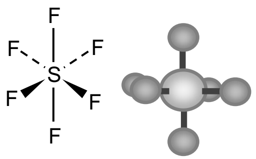
trigonal bipyramidal



Sulphur hexafluoride (SF_6):

- There are six bond pairs around the central S atom.
- The molecular shape is octahedral (F—S—F angles = 90º).

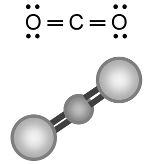
octahedral



Molecular shapes of molecules with multiple bonds

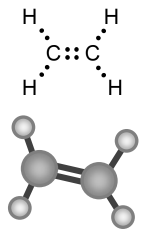
- While many molecules contain multiple bonds between atoms, the molecular shape is not affected by this.
- Two or three electron pairs are shared between the same atoms, but occupy the same space as a single electron pair.

The carbon dioxide molecule (CO_2):



- The Lewis diagram indicates that the C atom forms a double bond with two O atoms.
- A central C atom is therefore bonded with two atoms and contains no lone pairs.
- The atoms align themselves the furthest distance apart from each other.
- The geometry of the molecule is thus linear with a bond angle of 180º.

The ethene molecule (C_2H_4):



- The Lewis diagram shows that the two C atoms are combined by a double bond, and each forms a single bond with two H atoms.
- Therefore, every C atom is combined with three atoms and contains no lone pairs.
- The double bond occupies the same space as the single bonds.
- The three atoms of each CH_2 group align themselves the furthest distance apart.
- Therefore, the geometry of each CH_2 group is trigonal planar with a bond angle of 120º.

Non-ideal molecular shapes

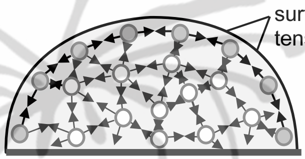
The central atom has bond pairs and lone pairs

- Molecules with **lone pairs** around the central atom **cannot** have **ideal** molecular shapes.
- A lone pair takes the place of a bond pair and the central atom can combine with one less atom. The one 'leg' of the ideal shape falls away and thus the molecular shape changes.
- Lone pairs are slightly larger and **repel** each other and the bond pairs more strongly so that the bond angles become slightly smaller.

- Molecules on the surface only experience a downward and inward force (as there are no liquid molecules above them) and are drawn into the liquid.
- This causes an internal pressure that contracts the surface to a minimum size. Therefore, the surface molecules are more densely packed than the rest of the molecules.
- The forces of attraction between the liquid molecules are responsible for the surface tension phenomenon.

> **Surface tension** is the property of a liquid that resists any external force trying to enlarge the surface.

Practical Investigation



Requirements and method:

- Take small quantities of the following substances:
  - water
  - oil (e.g. olive oil)
  - glycerine
  - acetone
  - methylated spirits
- Take a few 50c coins and place them next to each other. Use a medicine dropper and try to put as many drops of each liquid onto a coin without it spilling over.
- Count the total number of drops in each case.

Variables:

- Independent variable: type of liquid
- Dependent variable: number of drops that accumulate (surface tension)
- Constants: the same temeprature and pressure, the same dropper and type of coin

Results:

Liquid	Number of drops (surface tension)
acetone	increases ↓
methylated spirits	
oil	
glycerine	
water	

Explanation:

An explanation can be formulated in terms of the strength of the inter-molecular forces between the molecules *(see table on p. 2.20)*. Oil consists of non-polar molecules with long C-chains and Van der Waals forces between the molecules. Glycerine molecules have 3 OH-groups with strong H-bonds between the molecules.

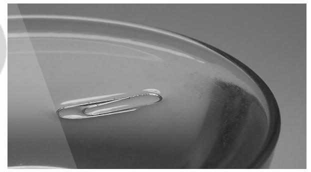
Conclusion:

- The more drops that accumulate without spilling over, the greater the surface tension in the liquid.
- Substances with stronger intermolecular forces between the molecules have greater surface tension.
- Water has the highest surface tension of the substances being investigated.

