education

Department of
Education
FREE STATE PROVINCE

Dear Grade 11 learner in 2021

This is an **extract** from the Examinable Content booklet we have handed out last year. It has all the correct definitions, laws, etc. that you need to know. Use it to ensure you write them down correctly in examinations and tests. You can also see what is required in each topic.

Important: Due to Covid-19 some of the content in this booklet is not required for this year. Refer to the FSAG to see what you need for this year. Ask your teacher if you are uncertain.

PHYSICAL SCIENCES
EXAMINABLE CONTENT
GRADE 11
CAPS
2020 ONWARDS

Dear Grade 11 Physical Sciences learner

1. **You must have your own copy of this document.**
2. **Use this document to ensure that all the content is covered in class.**
3. **Read this document on a daily basis to acquaint yourself with what is expected. Use a pencil/pen to tick off as aspects are completed in class.**
4. **You must complete a minimum of 5 examination type questions on each topic in your homework book. Ensure that these tasks are present in your homework book and that you do corrections of mistakes made. To help you to control that you do enough homework, the content are divided into topics.**
5. **Make sure that you know all definitions described in this document. Most of the definitions are printed in bold so that it is easier to recognise them.**
6. **When preparing for a test or an examination, ensure that you study all concepts described in this document that are applicable to the test/examination.**
7. **You are expected to solve different types of problems based on Newton's second law. You will find an example of each type of problem in Appendix A. Make sure you work through all these examples.**
8. **Also study the formulae of positive and negative ions given in Appendix B. You should be able to write formulae from any combinations of these positive and negative ions.**

SKILLS IN PHYSICAL SCIENCES

- Identify and question phenomena:
  - Formulate an investigative question.
  - List all possible variables.
  - Formulate a testable hypothesis.

- Design/Plan of an investigation:
  - Identify variables (dependent, independent and controlled variables).
  - List appropriate apparatus.
  - Plan the sequence of steps which should include, amongst others:
    - The need for more than one trial to minimise experimental errors.
    - Identify safety precautions that need to be taken.
    - Identify conditions that ensure a fair test.
    - Set an appropriate control.

- Graphs:
  - Draw accurate graphs from given data/information.
  - Interpret graphs.
  - Draw sketch graphs from given information.

- Results:
  - Identify patterns/relationships in data.
  - Interpret results.

- Conclusions:
  - Draw conclusions from given information, e.g. tables, graphs.
  - Evaluate the validity of conclusions.

- Calculations:
  - Solve problems using two or more different calculations (multistep calculations).

- Descriptions:
  - Explain/Describe/Argue the validity of a statement/event using scientific principles.

FIRST TERM

Topic 1: Vectors in two dimensions

Resultant of vectors

- Define a **resultant** as **the vector sum of two or more vectors, i.e. a single vector having the same effect as two or more vectors together.**
- Determine the resultant of vectors (maximum four) on a Cartesian plane, using the component method i.e. find the vertical and horizontal components of each vector and then add co-linear vertical components and co-linear horizontal components to obtain the resultant vertical vector (R_y) and resultant horizontal vector (R_x).
- Sketch the resultant vertical vector (R_y) and the resultant horizontal vector (R_x) on a Cartesian plane.
- Calculate the magnitude of the resultant using the theorem of Pythagoras.
- Determine the direction of the resultant using simple trigonometric ratios.
- Determine the resultant (R) of two vectors graphically using either the tail-to-head or tail-to-tail method (parallelogram method) as well as by calculation (component method) for a maximum of four vectors in both 1-dimension and 2-dimensions.
- Explain the meaning of a closed vector diagram.

Resolution of a vector into its horizontal and vertical components

- Use $R_x = R\cos\theta$ for the resultant x component if θ is the angle between R and the x axis.
- Use $R_y = R\sin\theta$ for the resultant y component if θ is the angle between R and the x axis.

Topic 2: Newton's laws and application of Newton's laws

Different kinds of forces: weight, normal force, frictional force, applied force (push, pull), tension (strings or cables)

- Define **normal force, N,** as **the force or the component of a force which a surface exerts on an object in contact with it, and which is perpendicular to the surface.**
  NOTE: The normal force acts perpendicular to the surface irrespective of whether the plane is horizontal or inclined. For horizontal planes, the only forces perpendicular to the plane should be the weight, w, and the normal force, N. All other forces should be parallel to the plane. For inclined planes, the only forces perpendicular to the plane is the component of weight, $w\cos\theta$, and the normal, N. All other forces should be parallel to the plane.
- Define **frictional force, f,** as **the force that opposes the motion of an object and which acts parallel to the surface.**
  Know that a frictional force:
    - Is proportional to the normal force
    - Is independent of the area of the surfaces that are in contact with each other
- Define the **static frictional force**, f_s, as **the force that opposes the tendency of motion of a stationary object relative to a surface and acts parallel to the surface.** The static frictional force can have a range of values from zero up to a maximum value, $\mu_s N$. If a force, F, applied to an object parallel to the surface, does not cause the object to move, F is equal in magnitude to the static frictional force.
- State that the static frictional force is a maximum, f_s^{max}, just before the object starts to move across the surface. The maximum static frictional force, f_s^{max}, is equal to the magnitude of the maximum horizontal force that can be applied to the object without it starting to move across the surface.
- Solve problems using $f_s^{max} = \mu_s N$ where f_s^{max} is the maximum static frictional force and μ_s is the coefficient of static friction. If the applied force exceeds f_s^{max}, a net force accelerates the object.
- Define the **kinetic frictional force**, f_k, as **the force that opposes the motion of a moving object relative to a surface and acts parallel to the surface.** The kinetic frictional force on an object is constant for a given surface and equals $\mu_k N$.

- Solve problems using $f_k = \mu_k N$, where f_k is the kinetic frictional force and μ_k the coefficient of kinetic friction.

Force diagrams, free-body diagrams

- Draw force diagrams. **In a force diagram the force is represented by an arrow. The direction of the arrow indicates the direction of the force and the length of the arrow indicates the magnitude of the force.**
- Draw **free-body diagrams**. Such a diagram **shows the relative magnitudes and directions of forces acting on an object that has been isolated from its surroundings. The object is drawn as a dot and all the forces acting on it are drawn as arrows pointing away from the dot. The length of the arrows are proportional to the magnitude of the respective forces.**
- Resolve a two-dimensional force e.g. the weight of an object on an inclined plane, into its parallel ($F_{//}$) and perpendicular ($F_{\perp}$) components.
- Determine the resultant/net force of two or more forces.

Newton's first, second and third laws of motion

- State **Newton's first law of motion: A body will remain in its state of rest or motion at constant velocity unless a non-zero resultant/net force acts on it.**
- Define **inertia** as **the resistance of an object to any change in its state of motion.** The mass of an object is a quantitative measure of its inertia.
- Discuss why it is important to wear seatbelts using Newton's first law of motion.
- State **Newton's second law of motion**: **When a resultant/net force acts on an object, the object will accelerate in the direction of the force at an acceleration directly proportional to the force and inversely proportional to the mass of the object.**

  In symbols: $a \propto F_{net}$, constant m and $a \propto \frac{1}{m}$, constant F_{net}, and therefore $F_{net} = ma$
- Draw force diagrams and free-body diagrams for objects that are in equilibrium or accelerating.
- Apply Newton's second law of motion, and therefore, to a variety of equilibrium and non-equilibrium problems including:
  - A single object:
    - Moving in a horizontal plane with or without friction
    - Moving on an inclined plane with or without friction
    - Moving in the vertical plane (lifts, rockets, etc.)
  - Two-body systems (joined by a light inextensible string):
    - Both on a flat horizontal plane with or without friction
    - One in a horizontal plane with or without friction, and a second hanging vertically from a string over a frictionless pulley
    - Both on an inclined plane with or without friction
    - Both hanging vertically from a string over a frictionless pulley

    NOTE: When an object accelerates, the equation $F_{net} = ma$ must be applied separately in the x and y directions. If there is more than one object, a free body diagram must be drawn for each object and Newton's second law must be applied to each object separately.
- State **Newton's third law of motion**: **When object A exerts a force on object B, object B SIMULTANEOUSLY exerts an oppositely directed force of equal magnitude on object A.** (The forces are therefore an interaction between two bodies.)
- Identify Newton III force pairs (action-reaction pairs) and list the properties of the force pairs (action-reaction pairs). When identifying the forces, it must be clearly stated which body exert a force on which body, and what kind of force it is, e.g. the earth exerts a downward gravitational force on the object, and the object exerts an upward gravitational force of equal magnitude on the earth.

Newton's Law of Universal Gravitation

- State **Newton's Law of Universal Gravitation**: **Each particle in the universe attracts every other particle with a gravitational force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.**
- Solve problems using $F = \frac{Gm_1m_2}{r^2}$.
- Calculate acceleration due to gravity on the Earth using $g = \frac{GM}{r_E^2}$, and on another planet using $g = \frac{GM_p}{r_p^2}$ where M_p is the mass of the planet and r_p is the radius of the planet.
- Describe **weight** as **the gravitational force, in newton (N), exerted by the Earth on an object.** Describe **mass** as **the amount of matter in a body measured in kilogram (kg)**.
- Calculate weight using the expression w = mg.
- Calculate the weight of an object on other planets with different values of gravitational acceleration.
- Explain **weightlessness** as **the sensation experienced when all contact forces are removed i.e. no external objects touch one's body.** For example, when in free fall, the only force acting on your body is the force of gravity that is a non-contact force. Since the force of gravity cannot be felt without any other opposing forces, you would have no sensation of it and you would feel weightless when in free fall.

Topic 3: Atomic combinations: molecular structure

A chemical bond

- Define a **chemical bond** as **a mutual attraction between two atoms resulting from the simultaneous attraction between their nuclei and the outer electrons.** (NOTE: The energy of the combined atoms is lower than that of the individual atoms resulting in higher stability.)
- Draw Lewis dot diagrams of elements.
  A Lewis dot diagram (electron dot formula/Lewis formula/electron diagram) **is a structural formula in which valence electrons are represented by dots or crosses.**
- Determine the number of valence electrons in an atom of an element.
  Valence electrons or outer electrons are the electrons in the highest energy level, of an atom, in which there are electrons.
- Explain, in terms of electrostatic forces between protons and electrons, and in terms of energy considerations, why:
  - Two H atoms form an H_2 molecule
  - He does not form He_2

  Interpret the graph of potential energy versus the distance between nuclei for two approaching hydrogen atoms.
- Define a **covalent bond** as **the sharing of electrons between two atoms to form a molecule.**
  Molecule: A group of two or more atoms covalently bonded and that function as a unit.
- Draw Lewis diagrams, given the formula and using electron configurations, for simple molecules e.g. H_2, F_2, H_2O, NH_3, HF, OF_2, HOCℓ and molecules with multiple bonds e.g. N_2, O_2 and HCN.
- Describe rules for bond formation:
  - Different atoms, each with an unpaired valence electron can share these electrons to form a chemical bond e.g. two H atoms form a H_2 molecule by sharing an electron pair.
  - Different atoms with **paired valence electrons**, called **lone pairs**, cannot share these four electrons and cannot form a chemical bond e.g. no bond forms between two He

atoms.