> *Various factors, such as the purity of the substance, play a role in determining the physical properties of substances. Therefore it is sometimes difficult to obtain exact results.*

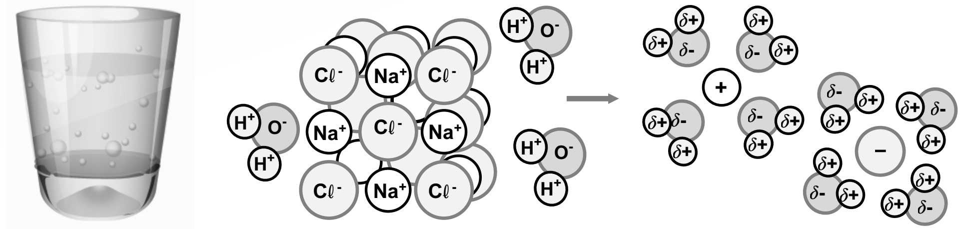
The surface tension of water

- Water has a relatively large surface tension due to strong hydrogen bonds between the water molecules. This is evident from the following phenomena:
  - water forms tear-shaped drops, e.g. on leaves, or droplets falling from a leaking tap.
  - small, light objects such as paper clips or some insects can float on water.



Solubility

- Dissolution is the process during which a substance breaks up into its components and is surrounded and attracted by the molecules of the solvent.



- Some substances are readily soluble and others only partially, while others are insoluble in a specific solvent.
- The solubility of a substance in a solvent depends on whether the intermolecular **forces of attraction** between the particles of the **dissolved substance** and those of the **solvent are strong enough** to overcome the mutual forces of attraction between particles of the substance. The following guidelines may be used:
  - Substances are soluble in one another if the intermolecular forces between the particles of the separate substances are of the same order of magnitude, i.e. if they are similar substances.

The Kelvin temperature scale

- Lord Kelvin (1824 - 1907), an Irish scientist, developed the kelvin temperature scale.
- The kelvin (K) is the SI unit for temperature.
- Conversion between temperature scales:
  - T (kelvin) = t (ºC) + 273º $\quad \therefore$ 0ºC: T = 0º + 273 = 273 K
    $\therefore$ 100ºC: T = 100º + 273 = 373 K
  - A difference of T (K) = a difference of t (ºC)

The Ideal Gas Law

The Ideal Gas Law: combination of the three gas laws

From the three gas laws, it follows that:

$p \propto \frac{1}{V}$ (Boyle) $\quad V \propto T$ (Charles) $\quad p \propto T$ (Gay-Lussac)

The three relationships can be combined in a single equation, i.e.:

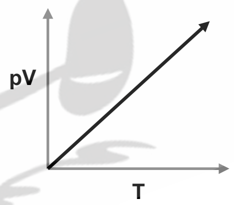
$$p \propto \frac{T}{V} \quad \textbf{OR} \quad V \propto \frac{T}{p} \qquad \therefore pV \propto T$$

$$\therefore pV = kT$$

$$\therefore \frac{pV}{T} = k$$

$$\therefore \frac{p_1V_1}{T_1} = k = \frac{p_2V_2}{T_2}$$

Relationship between p, V and T



This equation is known as the **Universal Gas Equation** or **Ideal Gas Law**. It applies to a fixed mass (number of moles) of gas and is used when the volume, temperature or pressure of a gas changes and the other values change accordingly.

NB: *p_1 and p_2 indicate pressure in Pa or kPa. V_1 and V_2 indicate volume in cm^3, dm^3 or m^3. Use the same units on either side of the equation. T_1 and T_2 indicate the temperature in kelvin.*

Example:

A large inflatable ball is pumped up. Initially, the volume of the ball is 63 dm^3 and the gas in the ball exerts a pressure of 101,3 kPa at 20ºC. Calculate the pressure of the gas if the volume of the ball increases to 75 dm^3 and the temperature rises to 24ºC.

Solution:

p_1 = 101,3 kPa
V_1 = 63 cm^3
T_1 = 20ºC = 293 K
V_2 = 75 cm3
T_2 = 24ºC = 297 K
p_2 = ?

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

$$\frac{101{,}3 \times 63}{293} = \frac{p_2 \times 75}{297}$$

$$\therefore p_2 = 86{,}25 \text{ kPa}$$

The Ideal Gas law for a specific amount of gas

- So far, the equations have only been applicable to a given/fixed amount (number of moles) of gas.
- It is, however, useful to adapt the equation so that it may be used for any amount of gas.
- It should be clear that if the amount (number of moles) of gas in a container is doubled, the number of collisions with the walls of the container per unit time will double, as well as the pressure.

  Therefore:

  $$\mathbf{p \propto n}$$

- From Avogadro's law it follows that:
  - one mole of all gases at standard temperature and pressure, fills 22,4 dm^3
  - the volume of a gas is proportional to the number of moles of gas at the same temperature and pressure.