- Different atoms, with unpaired valence electrons, can share these electrons and form a chemical bond for each electron pair shared. The two atoms can form multiple bonds between them. If two pairs of electrons are shared, a double bond is formed e.g. between two O atoms to form O_2.
- Atoms with an empty valence shell can share a lone pair of electrons from another atom to form a coordinate covalent or dative covalent bond e.g. in NH_4^+ the lone pair of nitrogen is shared with H^+ and in H_3O^+ the lone pair of oxygen is shared with H^+.

- Define a **bonding pair** as **a pair of electrons that is shared between two atoms in a covalent bond.**
  Define a **lone pair** as **a pair of electrons in the valence shell of an atom that is not shared with another atom.**
- Describe the formation of the dative covalent (or coordinate covalent) bond by means of electron diagrams using NH_4^+ and H_3O^+ as examples.

Molecular shape: Valence shell electron pair repulsion (VSEPR) theory

- **State the major principles used in the VSEPR:**
  - Molecular shape is determined by the repulsions between electron pairs present in the valence shell of the central atom.
  - The number of electron pairs around the central atom can be determined by writing the Lewis structure for the molecule.
  - The shape of the molecule depends on the number of bonding electron groups (or atoms bonded to the central atom) and the number of lone pairs on the central atom.
  - **A** is used to represent the central atom and **X** is used to represent terminal atoms.
  - There are five ideal shapes found when there are NO lone pairs on the central atom, ONLY bond pairs.
- Use the VSEPR theory to classify given molecules as one of the five ideal molecular shapes by finding the number of atoms bonded to the central atom in molecules where there are NO lone pairs on the central atom. If this number equals:
  - Two, the molecular shape is linear - AX_2
    Examples: CO_2, $BeC\ell_2$, C_2H_2
  - Three, the molecular shape is trigonal planar - AX_3
    Example: BF_3
  - Four, the molecular shape is tetrahedral - AX_4
    Example: CH_4, $CC\ell_4$
  - Five, the molecular shape is trigonal bipyramidal - AX_5
    Example: $PC\ell_5$
  - Six, the molecular shape is octahedral - AX_6
    Example: SF_6
- Use the VSEPR theory to determine the shapes of molecules with lone pairs on the central atom (H_2O, NH_3, SO_2) and that CANNOT have one of the ideal shapes.

Electronegativity of atoms to explain the polarity of bonds

- Define **electronegativity** as **a measure of the tendency of an atom in a molecule to attract bonding electrons.**
- Describe a **non-polar covalent bond** as **a bond in which the electron density is shared equally between the two atoms.** An example is the bond between two H atoms.
- Describe a **polar covalent bond** as **a bond in which the electron density is shared unequally between the two atoms.** An example is the bond between an H atom and a Cℓ atom.
- Show polarity of bonds using partial charges e.g. $^{\delta+}H - C\ell^{\delta-}$
- Compare the polarity of chemical bonds using a table of electronegativities:
  - With an electronegativity difference $\Delta EN > 2,1$ electron transfer will take place and the

bond will be ionic.
  - With an electronegativity difference ∆EN > 1 the bond will be polar covalent.
  - With an electronegativity difference ∆EN < 1 the bond will be very weakly polar covalent.
  - With an electronegativity difference ∆EN = 0 the bond will be nonpolar covalent

- Explain that the character of a bond varies from purely covalent (when ∆EN = 0) to almost purely ionic (when ∆EN > 3). The above differences in electronegativity is only a guideline, many bonds have both ionic and covalent character.
- Use difference in electronegativity and molecular shape to explain that polar bonds do not always lead to polar molecules.

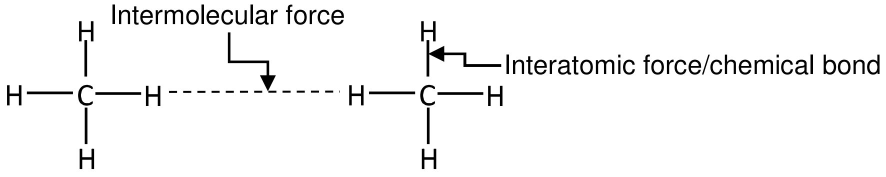
Bond energy and bond length

- Define **bond energy** of a compound as **the energy needed to break one mole of its molecules into separate atoms.**
- Define **bond length** as **the average distance between the nuclei of two bonded atoms.**
- Explain the relationship between bond energy and bond length i.e. bonds with a shorter bond length requires more energy to break than bonds with a longer bond length.
- Explain the relationship between the strength of a chemical bond between two atoms and the:
  - Length of the bond between them
    If the force of attraction between two atoms is strong, the nuclei come very close together resulting in a short bond length.
  - Size of the bonded atoms
    The bond length between larger atoms is longer than the bond length between smaller atoms.
  - Number of bonds (single, double, triple) between the atoms
    Bond strength increases as the number of bonds between atoms increases i.e. triple bonds are stronger than double bonds which are stronger than single bonds.

Topic 4: Intermolecular forces

Intermolecular forces and interatomic forces (chemical bonds)

- Name and explain the **different intermolecular forces** (Van der Waal's forces):
  (i) **Mutually induced dipole forces or London forces**: Forces between non-polar molecules
  (ii) **Dipole-dipole forces:** Forces between two polar molecules
  (iii) **Dipole-induced dipole forces:** Forces between polar and non-polar molecules
  (iv) **Hydrogen bonding:** Forces between molecules in which hydrogen is covalently bonded to nitrogen, oxygen or fluorine – a special case of dipole-dipole forces
  (v) **Ion-dipole forces:** Forces between ions and polar molecules
- Describe the difference between intermolecular forces and interatomic forces (intramolecular forces) using a diagram of a group of small molecules; and in words.
  Example:



- State the relationship between intermolecular forces and molecular mass. For non-polar molecules, the strength of induced dipole forces increases with molecular size.
- Explain the effect of intermolecular forces on boiling point, melting point, vapour pressure and solubility.
  Boiling point: The temperature at which the vapour pressure of a substance equals atmospheric pressure. The stronger the intermolecular forces, the higher the boiling point.
  Melting point: The temperature at which the solid and liquid phases of a substance are at equilibrium. The stronger the intermolecular forces, the higher the melting

point.
Vapour pressure: The pressure exerted by a vapour at equilibrium with its liquid in a closed system. The stronger the intermolecular forces, the lower the vapour pressure.
Solubility: The property of a solid, liquid, or gaseous chemical substance (solute) to dissolve in a solid, liquid, or gaseous solvent to form a homogeneous solution.

SECOND TERM

Topic 5: Geometrical optics

Refraction

- Know that the speed of light as being constant when passing through a given medium and having a maximum value of $c = 3 \times 10^8\ m \cdot s^{-1}$ in a vacuum.
- Define **refraction of light** as **the change in direction of a light ray due to a change in speed when light travels from one medium into the another of different optical density.**
- Define **optical density** as **a measure of the refracting power of a medium.** The higher the optical density, the more the light will be refracted or slowed down as it moves through the medium.
- Define the **refractive index (n)** of a material **as the ratio of the speed of light in vacuum (c) to the speed of light in a material (v).**
- Solve problems using $n = \frac{c}{v}$.
- Relate optical density to the refractive index of the material. Materials with a high refractive index will also have a high optical density.
- Define the terms normal, angle of incidence and angle of refraction, and identify them on a ray diagram.
  Normal: The line which is perpendicular to the plane of the surface.
  Angle of incidence: The angle between the normal to a surface and the incident light ray.
- **Angle of refraction: The angle between the normal to a surface and the refracted light ray.**
- Draw ray diagrams to show the path of a light ray moving from one medium into another.
- State **Snell's Law**: **The ratio of the sine of the angle of incidence in one medium to the sine of the angle of refraction in the other medium is constant.**
  $\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$ OR $n_1\sin\theta_1 = n_2\sin\theta_2$ OR $\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_r}{n_i}$ OR $n_i\sin\theta_i = n_r\sin\theta_r$
- Solve problems using the above equations for Snell's law.
- Determine the refractive index of an optical medium by using $n = \frac{\sin\theta_1}{\sin\theta_2}$ for a ray of light traveling from vacuum (or air) to the medium.

Critical angles and total internal reflection

- State the **law of reflection**: **When light is reflected the angle of incidence is always equal to the angle of reflection.**
  Angle of incidence: The angle between the normal to a reflecting surface and the incident light ray.
  Angle of reflection: The angle between the normal to a reflecting surface and the reflected light ray.
- Define the **critical angle** as **the angle of incidence in the optically more dense medium for which the angle of refraction in the optically less dense medium is 90°.**
- List conditions required for total internal reflection i.e. when the refracted ray does not emerge from the medium, but is reflected back into the medium:
  - Light must travel from an optically denser medium (higher refractive index) to an

  optically less dense medium (lower refractive index).
  - The angle of incidence in the optically denser medium must be greater than the critical angle.
- Use Snell's law to calculate the critical angle at the surface between two optically different media.
- Explain the use of optical fibres in endoscopes and telecommunications.

Topic 6: 2D and 3D wave fronts

Diffraction

- Define a **wavefront** as **an imaginary line joining points on a wave that are in phase.**
- State **Huygens' principle**: **Every point of a wave front serves as a point source of spherical, secondary waves that move forward with the same speed as the wave.**
- Define **diffraction** as **the ability of a wave to spread out in wavefronts as the wave passes through a small aperture or around a sharp edge.**
- Sketch the diffraction pattern for a single slit.
- Relate the degree of diffraction to the wavelength (λ) and width of slit (w): $\text{degree of diffraction } \alpha \ \frac{\lambda}{w}$
- State that diffraction demonstrates the wave nature of light.

Topic 7: Ideal gases and thermal properties

Motion of particles; kinetic theory of gases

- Describe the motion of individual gas molecules:
  - Molecules are in constant motion and collide with each other and the walls of the container.
  - There are forces of attraction between molecules.
  - Molecules in a gas move at different speeds.
- Describe an **ideal gas** as a gas:
  - **That has identical particles of zero volume**
  - **With no intermolecular forces between particles**
  - **In which all collisions of the molecules with themselves or the walls of the container, are perfectly elastic**
- Explain that **real gases deviate from ideal gas behaviour at high pressures and low temperatures.**
- State the conditions under which a real gas approaches ideal gas behaviour.

Ideal gas law

- State **Boyle's law**: **The pressure of an enclosed gas is inversely proportional to the volume it occupies at constant temperature.**

  In symbols: $p \alpha \frac{1}{V}$, therefore $p_1V_1 = p_2V_2$, T = constant
- State **Charles' Law**: **The volume of an enclosed gas is directly proportional to its kelvin temperature provided the pressure is kept constant.**

  In symbols: $V \alpha T$, therefore $\frac{V_1}{T_1} = \frac{V_2}{T_2}$, p = constant
- State that the **pressure of a gas is directly proportional to its temperature in kelvin at constant volume (Gay Lussac).** In symbols: $p \alpha T$, therefore $\frac{p_1}{T_1} = \frac{p_2}{T_2}$, V = constant
- For each of the above three relationships:
  - Interpret a table of results or a graph
  - Draw a graph from given results
  - Solve problems using a relevant equation
  - Use kinetic theory to explain the gas laws

- Use the general gas equation, $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$, to solve problems.
- Use the **ideal gas equation, pV = nRT**, to solve problems.
- Convert temperatures in celcius to kelvin for use in ideal and general gas equations.

Temperature and heating, pressure

- Explain the temperature of a gas in terms of average kinetic energy of the gas molecules.
- Explain the pressure exerted by a gas in terms of the collision of the molecules with the walls of the container.

Topic 8A: Representing Chemical Change (revision of grade 10 topic)

Balanced chemical equations

- Write and balance chemical equations. Use formulae for reactants and products and indicate the phases in brackets i.e. (s), (ℓ), (g) and (aq).
- Interpret balanced reaction equations in terms of:
  - Conservation of atoms
  - Conservation of mass (use relative atomic masses)

Topic 8: Quantitative aspects of chemical change

The mole concept

- Describe the **mole** as **the SI unit for amount of subst**ance.
- Define **one mole** as **the amount of substance having the same number of particles as there are atoms in 12 g carbon-12.**
- Describe **Avogadro's number, N_A,** as **the number of particles (atoms, molecules, formula-units) present in one mole (N_A = 6,023 x 10^{23} particles·mol^{-1}).**
- Define **molar mass** as **the mass of one mole of a substance measured in g·mol^{-1}.**
- Calculate the molar mass of a substance given its formula.

Molar volume of gases

- State **Avogadro's Law** i.e. **one mole of any gas occupies the same volume at the same temperature and pressure.**
- At STP: 1 mole of any gas occupies 22,4 dm^3 at 0 °C (273 K) and 1 atmosphere (101,3 kPa). Thus the molar gas volume, V_M, at STP = 22,4 dm^3·mol^{-1}.

Volume relationships in gaseous reactions

- Interpret balanced equations in terms of volume relationships for gases, i.e. under the same conditions of temperature and pressure, equal amounts (in mole) of all gases occupy the same volume.

Concentration of solutions

- Define **concentration** as **the amount of solute per litre of solution.**
- Calculate concentration in mol·ℓ$^{-1}$ (or mol·dm^{-3}) using $c = \frac{n}{V}$.

More complex stoichiometric calculations

- Determine the empirical formula and molecular formula of compounds.
- Determine the percentage yield of a chemical reaction.
- Determine percentage purity or percentage composition, e.g. the percentage $CaCO_3$ in an impure sample of seashells.
- Perform stoichiometric calculations based on balanced equations that may include limiting reagents.

THIRD TERM

Topic 9: Electrostatics

Coulomb's law

- State **Coulomb's law**: **The magnitude of the electrostatic force exerted by two point charges (Q_1 and Q_2) on each other is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them.**
- Solve problems using the equation $F = \frac{kQ_1Q_2}{r^2}$ for charges in one dimension (1D) - restrict to three charges.
- Solve problems using the equation $F = \frac{kQ_1Q_2}{r^2}$ for charges in two dimensions (2D) – for three charges in a right-angled formation (limit to charges at the 'vertices of a right- angled triangle').

Electric field

- Describe an **electric field** as **a region in space in which an electric charge experiences a force.** The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.
- Draw electric field patterns for the following configurations:
  - A single point charge
  - Two point charges (one negative, one positive OR both positive OR both negative)
  - A charged sphere

  NOTE: Restrict to situations in which the charges are identical in magnitude.
- Define the **electric field strength at a point**: **The electric field strength at a point is the electrostatic force experienced per unit positive charge placed at that point.**

  In symbols: $E = \frac{F}{Q}$
- Solve problems using the equation $E = \frac{F}{Q}$.
- Calculate the electric field strength at a point due to a number of point charges, using the equation $E = \frac{kQ}{r^2}$ to determine the contribution to the field due to each charge. Restrict to three charges in a straight line.

Topic 10: Electromagnetism

Magnetic field associated with current carrying conductors

- Use the **Right Hand Rule** to determine the magnetic field (B) associated with a:
  - Straight current carrying conductor
  - Current carrying loop (single turn)
  - Solenoid
- Draw the **magnetic field pattern** around a:
  - Straight current carrying wire
  - Current carrying loop (single turn)
  - Solenoid

Faraday's law

- State **Faraday's law of electromagnetic induction**: **The magnitude of the induced emf across the ends of a conductor is directly proportional to the rate of change in the magnetic flux linkage with the conductor.**
- Use the Right Hand Rule to determine the direction of the current induced in a solenoid when a pole of a bar magnet moves into and out of the solenoid.

- Solve problems using Φ = BAcosθ.
- Predict the direction of the induced current in a coil.
- Solve problems using $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$.

Topic 11: Electric circuits

Ohm's law

- State **Ohm's law** in words: **The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature.**
- Interpret data/graphs on the relationship between current, potential difference and resistance at constant temperature.
- State the difference between ohmic and non-ohmic conductors and give an example of each.
- Solve problems using $R = \frac{V}{I}$ for circuits containing resistors that are connected in series and/or in parallel (maximum four resistors).

Power, energy

- Define **power** as **the rate at which work is done or energy is transferred**.
- Solve problems using $P = \frac{W}{\Delta t}$.
- Recall that W = VQ, and therefore, by substituting V = IR in the equation, W = VIΔt, $W = I^2R\Delta t$ and $W = \frac{V^2}{R}\Delta t$ are obtained.
- Deduce, by substituting $P = \frac{W}{\Delta t}$ into above equations, the following equations: P = VI, $P = I^2R$ and $P = \frac{V^2}{R}$.
- Solve problems using P = VI, $P = I^2R$ and $P = \frac{V^2}{R}$.
- Solve circuit problems involving the concepts of power and electrical energy.
- Deduce that the **kilowatt hour (kWh)** refers to the use of 1 kilowatt of electricity for 1 hour. **1 kWh is an amount of electrical energy known as one unit of electricity.**
- Calculate the cost of electricity usage given the power specifications of the appliances used, the duration and the cost of 1 kWh.

Topic 12: Energy and chemical change

Energy changes in reactions related to bond energy changes

- Define **heat of reaction (ΔH)** as **the energy absorbed or released per mole in a chemical reaction.**
  $\Delta H = H_{products} - H_{reactants}$, where $H_{products}$ and $H_{reactants}$ are the heat (energy) of the products and reactants respectively.
- Define **exothermic reactions** as **reactions that release energy.**
- Define **endothermic reactions** as **reactions that absorb energy.**
- Classify, with reason, reactions as exothermic or endothermic.

Exothermic and endothermic reactions

- State that ΔH > 0 for endothermic reactions (reactions in which energy is absorbed).
- State that ΔH < 0 for exothermic reactions (reactions in which energy is released).

Activation energy

- Define **activation energy** as **the minimum energy needed for a reaction to take place.**
- Define an **activated complex** as **the unstable transition state from reactants to products.**

- Draw or interpret fully labelled sketch graphs (potential energy versus course of reaction graphs) of catalysed and uncatalysed endothermic and exothermic reactions.

Topic 13: Types of reaction

Acid-base reactions

- Define acids and bases according to Arrhenius and Lowry-Brønsted:
  Arrhenius theory: An acid is a substance that produces hydrogen ions (H^+)/hydronium ions (H_3O^+) when it dissolves in water. A base is a substance that produces hydroxide ions (OH^-) when it dissolves in water.
  Lowry-Brønsted theory: An acid is a proton / H^+ ion donor. A base is a proton / H^+ ion acceptor.
- Identify conjugate acid-base pairs for given compounds. When the acid, HA, loses a proton, its conjugate base, A^-, is formed. When the base, A^-, accepts a proton, its conjugate acid, HA, is formed. These two are a conjugate acid-base pair.
- Describe a substance that can act as either acid or base as amphiprotic or as an ampholyte. Water is a good example of an ampholyte. Write equations to show how an amphiprotic substance can act as acid or base.
- Write names and formulae of common acids: hydrochloric acid, nitric acid, sulphuric acid and ethanoic acid (acetic acid)
- Write names and formulae of common bases: ammonia, sodium carbonate (washing soda), sodium hydrogen carbonate, sodium hydroxide (caustic soda) and potassium hydroxide.
- Write reaction equations for the dissolution of acids and bases in water.
  Examples: $HC\ell(g) + H_2O(\ell) \rightarrow H_3O^+(aq) + C\ell^-(aq)$
  $NH_3(g) + H_2O(\ell) \rightarrow NH_4^+(aq) + OH^-(aq)$
  $H_2SO_4(aq) + 2H_2O(\ell) \rightarrow 2H_3O^+(aq) + SO_4^{2-}(aq)$
- Write the overall equations for reactions of acids with metal hydroxides, metal oxides and metal carbonates:
  $HC\ell(aq) + NaOH(aq) \rightarrow NaC\ell(aq) + H_2O(\ell)$
  $HC\ell(aq) + KOH(aq) \rightarrow KC\ell(aq) + H_2O(\ell)$
  $HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(\ell)$
  $HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(\ell)$
  $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell)$
  $H_2SO_4(aq) + KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(\ell)$
  $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(\ell)$
  $2HC\ell(aq) + CaO(aq) \rightarrow CaC\ell_2(aq) + H_2O(\ell)$
  $2HC\ell(aq) + MgO(aq) \rightarrow MgC\ell_2(aq) + H_2O(\ell)$
  $2HC\ell(aq) + MgO(aq) \rightarrow MgC\ell_2(aq) + H_2O(\ell)$
  $2HC\ell(aq) + CuO(aq) \rightarrow CuC\ell_2(aq) + H_2O(\ell)$
  $2HC\ell(aq) + Na_2CO_3(aq) \rightarrow 2NaC\ell(aq) + H_2O(\ell) + CO_2(g)$
  $2HC\ell(aq) + CaCO_3(aq) \rightarrow CaC\ell_2(aq) + H_2O(\ell) + CO_2(g)$
- Describe an acid-base indicator as a weak acid, or a weak base, which colour changes as the H^+ ion concentration or the OH^- ion concentration in a solution changes. Know the colours of litmus, methyl orange, phenolphthalein and bromothymol blue in acids and in bases.
- Identify the acid and the base needed to prepare a given salt and write an equation for the reaction.
- Write down neutralisation reactions of common laboratory acids and bases.

Oxidation numbers of atoms in molecules

- Explain the meaning of oxidation number.
- Assign oxidation numbers to atoms in various ions and molecules e.g. H_2O, CH_4, CO_2, H_2O_2 and $HOC\ell$, by using oxidation number guidelines or rules.