    Therefore:

    $$\mathbf{V \propto n}$$
    $$\therefore \mathbf{pV \propto n}$$

▸ The constant **k** in the equation $pV = kT$ can be replaced by nR

$$\therefore pV = nRT$$

where: p = pressure in pascal (Pa)
V = volume in metre^3 (m^3)
n = number of moles
R = universal gas constant
= 8,31 $J \cdot K^{-1} \cdot mol^{-1}$
T = temperature in kelvin (K)

Remember:

$n = \frac{m}{M}$ if mass of gas is given.

NB: *It is important to use SI units in the above equation.*

Standard Temperature and Pressure (STP)

The temperature and pressure values determined by scientists for comparison of results are known as Standard Temperature and Pressure.

The values are:

Standard temperature: 273 K or 0ºC

Standard pressure: 101,3 kPa or 101 300 Pa (atmospheric pressure at sea level)

Ideal Gas law
$pV = kT$

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

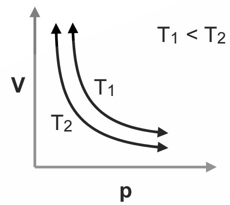
- the mass of gas remains the same
- the units of p and V must be the same on both sides
- the temperature must be in kelvin (K)

$$pV = nRT$$

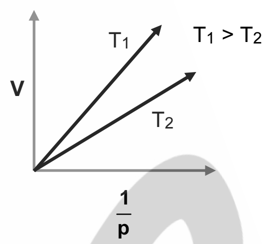
- the equation provides for different amount (number of moles) of gas
- SI units are used: pressure = Pa, volume = m^3
- the temperature must be in kelvin (K)

Comparison of graphs at different states of temperature, pressure and volume

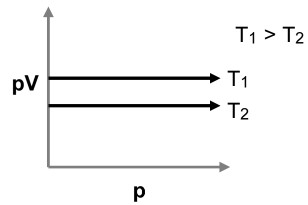
1) $p \propto \frac{1}{V}$ **(T constant)**



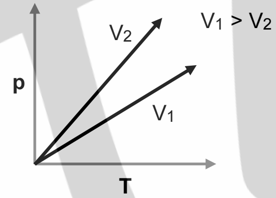
$T_1 > T_2$



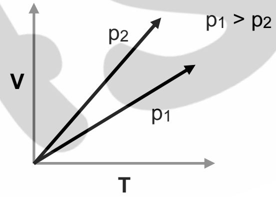
$T_1 > T_2$



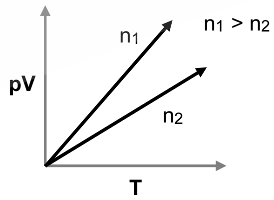
2) $p \propto T$ **(V constant)**



$V \propto T$ **(p constant)**



3) $pV \propto T$



$pV = kT$
OR $pV = nRT$

The gradient = $\frac{pV}{T}$; from the equation it follows that $\frac{pV}{T} = nR$,
$\therefore$ gradient $\propto$ n $\therefore$ the graph with the steeper gradient, represents a greater number of moles.

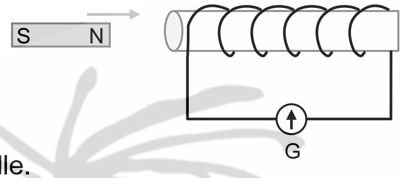
Below is a breakdown of the investigations that led to Faraday's law.

The induction of an electric current

Practical Investigation: The induction of potential difference and current in a conductor

Method:

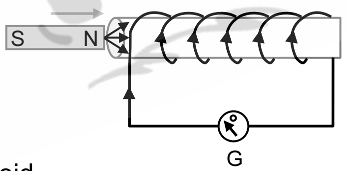
- Connect a solenoid to a zero-centred galvanometer or ammeter in a closed circuit as in the sketch below.
- Quickly push the N-pole of a bar magnet into the solenoid, hold the magnet motionless inside the solenoid for a short while and then quickly pull it out. Observe the deflection of the galvanometer needle.



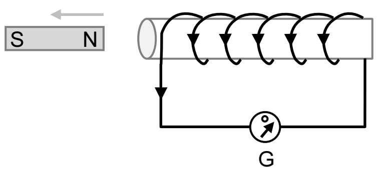
- Repeat by pushing the S-pole of the magnet quickly in and then out again.
- Repeat by holding the magnet still and quickly moving the solenoid back and forth over the magnet.
- Further investigate what happens if:
  - two magnets are placed on top of each other and pushed in and out of the solenoid
  - the number of turns on the solenoid is increased
  - the speed at which the magnet or solenoid is moved, increases or decreases.