Redox reactions

- Describe a **redox** (oxidation-reduction) **reaction** as **involving an electron transfer.**
- Describe a redox reaction as always involving changes in oxidation numbers.
- Identify a redox reaction and apply the correct terminology to describe all the processes:
  Oxidation: A loss of electrons / An increase in oxidation number.
  Reduction: A gain of electrons / A decrease in oxidation number.
  Reducing agent: A substance that is oxidised / that loses electrons / whose oxidation number increases.
  Oxidising agent: A substance that is reduced / that gains electrons / whose oxidation number decreases.
- Balance redox reactions by using half-reactions from the Table of Standard Reduction Potentials (Table 4A and 4B).

FOURTH TERM

Topic 14: Exploiting the lithosphere or earth's crust

Mining and processing of minerals

- Apply knowledge of chemistry, learnt in previous sections, to given reactions of the extraction processes of gold and iron.

Gold mining and processing

- State that South African gold is mined from deep level underground mines.
- State that the ore undergoes a series of crushing and milling steps to reduce its size for further processing.
- Describe the leaching of gold from the slurry by a dilute sodium cyanide (NaCN) or potassium cyanide (KCN) solution:
  $4Au + 8NaCN + O_2 + 2H_2O \rightarrow 4NaAu(CN)_2 + 4NaOH$
  The solution containing the gold complex ion can now be filtered from the unwanted rock.
- Describe the addition of zinc powder to precipitate the gold:
  $Zn + 2NaAu(CN)_2 \rightarrow 2Au + Zn(CN)_2 + 2NaCN$
  Solid gold can now be filtered from the solution.
- Classify the above reactions as redox reactions, giving reasons.
- Identify the oxidation, reduction, oxidising agent and reducing agent in the above reactions.

Iron mining and processing

- Open pit mining is used to excavate iron ore that is close to the surface.
- The ore undergoes a series of crushing steps to reduce the particle size.
- After washing, screening and separation, the iron ore, containing 65% iron, goes into a blast furnace with coke (C), limestone ($CaCO_3$) and hot air.
- The following reactions takes place in the blast furnace:
  - Coke (carbon) is oxidised to carbon monoxide:
    $2C + O_2 \rightarrow 2CO$
  - CO reacts with iron ore to form iron:
    $3CO + Fe_2O_3 \rightarrow 2Fe + 3CO_2$
  - Limestone is added to remove impurities from the molten iron to form slag:
    $CaCO_3 \rightarrow CaO + CO_2$
    $CaO + SiO_2 \rightarrow CaSiO_3$ (slag)
  - Molten slag floats on top of the molten iron. The blast furnace produces pig iron that is sent to steel manufacturers.
- Classify the above reactions as redox reactions where applicable, giving reasons.
- Identify the oxidation, reduction, oxidising agent and reducing agent in the above reactions where applicable.

APPENDIX A: DATA SHEETS

DATA SHEETS – PAPER 1 (PHYSICS)

TABLE 1: PHYSICAL CONSTANTS/*TABEL 1: FISIESE KONSTANTES*

NAME/*NAAM*	**SYMBOL/*SIMBOOL***	**VALUE/*WAARDE***
Acceleration due to gravity *Swaartekragversnelling*	g	$9{,}8\ m\cdot s^{-2}$
Gravitational constant *Swaartekragkonstante*	G	$6{,}67 \times 10^{-11}\ N\cdot m^2\cdot kg^{-2}$
Radius of Earth *Straal van Aarde*	R_E	$6{,}38 \times 10^6\ m$
Coulomb's constant *Coulomb se konstante*	k	$9{,}0 \times 10^9\ N\cdot m^2\cdot C^{-2}$
Speed of light in a vacuum *Spoed van lig in 'n vakuum*	c	$3{,}0 \times 10^8\ m\cdot s^{-1}$
Charge on electron *Lading op elektron*	e	$-1{,}6 \times 10^{-19}\ C$
Electron mass *Elektronmassa*	m_e	$9{,}11 \times 10^{-31}\ kg$
Mass of the earth *Massa van die aarde*	M	$5{,}98 \times 10^{24}\ kg$

TABLE 2: FORMULAE/*TABEL 2: FORMULES*

MOTION/*BEWEGING*

$v_f = v_i + a\Delta t$	$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$
$v_f^2 = v_i^2 + 2a\Delta x$	$\Delta x = \left(\frac{v_f + v_i}{2}\right)\Delta t$

FORCE/*KRAG*

$F_{net} = ma$	$w = mg$
$F = \frac{Gm_1m_2}{r^2}$	$\mu_s = \frac{f_{s(max)}}{N}$
$\mu_k = \frac{f_k}{N}$	

WAVES, SOUND AND LIGHT/*GOLWE, KLANK EN LIG*

$v = f\lambda$	$T = \frac{1}{f}$
$n_i \sin\theta_i = n_r \sin\theta_r$	$n = \frac{c}{v}$

ELECTROSTATICS/*ELEKTROSTATIKA*

$F = \frac{kQ_1Q_2}{r^2}$ (k = 9,0 x 10^9 N·m^2·C^{-2})	$E = \frac{F}{Q}$
$E = \frac{kQ}{r^2}$ (k = 9,0 x 10^9 N·m^2·C^{-2})	$V = \frac{W}{Q}$

ELECTROMAGNETISM/*ELEKTROMAGNETISME*

$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$	$\Phi = BA\cos\theta$

CURRENT ELECTRICITY/*STROOMELEKTRISITEIT*

$I = \frac{Q}{\Delta t}$	$R = \frac{V}{I}$
$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \ldots$	$R = r_1 + r_2 + r_3 + \ldots$
$W = Vq$ $W = VI\Delta t$ $W = I^2R\Delta t$ $W = \frac{V^2\Delta t}{R}$	$P = \frac{W}{\Delta t}$ $P = VI$ $P = I^2R$ $P = \frac{V^2}{R}$

INFORMATION SHEETS – PAPER 2 (CHEMISTRY)

TABLE 1: PHYSICAL CONSTANTS/*TABEL 1: FISIESE KONSTANTES*

NAME/*NAAM*	**SYMBOL/*SIMBOOL***	**VALUE/*WAARDE***
Avogadro's constant *Avogadro-konstante*	N_A	$6{,}02 \times 10^{23}$ mol^{-1}
Molar gas constant *Molêre gaskonstante*	R	$8{,}31$ J·K^{-1}·mol^{-1}
Standard pressure *Standaarddruk*	p^θ	$1{,}013 \times 10^5$ Pa
Molar gas volume at STP *Molêre gasvolume by STD*	V_m	$22{,}4$ dm^3·mol^{-1}
Standard temperature *Standaardtemperatuur*	T^θ	273 K

TABLE 2: FORMULAE/*TABEL 2: FORMULES*

$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$	$pV = nRT$
$n = \frac{m}{M}$	$n = \frac{N}{N_A}$
$n = \frac{V}{V_m}$	$c = \frac{n}{V}$ OR/*OF* $c = \frac{m}{MV}$

TABLE 3: THE PERIODIC TABLE OF ELEMENTS/*TABEL 3: DIE PERIODIEKE TABEL VAN ELEMENTE*

KEY/*SLEUTEL*

Atomic number / ***Atoomgetal***: 29
Electronegativity / ***Elektronegatiwiteit***: 1,9
Symbol / ***Simbool***: Cu
Approximate relative atomic mass / ***Benaderde relatiewe atoommassa***: 63,5

1 (I)	2 (II)	3	4	5	6	7	8	9	10	11	12	13 (III)	14 (IV)	15 (V)	16 (VI)	17 (VII)	18 (VIII)
1 2,1 **H** 1																	2 **He** 4
3 1,0 **Li** 7	4 1,5 **Be** 9											5 2,0 **B** 11	6 2,5 **C** 12	7 3,0 **N** 14	8 3,5 **O** 16	9 4,0 **F** 19	10 **Ne** 20
11 0,9 **Na** 23	12 1,2 **Mg** 24											13 1,5 **Aℓ** 27	14 1,8 **Si** 28	15 2,1 **P** 31	16 2,5 **S** 32	17 3,0 **Cℓ** 35,5	18 **Ar** 40
19 0,8 **K** 39	20 1,0 **Ca** 40	21 1,3 **Sc** 45	22 1,5 **Ti** 48	23 1,6 **V** 51	24 1,6 **Cr** 52	25 1,5 **Mn** 55	26 1,8 **Fe** 56	27 1,8 **Co** 59	28 1,8 **Ni** 59	29 1,9 **Cu** 63,5	30 1,6 **Zn** 65	31 1,6 **Ga** 70	32 1,8 **Ge** 73	33 2,0 **As** 75	34 2,4 **Se** 79	35 2,8 **Br** 80	36 **Kr** 84
37 0,8 **Rb** 86	38 1,0 **Sr** 88	39 1,2 **Y** 89	40 1,4 **Zr** 91	41 **Nb** 92	42 1,8 **Mo** 96	43 1,9 **Tc**	44 2,2 **Ru** 101	45 2,2 **Rh** 103	46 2,2 **Pd** 106	47 1,9 **Ag** 108	48 1,7 **Cd** 112	49 1,7 **In** 115	50 1,8 **Sn** 119	51 1,9 **Sb** 122	52 2,1 **Te** 128	53 2,5 **I** 127	54 **Xe** 131
55 0,7 **Cs** 133	56 0,9 **Ba** 137	57 **La** 139	72 1,6 **Hf** 179	73 **Ta** 181	74 **W** 184	75 **Re** 186	76 **Os** 190	77 **Ir** 192	78 **Pt** 195	79 **Au** 197	80 **Hg** 201	81 1,8 **Tℓ** 204	82 1,8 **Pb** 207	83 1,9 **Bi** 209	84 2,0 **Po**	85 2,5 **At**	86 **Rn**
87 0,7 **Fr**	88 0,9 **Ra** 226	89 **Ac**															
				58 **Ce** 140	59 **Pr** 141	60 **Nd** 144	61 **Pm**	62 **Sm** 150	63 **Eu** 152	64 **Gd** 157	65 **Tb** 159	66 **Dy** 163	67 **Ho** 165	68 **Er** 167	69 **Tm** 169	70 **Yb** 173	71 **Lu** 175
				90 **Th** 232	91 **Pa**	92 **U** 238	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**