Observation:

- When the N-pole is moved into the solenoid, the galvanometer deflects rapidly but returns to zero once the magnet is held still.



- When the N-pole is pulled from the solenoid, the galvanometer rapidly deflects to the opposite side and again returns to zero.
- When the magnet poles are switched around and the S-pole is pushed in and out, the direction in which the galvanometer deflects is reversed.



- The galvanometer also shows a reading when the magnet is kept still and the solenoid is moved, because there is still a changing magnetic field linked to the solenoid.
- There is no reading if both the magnet and the solenoid are kept still and there is **no relative motion** between the magnet and the solenoid.
- The galvanometer reading increases if:
  - the two magnets are placed on top of each other
  - the turns on the solenoid are increased
  - the magnet and coil are moved faster in relation to each other

Conclusion:

- When the N-pole or S-pole of a magnet approaches the solenoid/(circular) coil, the magnetic flux increases *(see p. 5.16)*. When the magnet pole is moved away, the magnetic flux decreases.
- The turns of the coil cut through the magnetic field lines and contribute to the changing magnetic flux.
- The changing magnetic flux:
  - works on the charges in the conductor and thus induces a potential difference or emf between the terminals of the conductor $\left(V = \frac{W}{Q}\right)$
  - the induced emf, in turn, induces an electric current in the conductor if the conductor is part of a closed circuit

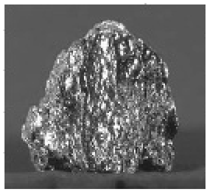
  This phenomenon is known as **electromagnetic induction.**

- The magnitude of the emf and strength of the current can be increased by:
  - using a stronger magnet
  - increasing the number of turns in the wire
  - increasing the speed at which the magnet or coil is moved

NB: ***Coil*** *is the general term used here to describe a solenoid (with many turns of wire) or a conductor with only a few turns of wire or only a single loop.*

The main steps in the mining of other selected minerals

Iron



- Iron is the fourth most plentiful element found in the lithosphere, and after aluminium, the most plentiful metal. According to scientists, the earth's outer core consists of molten iron and nickel.
- Iron occurs mainly as iron ore, of which magnetite (Fe_3O_4) and hematite (Fe_2O_3) are the most important. Both contain about 70% iron.
- Archaeological excavations have shown that iron objects were used as tools and weapons by early civilisations.
- South Africa has large iron ore reserves and it is mined on a large scale at Thabazimbi and Phalaborwa in Limpopo province, at Sishen in Northern Cape and at Dundee in KwaZulu Natal.
- Iron is a silvery metal with a high boiling and melting point. It is not strong enough to be used on its own and is therefore mostly used in alloys with other elements such as carbon, tungsten (wolfram) or nickel. These form a stronger substance called steel.

- **The mining and refining of iron ore**

  Iron is mined in opencast mines. Holes are drilled into rock, filled with explosives and the rock is blasted apart. Chunks of rock containing iron ore are transported to plants where it is crushed, washed, drained and then refined into iron.

  Steps during refinement:

  - The iron ore is placed in a blast furnace together with limestone ($CaCO_3$) and coke (carbon).
  - Warm air is blown into the blast furnace through holes at the bottom. The coke burns in the oxygen and is oxidised to carbon dioxide (CO_2). The furnace reaches a temperature of approximately 2 000 ºC.

    $$C(s) + O_2(g) \rightarrow CO_2(g)$$

  - The CO_2 further reacts with the coke and forms carbon monoxide (CO). The reaction is endothermic and the temperature drops to about 1 300 ºC.

    $$C(s) + CO_2(g) \rightarrow 2CO(g)$$

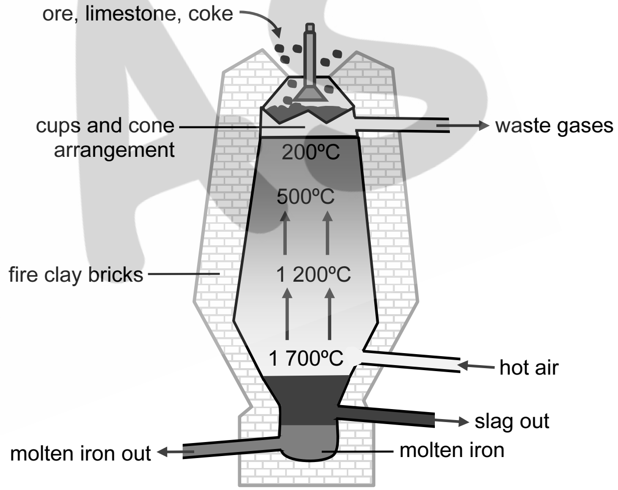
  - The CO now reacts with the iron oxide and reduces it to iron.

    $$Fe_2O_3(s) + 3CO(g) \rightarrow 3CO_2(g) + 2Fe(s)$$

  - The temperature of the furnace is higher than the melting point of iron, so the iron melts and is drawn off.
  - However, the iron ore contains other impurities such as sand or silica (SiO_2). The limestone ($CaCO_3$) decomposes to form CaO and CO_2. The CaO then reacts with the silica and forms a floating slag of waste material. This is drawn off and left to solidify; it forms an important component of cement.

    $$CaCO_3(s) \rightarrow CaO(s) + O_2(g)$$

    $$CaO(s) + SiO_2(s) \rightarrow CaSiO_3(\ell) \text{ (slag)}$$



- **Corrosion of iron**

  Iron is a very useful material with numerous applications, but unfortunately has one negative property: In the presence of moisture in the air, it reacts with oxygen to form rust. This is a redox reaction during which the iron is oxidised and thus corrodes.

  The corrosion or rusting of iron takes place more readily at the coast than inland. Iron can be protected against rust by galvanising treatment.

  Galvanising is when iron is dipped in molten zinc to form a protective coating.

The matter eventually ends up in court. Before passing judgement, the judge asks you, a science student, to determine whether the coefficient of static friction of the floor is a minimum of 0,5 as required. He provides you with a tile from the floor, as well as one of the shoes that the lady was wearing on the day of the incident.

22.1 Write down an expression for the coefficient of static friction.

22.2 Plan an investigation that you will perform in order to assist the judge in his judgement. Follow the steps outlined below to ensure that your plan meets the requirements:

22.2.1 Formulate an investigative question.

22.2.2 Apparatus: list ALL the other apparatus, besides the tile and the shoe, that you will need.

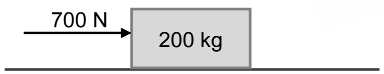
22.2.3 A stepwise method: How will you perform the investigation? Also include a relevant, labelled diagram.

22.2.4 Results: What will you record?

22.2.5 Conclusion: How will you interpret the results to draw a conclusion?

Question 23

A 200 kg concrete block lies on a horizontal surface with a coefficient of static friction of 0,4 and a coefficient of kinetic friction of 0,3. Initially, a push of 700 N is applied to the block.



23.1 Define: *maximum static frictional force* and *kinetic frictional force*.

23.2 Show why the coefficient of kinetic friction is smaller than the coefficient of static friction.

23.3 Do a calculation to determine if the force of 700 N is sufficient to set the block in motion.

23.4 Draw a free-body diagram and show all the forces being applied to the block at this stage.

23.5 Now the push is increased to 900 N. Calculate the acceleration of the block.

Application of Newton's Laws of Motion

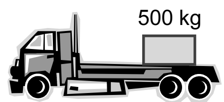
Question 24

24.1 Define: *Newton's first law of motion*.

24.2 Explain why it is very dangerous when small children are not secured in a child's car seat while travelling in a car.

Question 25

A granite block of mass 500 kg is at rest at the back of the bed of a flat-bed lorry travelling at 108 $km \cdot h^{-1}$. The brakes of the lorry fail, causing the lorry to crash head-on into a concrete pillar at the above-mentioned speed. The lorry comes to a standstill and a moment later the granite block collides with the back of the driver's cab. The block pushes the cab 100 mm inwards, before coming to a standstill. Assume that the frictional force between the granite block and the lorry bed is negligible.



25.1 Describe the motion of the granite block, from the moment of the lorry's collision until the block comes to a rest. Also show how all three of Newton's laws of motion could be applied to the granite block during its motion.

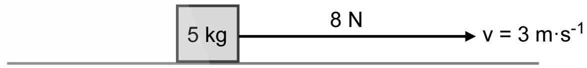
25.2 Draw a free-body diagram of the forces being applied to the block during the collision with the driver's cab.