TABLE 4A: STANDARD REDUCTION POTENTIALS
TABEL 4A: STANDAARDREDUKSIEPOTENSIALE

Increasing oxidising ability/*Toenemende oksiderende vermoë*

Half-reactions			E^θ (V)
$F_2(g) + 2e^-$	$\rightleftharpoons$	$2F^-$	+ 2,87
$Co^{3+} + e^-$	$\rightleftharpoons$	Co^{2+}	+ 1,81
$H_2O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	$2H_2O$	+1,77
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	+ 1,51
$C\ell_2(g) + 2e^-$	$\rightleftharpoons$	$2C\ell^-$	+ 1,36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons$	$2Cr^{3+} + 7H_2O$	+ 1,33
$O_2(g) + 4H^+ + 4e^-$	$\rightleftharpoons$	$2H_2O$	+ 1,23
$MnO_2 + 4H^+ + 2e^-$	$\rightleftharpoons$	$Mn^{2+} + 2H_2O$	+ 1,23
$Pt^{2+} + 2e^-$	$\rightleftharpoons$	Pt	+ 1,20
$Br_2(\ell) + 2e^-$	$\rightleftharpoons$	$2Br^-$	+ 1,07
$NO_3^- + 4H^+ + 3e^-$	$\rightleftharpoons$	$NO(g) + 2H_2O$	+ 0,96
$Hg^{2+} + 2e^-$	$\rightleftharpoons$	$Hg(\ell)$	+ 0,85
$Ag^+ + e^-$	$\rightleftharpoons$	Ag	+ 0,80
$NO_3^- + 2H^+ + e^-$	$\rightleftharpoons$	$NO_2(g) + H_2O$	+ 0,80
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	+ 0,77
$O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O_2	+ 0,68
$I_2 + 2e^-$	$\rightleftharpoons$	$2I^-$	+ 0,54
$Cu^+ + e^-$	$\rightleftharpoons$	Cu	+ 0,52
$SO_2 + 4H^+ + 4e^-$	$\rightleftharpoons$	$S + 2H_2O$	+ 0,45
$2H_2O + O_2 + 4e^-$	$\rightleftharpoons$	$4OH^-$	+ 0,40
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	Cu	+ 0,34
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(g) + 2H_2O$	+ 0,17
$Cu^{2+} + e^-$	$\rightleftharpoons$	Cu^+	+ 0,16
$Sn^{4+} + 2e^-$	$\rightleftharpoons$	Sn^{2+}	+ 0,15
$S + 2H^+ + 2e^-$	$\rightleftharpoons$	$H_2S(g)$	+ 0,14
$2H^+ + 2e^-$	**$\rightleftharpoons$**	**$H_2(g)$**	**0,00**
$Fe^{3+} + 3e^-$	$\rightleftharpoons$	Fe	– 0,06
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	Pb	– 0,13
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	Sn	– 0,14
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	Ni	– 0,27
$Co^{2+} + 2e^-$	$\rightleftharpoons$	Co	– 0,28
$Cd^{2+} + 2e^-$	$\rightleftharpoons$	Cd	– 0,40
$Cr^{3+} + e^-$	$\rightleftharpoons$	Cr^{2+}	– 0,41
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	Fe	– 0,44
$Cr^{3+} + 3e^-$	$\rightleftharpoons$	Cr	– 0,74
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	Zn	– 0,76
$2H_2O + 2e^-$	$\rightleftharpoons$	$H_2(g) + 2OH^-$	– 0,83
$Cr^{2+} + 2e^-$	$\rightleftharpoons$	Cr	– 0,91
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	Mn	– 1,18
$A\ell^{3+} + 3e^-$	$\rightleftharpoons$	$A\ell$	– 1,66
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	Mg	– 2,36
$Na^+ + e^-$	$\rightleftharpoons$	Na	– 2,71
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	Ca	– 2,87
$Sr^{2+} + 2e^-$	$\rightleftharpoons$	Sr	– 2,89
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	Ba	– 2,90
$Cs^+ + e^-$	$\rightleftharpoons$	Cs	- 2,92
$K^+ + e^-$	$\rightleftharpoons$	K	– 2,93
$Li^+ + e^-$	$\rightleftharpoons$	Li	– 3,05

Increasing reducing ability/*Toenemende reduserende vermoë*

TABLE 4B: STANDARD REDUCTION POTENTIALS
TABEL 4B: STANDAARDREDUKSIEPOTENSIALE

Increasing oxidising ability/*Toenemende oksiderende vermoë*

Half-reactions			E^{θ} (V)
$Li^+ + e^-$	$\rightleftharpoons$	Li	− 3,05
$K^+ + e^-$	$\rightleftharpoons$	K	− 2,93
$Cs^+ + e^-$	$\rightleftharpoons$	Cs	− 2,92
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	Ba	− 2,90
$Sr^{2+} + 2e^-$	$\rightleftharpoons$	Sr	− 2,89
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	Ca	− 2,87
$Na^+ + e^-$	$\rightleftharpoons$	Na	− 2,71
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	Mg	− 2,36
$A\ell^{3+} + 3e^-$	$\rightleftharpoons$	$A\ell$	− 1,66
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	Mn	− 1,18
$Cr^{2+} + 2e^-$	$\rightleftharpoons$	Cr	− 0,91
$2H_2O + 2e^-$	$\rightleftharpoons$	$H_2(g) + 2OH^-$	− 0,83
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	Zn	− 0,76
$Cr^{3+} + 3e^-$	$\rightleftharpoons$	Cr	− 0,74
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	Fe	− 0,44
$Cr^{3+} + e^-$	$\rightleftharpoons$	Cr^{2+}	− 0,41
$Cd^{2+} + 2e^-$	$\rightleftharpoons$	Cd	− 0,40
$Co^{2+} + 2e^-$	$\rightleftharpoons$	Co	− 0,28
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	Ni	− 0,27
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	Sn	− 0,14
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	Pb	− 0,13
$Fe^{3+} + 3e^-$	$\rightleftharpoons$	Fe	− 0,06
$2H^+ + 2e^-$	**$\rightleftharpoons$**	**$H_2(g)$**	**0,00**
$S + 2H^+ + 2e^-$	$\rightleftharpoons$	$H_2S(g)$	+ 0,14
$Sn^{4+} + 2e^-$	$\rightleftharpoons$	Sn^{2+}	+ 0,15
$Cu^{2+} + e^-$	$\rightleftharpoons$	Cu^+	+ 0,16
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(g) + 2H_2O$	+ 0,17
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	Cu	+ 0,34
$2H_2O + O_2 + 4e^-$	$\rightleftharpoons$	$4OH^-$	+ 0,40
$SO_2 + 4H^+ + 4e^-$	$\rightleftharpoons$	$S + 2H_2O$	+ 0,45
$Cu^+ + e^-$	$\rightleftharpoons$	Cu	+ 0,52
$I_2 + 2e^-$	$\rightleftharpoons$	$2I^-$	+ 0,54
$O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O_2	+ 0,68
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	+ 0,77
$NO_3^- + 2H^+ + e^-$	$\rightleftharpoons$	$NO_2(g) + H_2O$	+ 0,80
$Ag^+ + e^-$	$\rightleftharpoons$	Ag	+ 0,80
$Hg^{2+} + 2e^-$	$\rightleftharpoons$	$Hg(\ell)$	+ 0,85
$NO_3^- + 4H^+ + 3e^-$	$\rightleftharpoons$	$NO(g) + 2H_2O$	+ 0,96
$Br_2(\ell) + 2e^-$	$\rightleftharpoons$	$2Br^-$	+ 1,07
$Pt^{2+} + 2e^-$	$\rightleftharpoons$	Pt	+ 1,20
$MnO_2 + 4H^+ + 2e^-$	$\rightleftharpoons$	$Mn^{2+} + 2H_2O$	+ 1,23
$O_2(g) + 4H^+ + 4e^-$	$\rightleftharpoons$	$2H_2O$	+ 1,23
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons$	$2Cr^{3+} + 7H_2O$	+ 1,33
$C\ell_2(g) + 2e^-$	$\rightleftharpoons$	$2C\ell^-$	+ 1,36
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	+ 1,51
$H_2O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	$2H_2O$	+1,77
$Co^{3+} + e^-$	$\rightleftharpoons$	Co^{2+}	+ 1,81
$F_2(g) + 2e^-$	$\rightleftharpoons$	$2F^-$	+ 2,87

Increasing reducing ability/*Toenemende reduserende vermoë*

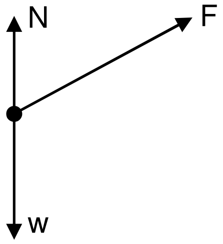
APPENDIX B: SOLVING FORCE PROBLEMS – NEWTON'S SECOND LAW OF MOTION

PROBLEM 1: *A single object moving on a horizontal plane without friction.*

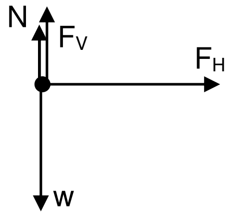
A 15 kg cement block is pulled to the right across a smooth surface with a force of 100 N, which forms an angle of 14° with the horizontal. Calculate the magnitude of the normal force and the acceleration of the cement block. The effects of friction may be ignored.

SOLUTION

Step 1: Draw a free body diagram



OR



Step 2: Identify the formula

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- In this case, the applied force acts at an angle and therefore the normal force is not just equal to the weight of the object. The magnitude of the vertical component of the applied force together with the magnitude of the normal force equals the magnitude of the weight i.e. $w = N + F\sin14°$.
- The forces in the vertical plane i.e. the normal force, weight and the vertical component of the applied force do not affect the horizontal motion. Only one force i.e. the horizontal component of the applied force, influences horizontal motion.

Step 3: Solve

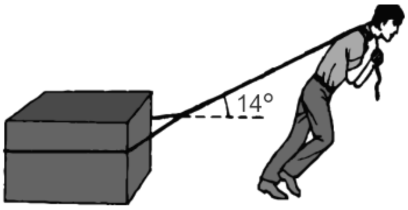
Normal force; upwards positive:
$w + N + F_v = 0$
$mg + N + F\sin14° = 0$
$-(15)(9,8) + N + 100\sin14° = 0$ (Use chosen sign convention when substituting.)
$\therefore N = 122,81$ N

Acceleration:
To the right as positive:
$F_{net} = ma$
$F\cos14° = ma$
$(100)\cos14° = 15a$
$\therefore a = 6,47 \text{ m·s}^{-2}$
$\therefore a = 6,47 \text{ m·s}^{-2}$ to the right

Step 4: Evaluate/interpret the answer
The answer is positive – it shows that the acceleration is towards the right.
The normal force is smaller than the weight due to the vertical component of the applied force.

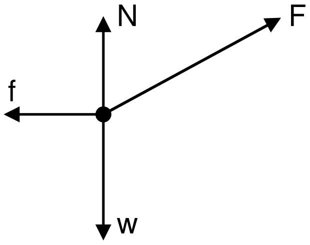
PROBLEM 2: *A single object moving in a horizontal plane with friction.*

A 15 kg cement block is pulled across the floor with a force of 100 N, which forms an angle of 14° with the horizontal. The coefficient of kinetic friction between the block and the floor is 0,4. Calculate the acceleration of the cement block.