25.3 Calculate the acceleration of the block.

25.4 Calculate the net force on the block.

Question 26

A constant pull of 8 N is applied to a block of mass 5 kg to set it in motion at a constant velocity of 3 $m \cdot s^{-1}$ to the right.

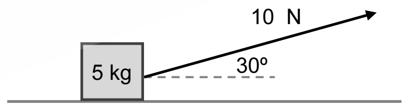


26.1 Define: *coefficient of friction*.

26.2 Draw a free-body diagram of all the forces acting on the block.

26.3 Calculate the coefficient of kinetic friction of the block and the floor surface moving over each other.

A pulling force of 10 N is applied to the block at an angle of 30º relative to the floor.



26.4 Again, draw a free-body diagram of all the forces and components of forces in the horizontal and vertical directions.

26.5 Calculate the normal force on the block.

26.6 Calculate the kinetic frictional force experienced by the block.

26.7 Calculate the net force parallel to the plane of motion.

26.8 Choose the correct answer: A, B or C.

From the net force it can be concluded that the block:

A moves at a constant velocity

B accelerates in the direction of motion

C accelerates against the direction of motion

Question 28

28.1 Which conditions must be satisfied for the formation of a dative covalent bond between atoms?

28.2 Using a Lewis diagram, show how the compound H_3O^+ is formed from H_2O.

28.3 What molecular shape will H_3O^+ take?

28.4 When BF_3 reacts with ammonia gas (NH_3) it produces a solid (NH_3BF_3).

Draw Lewis diagrams for NH_3 and BF_3 and decide which molecule has an empty orbital and which a lone pair. Show how the dative covalent bond between N and B takes place to produce NF_3BF_3.

Question 29

Read the following extract from a speech and answer the questions that follow:

Planet earth in danger!

It is now accepted that greenhouse gases are to blame for planet earth getting warmer. The increase in the number of sudden floods in Asia and droughts in Africa; the rising sea level and increasing average temperatures are global concerns. Without natural greenhouse gases, like carbon dioxide and water vapour, life on earth is not possible. However, the increase in levels of carbon dioxide in the atmosphere since the Industrial Revolution is of great concern.

Greater disasters are expected which will create millions of climate refugees. It is our duty to take action for the sake of future generations who will pay dearly for the wait-and-see attitude of the current generation. Urgent action to reduce waste is needed. Global warming is a global challenge and calls for a global response now, not later.

[Adapted from a speech by the French President, Jacques Chirac]

29.1 How do greenhouse gases, such as carbon dioxide, heat up the earth's surface?

29.2 Draw a Lewis diagram for the carbon dioxide molecule.

29.3 The chemical bonds within the carbon dioxide molecule are polar. Support this statement by performing a calculation using the table of electronegativities.

29.4 Classify the carbon dioxide molecule as polar or non-polar. Give a reason for your answer.

Nitrogen is the most abundant gas in the atmosphere, but it is not a greenhouse gas.

29.5 In terms of charge distribution and dipole moments, explain why carbon dioxide is a greenhouse gas, but not nitrogen.

29.6 Suggest **one** way in which **you** can help to reduce the emissions of greenhouse gases.

Question 30

Read the newspaper article below and answer the questions that follow

The silent killer!

A family was admitted to hospital, showing symptoms of headache, chills, nausea and dizziness. After several tests, they were diagnosed with carbon monoxide poisoning. They recovered after treatment with hyperbaric oxygen, in other words oxygen at higher pressure, but some still suffer from chronic headaches and memory problems.

This incident sends out a warning to everybody. Proper ventilation is crucial when using gas heaters or making fires indoors. Blocked chimneys can also prevent the gas from escaping. Idling a car in a garage is just as dangerous. Even smoking can produce levels of carbon monoxide in the blood.

continued in next column...

Carbon monoxide is the product of **incomplete combustion of fossil fuels**. Exposure to small amounts of carbon monoxide greatly reduces the capacity of the blood to transport oxygen. It is a colourless, odourless gas. When detected, it is often too late. Carbon monoxide poisons the body by combining with haemoglobin 250 times more tightly than oxygen. The formation of this bond hinders the transport of oxygen to the body tissue. With only 0,1% carbon monoxide in the lungs more than half the bonding sites of haemoglobin become occupied with carbon monoxide, and the victim can die within an hour.

[From: Health Express, 20 June 2006]

30.1 State **two** physical properties of carbon monoxide that make it a 'silent killer'.

30.2 State **one** chemical property of carbon monoxide that makes it poisonous to humans.

30.3 Explain the meaning of the following words from the newspaper report

30.3.1 incomplete combustion

30.3.2 fossil fuels

30.4 Draw a Lewis diagram for the carbon monoxide molecule.

30.5 Refer to the Lewis diagram of the carbon monoxide molecule and explain why it can form a dative covalent bond with the Fe^{2+} ion.

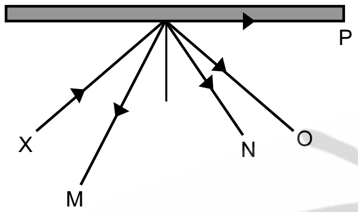
30.6 Many people in South Africa depend on coal as an energy source in their homes. What safety advice can you give to people who use coal as an energy source in their homes? Give a reason for your answer.

3: WAVES, SOUND AND LIGHT

Section A: Multiple Choice Questions

Question 1

The diagram shows the path of a light ray, X, directed at a reflective plane.



The correct reflected ray is:

A M **B** N

C O **D** P

Question 2

Endoscopes are used to examine a patient's body internally.

The principle on which the endoscope operates is:

A total internal reflection

B real and apparent depth

C lateral inversion

D refraction

Question 3

A ray of light passing from glass into ice is refracted away from the normal. The refractive indices of the two substances compare as follows:

A glass > ice

B ice > glass

C glass = ice

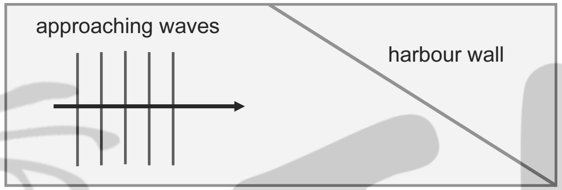
D too little information to know

Section B: Geometrical optics

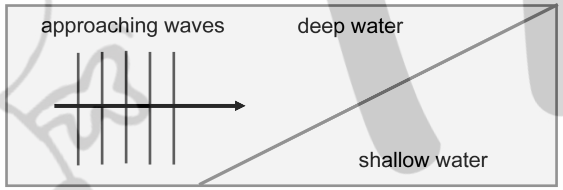
Question 4

The results of wave investigations carried out in water tanks are shown as incomplete diagrams below. Redraw each diagram, showing the likely pattern of the waves as they proceed further.
Indicate on each diagram which wave phenomenon is observed. (Remember to add normals and the names of any relevant angles to the diagrams).

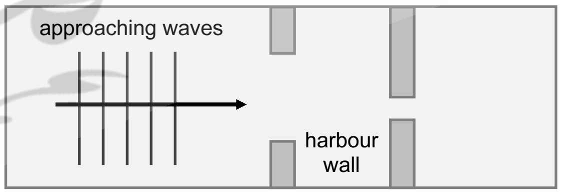
A



B



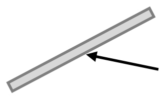
C



Question 5

5.1 State the law of reflection.

5.2 Copy the accompanying sketch and clearly show how the wave is reflected. Remember to sketch in the normal and show the relevant angles.



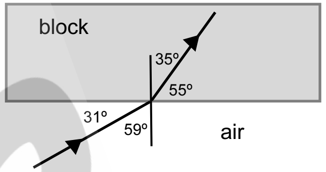
Question 6

6.1 Define the terms:

6.1.1 refraction

6.1.2 refractive index

6.2 Light travels from air into a transparent rectangular block as shown below.



6.2.1 Write down the value of the angle of incidence.

6.2.2 Write down the value of the angle of refraction.

6.2.3 Calculate the refractive index of the block.

6.2.4 Redraw and complete the above diagram (NOT to scale) to show the ray leaving the block at the second surface. Label the rays of light at the second surface. Include the angles and the normal at this surface.

6.2.5 A ray of light enters another block having a higher refractive index than the one above. State how the angle of refraction in this block will compare with the one above. Answer only **larger**, **smaller** or **the same**.

6.3 The following formula is given:

$$\text{refractive index} = \frac{\text{speed of light in air}}{\text{speed of light in medium}}$$

6.3.1 What is the approximate value of the speed of light in air?

6.3.2 If the refractive index for water = 1,33 and for perspex = 1,5, is the speed of light in water greater than or smaller than the speed of light in perspex?