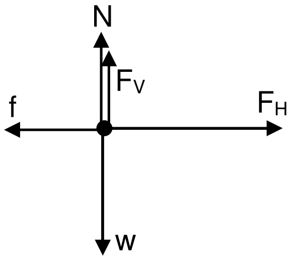


SOLUTION

Step 1: Draw a free body diagram



OR



Step 2: Identify the formula

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- In this case, the applied force acts at an angle and therefore the normal force is not equal to the weight. The magnitude of the vertical component of the applied force together with the magnitude of the normal force equals the magnitude of the weight i.e. $w = N + F\sin14°$.
- The forces in the vertical plane i.e. the normal force, weight and the vertical component of the applied force do not affect the horizontal motion. Only two forces i.e. friction and the horizontal component of the applied force, influence horizontal motion.
- Although the normal force is not asked in this question, it is needed to calculate the frictional force.

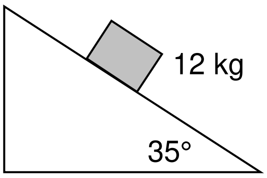
Step 3: Solve

To the right as positive:
$F_{net} = ma$
$F_H + f = ma$ (The net force is the vector sum of all the forces acting on the block.)
$F\cos14° + \mu_k N = ma$
$F\cos14° - (0{,}4)(mg – F\sin14°) = ma$ (Apply chosen sign convention when substituting.)
$100\cos14° - (0{,}4)[(15)(9{,}8) - 100\sin14°] = 15a$
$\therefore a = 3{,}19\ m{\cdot}s^{-2}$
$\therefore a = 3{,}19\ m{\cdot}s^{-2}$ to the right

Step 4: Evaluate/interpret the answer
The answer is positive – it shows that the acceleration is towards the right. The acceleration is smaller than in problem1 due to the presence of a frictional force.

PROBLEM 3: *A single object moving on an inclined plane without friction.*

An inclined surface makes an angle of 35° with the horizontal. Due to an applied force, F, parallel to the surface, the object with mass 12 kg accelerates at 1,5 $m \cdot s^{-2}$. Ignoring all frictional forces, calculate the magnitude and direction of F if the:

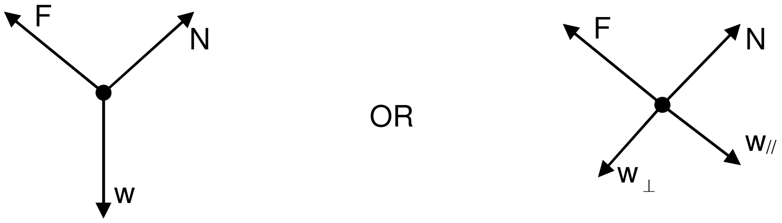


3.1 Acceleration is upwards, along the surface
3.2 Acceleration is downward, along the surface

SOLUTION

Step 1: Draw a free body diagram

3.1 To accelerate upwards, the applied force should act upwards along the inclined plane.



3.2 As above - to have an acceleration smaller than gsin35°, the applied force should act upwards along the inclined plane.

Step 2: Identify the formula
Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- Only the forces or component of forces parallel to the incline will influence motion along the incline i.e. F and mgsin35°.
- In Q3.1, the direction of the acceleration is opposite to that of the component of weight down the incline. In Q3.2 the direction of the acceleration is the same as that of the component of weight down the incline.

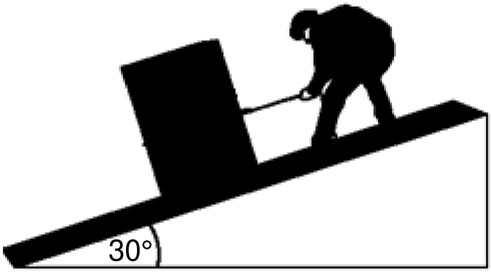
Step 3: Solve
Q3.1:
Upwards along the incline as positive:
$F_{net} = ma$
$F + w_{//} = ma$ (The net force is the vector sum of all the forces acting on the object.)
$F + mg\sin35° = ma$
$F - (12)(9,8)\sin35° = (12)(1,5)$ (Apply chosen sign convention when substituting.)
$\therefore$ F = 85,45 N
$\therefore$ F = 85,45 N upwards along the incline

Q3.2:
Upwards along the incline as positive:
$F_{net} = ma$
$F + w_{//} = ma$
$F + mg\sin35° = ma$
$F - (12)(9,8)\sin35° = (12)(-1,5)$ (Apply chosen sign convention when substituting.)
$\therefore$ F = 49,45 N
$\therefore$ F = 49,45 N upwards along the incline

Step 4: Evaluate/interpret the answer
Both answers are positive as expected – it shows that the force in both cases acts upwards parallel to the inclined plane.

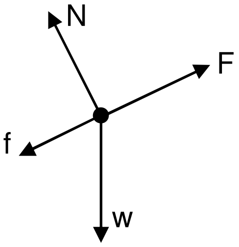
PROBLEM 4: *A single object moving on an inclined plane with friction.*

Richard pulls a crate of mass 20 kg with the help of a rope up along an inclined plane as shown. The tension in the rope is 147 N and the coefficient of kinetic friction between the crate and the inclined plane is 0,1. Calculate the acceleration of the block.

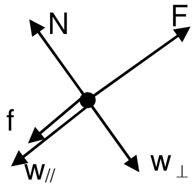


SOLUTION

Step 1: Draw a free body diagram



OR



Step 2: Identify the formula

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- The normal force is needed to calculate the frictional force. The magnitude of the normal force is equal to the magnitude of the component of weight perpendicular to the inclined plane i.e. mgcos30°.
- Three forces will influence the motion on the inclined plane i.e. f, F and $w_{//}$.

Step 3: Solve

Upward along the incline as positive:

$F_{net} = ma$

$F + f + w_{//} = ma$ (The net force is the vector sum of all the forces acting on the block.)

$F + \mu_k N + w_{//} = ma$

$F + \mu_k w_{\perp} + w_{//} = ma$

$F + \mu_k mg\cos30° + mg\sin30° = ma$

$147 - (0,1)(20)(9,8)\cos30° - (20)(9,8)\sin30° = 20a$

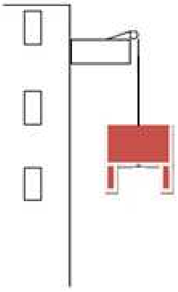
$\therefore a = 1,60\ m{\cdot}s^{-2}$

$\therefore a = 1,60\ m{\cdot}s^{-2}$ upwards along the incline

Step 4: Evaluate the answer

As expected the answer is positive i.e. the direction of motion upwards along the incline.

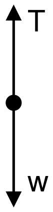
PROBLEM 5: *A single object moving in the vertical plane.*



A company needs to lift a 320 kg piano to the top floor of an apartment building. They use a rope and pulley system to pull the piano up. If the piano has an initial acceleration of 0,45 m·s^{-2}, calculate the tension in the rope.

SOLUTION

Step 1: Draw a free body diagram



Step 2: Identify the formula

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- No normal force is included in the free body diagram. The normal force is a force due to the contact between two surfaces; hence a normal force is a contact force. The piano is not resting on any surface – therefore there is no normal force.

Step 3: Solve

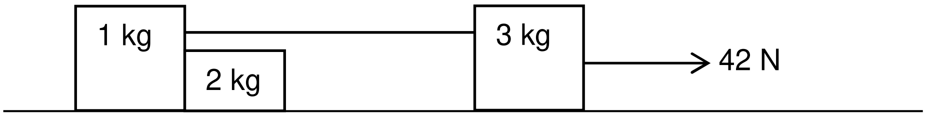
Upward as positive:
$F_{net} = ma$
$T + mg = ma$ (The net force is the vector sum of all the forces acting on the piano.)
$T - (320)(9,8) = (320)(0,45)$ (Apply chosen sign convention when substituting.)
$T = 3\ 280$ N

Step 4: Evaluate the answer

In this problem, the rope exerts an upwards force on the piano. The force by the rope needs to be large enough to support the weight of the piano (3 136 N) and to give it an upwards acceleration. So tension needs to be greater than 3 136 N.

PROBLEM 6: *Two-bodies joined by a light inextensible string, both on a flat horizontal plane without friction.*

Three blocks of masses 1 kg, 2 kg and 3 kg moves on a horizontal surface under the influence of a force of 42 N as shown. The effect of friction may be ignored.

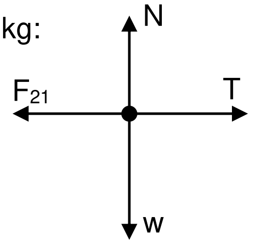


Calculate the:
6.1 Acceleration of the system
6.2 Tension in rope joining the 1 kg and the 3 kg blocks
6.3 Force exerted by the 1 kg block on the 2 kg block

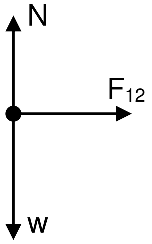
SOLUTION

Step 1: Draw a free body diagram for each block.

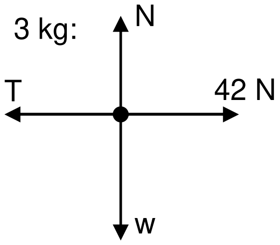
1 kg:



2 kg:



3 kg:



Step 2: Identify the formula

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- In the absence of a frictional force, the applied force is the net force acting on the system.
- To find the tension in the rope and the force exerted by the 1 kg block on the 2 kg block, each block should be isolated and Newton's second law should be applied to each block separately.

Step 3: Solve

To the right as positive:

6.1 $F_{net} = ma$
$42 = (2 + 1 + 3)a$
$a = 7\ m{\cdot}s^{-2}$ $\therefore a = 7\ m{\cdot}s^{-2}$ to the right

6.2 Consider the free body diagram of the 3 kg block; to the right as positive:
$F_{net} = ma$
$T + F = ma$
$T + 42 = (3)(7)$
$\therefore T = -21\ N$ $\therefore T = 21\ N$ to the left

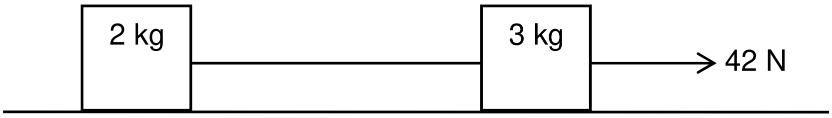
6.3 Consider the free body diagrams of the 1 kg or 2 kg blocks; to the right as positive:
For 2 kg block:
$F_{net} = ma$
$F_{12} = (2)(7) = 14$
$\therefore\ F_{12} = 14\ N$ $\therefore\ F_{12} = 14\ N$ to the right
OR
For 1 kg block:
$F_{net} = ma$
$T + F_{21} = ma$
$21 + F_{21} = (1)(7)$
$\therefore\ F_{21} = -14\ N$ $\therefore\ F_{12} = 14\ N$ to the right

Step 4: Evaluate the answer

The force exerted by the 1 kg block on the 2 kg is to the right (positive sign according to sign convention) whilst the force exerted by the 2 kg block on the 1 kg block is to the left (negative sign according to sign convention). This is in line with Newton's third law of motion.

PROBLEM 7: *Two bodies joined by a light inextensible string, both on a flat horizontal plane with friction.*

Two blocks of masses 2 kg and 3 kg, joined by a light inelastic string, move on a rough horizontal surface under the influence of a force of 42 N as shown. The coefficients of kinetic friction between the surface and the 2 kg and 3 kg blocks are 0,1 and 0,15 respectively.

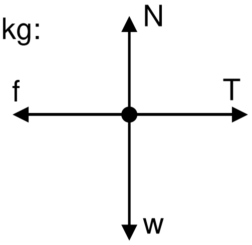


Calculate the tension in the rope joining the two blocks.

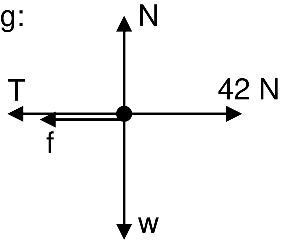
SOLUTION

Step 1: Draw a free body diagram for each block.

2 kg:



3 kg:



Step 2: Identify the formula

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- Both objects experience the same acceleration in the same direction.
- Different frictional forces act on the two blocks – therefore the frictional force on each should be calculated separately.
- To find the tension in the rope, each block should be isolated and Newton's second law should be applied to each block separately. Simultaneous equations must then be used because acceleration is unknown.

Step 3: Solve

Each block is considered separately. An equation with two unknowns is obtained for each block. T is obtained by solving these simultaneous equations.

Important: When using simultaneous equations to solve for the tension in the string joining two objects, it must be remembered that the force that the string exerts on one object is equal, but opposite in direction, to the force that the string exerts on the other object. Therefore, **when composing the two equations, the tension (T) should be given opposite signs.**

Consider the 2 kg block; to the right as positive:

$F_{net} = ma$

$T + f = ma$ (The net force is the vector sum of all the forces acting on the block.)

$T + \mu_k N = ma$

$T + \mu_k mg = ma$

$T - (0,1)(2)(9,8) = 2a$ (T acts to the right and is given a positive sign when substituting.)

$T – 1,96 = 2a$ ……………(1)

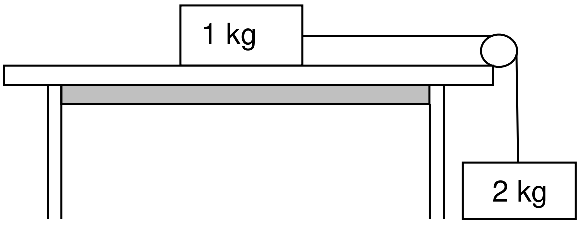
Consider the 3 kg block; to the right as positive:
$F_{net} = ma$
$T + f + F = ma$ (The net force is the vector sum of all the forces acting on the block.)
$T + \mu_k N + F = ma$
$T + \mu_k mg + F = ma$
$- T - (0,15)(3)(9,8) + 42 = 3a$ (T acts to the left and is given a negative sign when substituting.)
$- T + 37,59 = 3a$ …………(2)

Equation (1) + equation (2):
$35,63 = 5a$
$\therefore a = 7,13\ m{\cdot}s^{-2}$
$T – 1,96 = 2a$ …………….(1)
$T – 1,96 = 2(7,13)$
$\therefore T = 16,21\ N$

OR
$- T + 37,59 = 3a$ …………(2)
$-T + 37,59 = 3(7,13)$
$\therefore T = 16,21\ N$

PROBLEM 8: *Two bodies joined by a light, inextensible string, one on a horizontal plane without friction, and a second hanging vertically from a string over a light, frictionless pulley.*

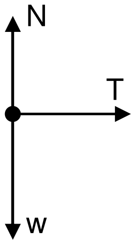
In the diagram below, a 1 kg mass on a smooth horizontal surface is joined to a 2 kg mass by a light, inextensible string running over a frictionless pulley.



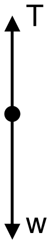
Calculate the tension in the string.

SOLUTION
Step 1: Draw a free body diagram

1 kg:



2 kg:



Step 2: Identify the formula
Points to consider:
- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- No normal force is included in the free body diagram of the 2 kg mass. The normal force is a force due to the contact between two surfaces; hence a normal force is a contact force. The 2 kg mass is not resting on any surface – therefore there is no normal force.

- The magnitude of the acceleration for both masses has the same value *a*. The directions of the accelerations are not the same. The 1 kg mass moves horizontally to the right and the 2 kg mass moves vertically downward.

Step 3: Solve
The two masses are considered separately. From the two free body diagrams, two equations with two unknowns each are obtained. T is obtained by solving these simultaneous equations.

Important: When using simultaneous equations to solve for the tension in the string joining two objects, it must be remembered that the force that the string exerts on one object is equal, but opposite in direction, to the force that the string exerts on the other object. Therefore, **when composing the two equations, the tension (T) should be given opposite signs.**

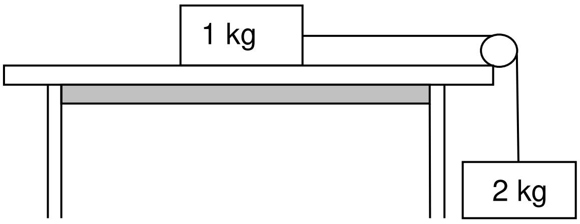
1 kg mass; to the right as positive:
$F_{net} = ma$
$T = ma$ (T acts to the right and is given a positive sign when substituting.)
$T = (1)a$
$\therefore T = a$ ……………………(1)

2 kg mass; downward as positive:
$F_{net} = ma$
$T + w = ma$
$-T + (2)(9,8) = 2a$ (T acts upwards and is given a negative sign when substituting.)
$-T + 19,6 = 2a$ …………..(2)

(1) in (2):
$-T + 19,6 = 2T$
$\therefore T = 6,53$ N

PROBLEM 9: *Two-bodies joined by a light inextensible string, one on a horizontal plane with friction, and a second hanging vertically from a string over a light, frictionless pulley.*

In the diagram below, a 1 kg mass on a rough horizontal surface is joined to a 2 kg mass by a light, inextensible string running over a frictionless pulley. The coefficient of kinetic friction between the 1 kg mass and the surface is 0,13.

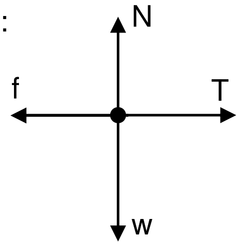


Calculate the tension in the string.

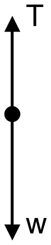
SOLUTION

Step 1: Draw a free body diagram

1 kg:



2 kg:



Step 2: Identify the formula
Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- No normal force is included in the free body diagram of the 2 kg mass. The normal force is a force due to the contact between two surfaces; hence a normal force is a contact force. The 2 kg mass is not resting on any surface – therefore there is no normal force.
- The magnitude of the acceleration for both masses has the same value *a*. The directions of the accelerations are not the same. The 1 kg mass moves horizontally to the right and the 2 kg mass moves vertically downward.
- Only the 1 kg object experiences a frictional force. Therefore two forces act on the 1 kg mass in the horizontal plane. The frictional force is calculated using the formula $f = \mu_k N$.

Step 3: Solve
The two masses are considered separately. From the two free body diagrams, two equations with two unknowns each are obtained. T is obtained by solving these simultaneous equations.

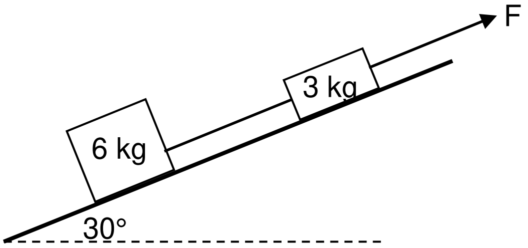
Important: When using simultaneous equations to solve for the tension in the string joining two objects, it must be remembered that the force that the string exerts on one object is equal to but opposite in direction to the force that the string exerts on the other object. Therefore, **when composing the two equations, the tension (T) should be given opposite signs.**

1 kg mass; to the right as positive:
$F_{net} = ma$
$T + f = ma$
$T + \mu_k N = ma$
$T + \mu_k mg = ma$
$T – (0,13)(1)(9,8) = (1)a$ (T acts to the right and is given a positive sign when substituting.)
$\therefore T – 1,27 = a$ ……………………(1)

2 kg mass; downward as positive:
$F_{net} = ma$
$mg + T = ma$
$(2)(9,8) -T = 2a$ (T acts upwards and is given a negative sign when substituting.)
$19,6 -T = 2a$ ……………………..(2)
(1) in (2):
$19,6 -T = 2(T – 1,27)$
$\therefore T = 7,38$ N

PROBLEM 10: *Two bodies joined by a light inextensible string, both on an inclined plane without friction.*

Two objects of mass 6 kg and 3 kg are connected by a light inelastic string. They are pulled up an inclined plane, which makes an angle of 30° with the horizontal, with a force of magnitude F. The effect of friction and the mass of the string may be ignored.

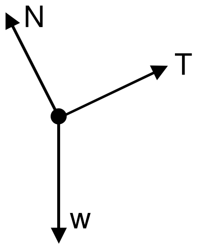


Calculate the:
10.1 Tension in the string if the system accelerates up the inclined plane at 4 $m \cdot s^{-2}$
10.2 Magnitude of F if the system moves up the inclined plane at CONSTANT VELOCITY

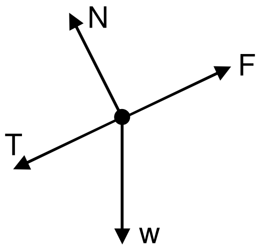
SOLUTION

Step 1: Draw a free body diagram

6 kg:



3 kg:



Step 2: Identify the formula
Points to consider:
- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- In Q10.1, the two objects experience the same acceleration. The acceleration is given and the only way to calculate the tension in the string is to consider the 6 kg object. The 3 kg object has two unknown forces i.e. F and T, acting on it.
- In Q10.2, the acceleration is zero because the objects move up the incline at constant velocity. The net force acting on the system is zero. Note that the tension in the string in this case is different from the tension in Q10.1 where the acceleration is not zero.

- The force exerted by the string on the 6 kg object is equal in magnitude, but opposite in direction to the force exerted on the 3 kg object. Therefore, when substituting, the sign of T in an equation using the 6 kg object will be opposite to that of T when using the 3 kg object.

Step 3: Solve

10.1

The two objects should be considered separately. Usually, from the two free body diagrams, two equations with two unknowns each are obtained. In this case, the acceleration is known and therefore only the 6 kg object is considered. No simultaneous equations will be used.

6 kg object; upwards along the incline as positive:

$F_{net} = ma$

$T + w_{//} = ma$

$T + mg\sin30° = ma$ (The net force is the vector sum of all the forces acting on the object.)

$T – (6)(9,8)\sin30° = 6(4)$ (Apply chosen sign convention when substituting.)

$T – 29,4 = 24$

$\therefore T = 53,4$ N

10.2

Consider the free body diagram of each object separately.

6 kg object; upwards along the incline as positive:

$F_{net} = ma$

$T + w_{//} = ma$

$T + mg\sin30° = ma$ (The net force is the vector sum of all the forces acting on the object.)

$T – (6)(9,8)\sin30° = 0$ (T on 6 kg object is upwards along incline, thus positive sign.)

$T – 29,4 = 0$

$\therefore T = 29,4$ N

3 kg object; upwards along the incline as positive:

$F_{net} = ma$

$F + w_{//} + T = ma$

$F + mg\sin30° + T = ma$ (The net force is the vector sum of all the forces acting on the object.)

$F – (3)(9,8)\sin30° - 29,4 = 0$ (T on 3 kg object is downward along incline, thus negative sign.)

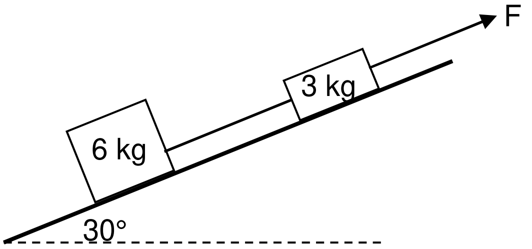
$\therefore F = 44,1$ N

Step 4: Evaluate the answer

An important observation in this problem is that the tension calculated in Q10.1 cannot be substituted when solving Q10.2. The acceleration in Q10.1 differs from that in Q10.2 and therefore the applied force F as well as the tension in the string are different.

PROBLEM 11: *Two bodies joined by a light inextensible string, both on an inclined plane with friction.*

Two objects of mass 6 kg and 3 kg are connected by a light inelastic string. The objects are pulled up an inclined plane which makes an angle of 30° with the horizontal, with a force of magnitude F. The coefficients of kinetic friction for the 3 kg object and 6 kg object are 0,1 and 0,2 respectively.The mass of the string may be ignored.



Calculate the:

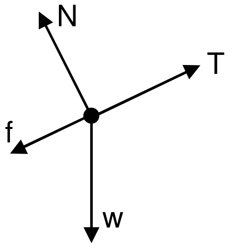
11.1 Tension in the string if the system accelerates up the inclined plane at 4 m·s^{-2}

11.2 Magnitude of F if the system moves up the inclined plane at CONSTANT VELOCITY

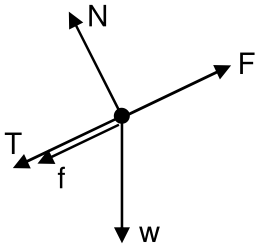
SOLUTION

Step 1: Draw a free body diagram

6 kg:



3 kg:



Step 2: Identify the formula

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- In Q11.1, the two objects experience the same acceleration. The acceleration is given and the only way to calculate the tension in the string is to consider the 6 kg object. The 3 kg object has two unknown forces i.e. F and T, acting on it.
- In Q11.2, the acceleration is zero and the objects move up the incline at constant velocity. The net force acting on the system is zero. Note that the tension in the string in this case will be different from the tension in Q11.1 where the acceleration is not zero.
- The tension in the string exerted on the 6 kg object is equal in magnitude, but opposite in direction to the tension exerted on the 3 kg object. Therefore, when substituting, the sign of T in an equation using the 6 kg object will be opposite to that of T when using the 3 kg object.
- The normal force is needed to calculate the frictional force on each object. The magnitude of the normal force is equal to the magnitude of the component of weight perpendicular to the inclined plane i.e. mgcos30°. The two objects experience different frictional forces and therefore a frictional force for each, using the normal force exerted on each, should be calculated.

Step 3: Solve

11.1

The two objects are considered separately. Usually, from the two free body diagrams, two equations with two unknowns each are obtained. In this case, the acceleration is known and therefore only the 6 kg object is considered. No simultaneous equations will thus be used.

6 kg object; upwards along the incline as positive:

$F_{net} = ma$

$T + f + w_{//} = ma$ (The net force is the vector sum of all the forces acting on the object.)

$T + \mu_k N + mg\sin30° = ma$

$T + \mu_k mg\cos30° + mg\sin30° = ma$

$T – (0,2)(6)(9,8)\cos30° - (6)(9,8)\sin30° = 6(4)$

$\therefore T = 63,58$ N

11.2

Consider the free body diagram of each object separately. Usually, from the two free body diagrams, two equations with two unknowns each are obtained. In this case, the acceleration is known and therefore the 6 kg object is used to calculate T.

6 kg; upwards along the incline as positive:

$F_{net} = ma$

$T + f + w_{//} = ma$

$T + \mu_k N_{6\ kg} + mg\sin30° = ma$

$T + \mu_k mg\cos30° + mg\sin30° = ma$

$T – (0,2)(6)(9,8)\cos30° - (6)(9,8)\sin30° = 0$

$T – 39,58 = 0 \therefore T = 39,58$ N

3 kg; upwards along the incline as positive:

$F_{net} = ma$

$F + f + w_{//} + T = ma$

$F + \mu_k N_{3\ kg} + mg\sin30° + T = ma$

$F + \mu_k mg\cos30° + mg\sin30° + T = ma$

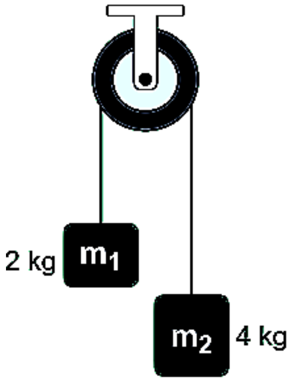
$F – (0,1)(3)(9,8)\cos30° - (3)(9,8)\sin30° - 39,58 = 0$

$\therefore F = 56,83$ N

Step 4: Evaluate the answer

Due to the presence of frictional forces, the tension in Q11.1 is greater than that in Q10.1. Also, due to the presence of frictional forces, the applied force in Q11.2 is greater than that in Q10.2.

PROBLEM 12: *Two bodies joined by a light inextensible string, both hanging vertically from a string over a frictionless pulley.*



Two blocks, one with a mass of 2 kg and the other with a mass of 4 kg, hang over a frictionless pulley on a thin, light rope.

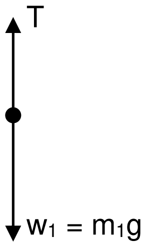
Calculate the:

12.1 Acceleration of the blocks
12.2 Tension in the rope

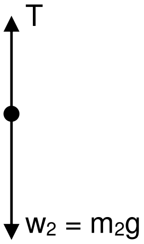
SOLUTION

Step 1: Draw a free body diagram

2 kg:



4 kg:



Step 2: Identify the formula
Points to consider:

- The key equation for any problem that relates forces and motion is Newton's second law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- Because the pulley turns easily (is frictionless), the tension in the rope is the same on both sides. Because the rope does not stretch, the magnitude of the acceleration will be the same for both blocks.
- The 2 kg block will accelerate upwards and the 4 kg block will accelerate downward.
- In problems like this one, it is convenient to consider the direction of motion as positive. The tension in the rope on the two objects will be equal in magnitude but opposite in direction.

Step 3: Solve
12.1
Consider the free body diagram of each object separately.

Important: When using simultaneous equations to solve for the tension in the string joining two objects, it must be remembered that the force that the string exerts on one object is equal to but opposite in direction to the force that the string exerts on the other object. Therefore, **when composing the two equations, the tension (T) should be given opposite signs.**

2 kg object; upwards (direction of motion) positive:
$F_{net} = ma$
$T + w_1 = m_1a$
$T + m_1g = m_1a$
$T - (2)(9,8) = 2a$ (T on 2 kg object is upwards, thus positive sign.)
$T - 19,6 = 2a$
$T = 19,6 + 2a$ ………………..(1)

For the 4 kg object, downward (direction of motion) positive:
$F_{net} = ma$
$w_2 + T = m_2a$
$m_2g + T = m_2a$
(4)(9,8) - T = 4a (T on 4 kg object is upwards, thus negative sign.)
39,2 - T = 4a
-T = -39,2 + 4a
T = 39,2 - 4a ……………….(2)

Equation (1) into equation (2):
19,6 + 2a = 39,2 - 4a $\therefore$ a = 3,27 $m \cdot s^{-2}$
The 2 kg block accelerates at 3,27 $m \cdot s^{-2}$ upwards
The 4 kg block accelerates at 3,27 $m \cdot s^{-2}$ downward.

12.2
From equation (1) for 2 kg object:
T = 19,6 + 2a
= 19,6 + 2(3,27) = 26,14 N

OR
From equation (2) for 4 kg object:
T = 39,2 - 4a = 39,2 - 4(3,27) = 26,14 N

APPENDIX C: TABLES OF POSITIVE AND NEGATIVE IONS

POSITIVE IONS					
+ 1		**+ 2**		**+ 3**	
Symbol	**Name**	**Symbol**	**Name**	**Symbol**	**Name**
H^+	hydrogen	Be^{2+}	beryllium	Al^{3+}	aluminium
Li^+	lithium	Mg^{2+}	magnesium	Fe^{3+}	iron(III)
Na^+	sodium	Ca^{2+}	calcium	Cr^{3+}	chromium(III)
K^+	potassium	Sr^{2+}	strontium	As^{3+}	arsenic(III)
Ag^+	silver	Ba^{2+}	barium	Sb^{3+}	antimony(III)
Hg^+	mercury(I)	Sn^{2+}	tin(II)	Bi^{3+}	bismuth(III)
Cu^+	copper(I)	Pb^{2+}	lead(II)		
NH_4^+	ammonium	Zn^{2+}	zinc		
H_3O^+	hydronium (oxonium)	Fe^{2+}	iron(II)		
		Hg^{2+}	mercury(II)		
		Mn^{2+}	manganese(II)		
		Ni^{2+}	nickel		
		Cd^{2+}	cadmium		
		Cr^{2+}	chromium(II)		
		Cu^{2+}	copper(II)		

NEGATIVE IONS					
– 1		**– 2**		**– 3**	
Symbol	**Name**	**Symbol**	**Name**	**Symbol**	**Name**
F^-	fluoride	O^{2-}	oxide	N^{3-}	nitride
$C\ell^-$	chloride	S^{2-}	sulphide	PO_4^{3-}	phosphate
Br^-	bromide	CO_3^{2-}	carbonate		
I^-	iodide	SO_4^{2-}	sulphate		
OH^-	hydroxide	SO_3^{2-}	sulphite		
NO_3^-	nitrate	CrO_4^{2-}	chromate		
NO_2^-	nitrite	$Cr_2O_7^{2-}$	dichromate		
CN^-	cyanide	$S_2O_3^{2-}$	thiosulphate		
HCO_3^-	hydrogen carbonate	MnO_4^{2-}	manganate		
HSO_4^-	hydrogen sulphate				
$C\ell O_3^-$	chlorate				
$C\ell O_4^-$	perchlorate				
MnO_4^-	permanganate				
IO_3^-	iodate				
CNS^-	thiocyanate				
CH_3COO^-	ethanoate (acetate)				