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It is difficult to perform experiments involving friction and thus the following statements should therefore be taken merely as approximate descriptions: 1. Friction is always parallel to the contact surface and in the opposite direction to the force tending to produce or producing motion. 2. Friction depends on the nature of the surfaces and materials in contact with each other. 3. Sliding (kinetic) friction is less than static friction (friction before the body starts to slide). 4. Kinetic friction is independent of speed. 5. Friction is independent of the area of contact. 6. Friction is proportional to the force pressing the two surfaces together. Applications of friction 1. Match stick 2. Chewing food 3. Brakes 4. Motion of motor vehicles 5. Walking Methods of reducing friction 1. Rollers 2. Ball bearings in vehicles and machines 3. Lubrication / oiling 4. Air cushioning in hovercrafts Example A wooden box of mass 30 kg rests on a rough floor. The coefficient of friction between the floor and the box is 0.6. Calculate a) The force required to just move the box b) If a force of 200 N is applied the box with what acceleration will it move? Solution a) Frictional force (F= μFn = μ(mg) = 0.6×30×10 = 180 N) b) The resultant force = 200 – 180 = 20 N From F =ma, then 20 = 30 a a = 20 / 30 = 0.67 m/s2 Viscosity This is the internal friction of a fluid. Viscosity of a liquid decreases as temperature increases. When a body is released in a viscous fluid it accelerates at first then soon attains a steady velocity called terminal velocity. Terminal velocity is attained when F + U = mg where F is viscous force, U is upthrust and mg is weight. Chapter Four Energy, Work, Power and Machines Energy This is the ability to do work. Forms of energy. 1. Chemical energy: - this is found in foods, oils charcoal firewood etc. 2. Mechanical energy: - there are two types; i. Potential energy – a body possesses potential energy due to its relative position or state ii. Kinetic energy – energy possessed by a body due to its motion i.e. wind, water iii. Wave energy – wave energy may be produced by vibrating objects or particles i.e. light, sound or tidal waves. iv. Electrical energy – this is energy formed by conversion of other forms of energy i.e. generators. Transformation and conservation of energy Any device that facilitates energy transformations is called transducer. Energy can be transformed from one form to another i.e. mechanical – electrical – heat energy. The law of conservation of energy states that "energy cannot be created or destroyed; it can only be transformed from one form to another". Work Work is done when a force acts on a body and the body moves in the direction of the force. Work done = force × distance moved by object W = F × d Work is measured in Nm. 1 Nm = 1 Joule (J) Examples 1. Calculate the work done by a stone mason lifting a stone of mass 15 kg through a height of 2.0 m. (take g=10N/kg) Solution Work done = force × distance = (15× 10) × 2 = 300 Nm or 300 J 2. A girl of mass 50 kg walks up a flight of 12 steps. If each step is 30 cm high, calculate the work done by the girl climbing the stairs. Solution Work done = force × distance = (50× 10) × (12 ×30) ÷ 100 = 500 × 3.6 = 1,800 J 3. A force of 7.5 N stretches a certain spring by 5 cm. How much work is done in stretching this spring by 8.0 cm? Solution A force of 7.5 produces an extension of 5.0 cm. Hence 8.0 cm = (7.5 ×8) / 5 = 12.0 N Work done = ½ × force × extension = ½ × 12.0 × 0.08 = 0.48 J 4. A car travelling at a speed of 72 km/h is uniformly retarded by an application of brakes and comes to rest after 8 seconds. If the car with its occupants has a mass of 1,250 kg. Calculate; a) The breaking force b) The work done in bringing it to rest Solution a) F = ma and a = v - u/t But 72 km/h = 20m/s a = (0 –20)/8 = - 2.5 m/s Retardation = 2.5 m/s Braking force F = 1,250 × 2.5 = 3,125 N b) Work done = kinetic energy lost by the car = ½ mv2 - ½ mu2 = ½ × 1250 × 202 – ½ × 1250 × 202 = - 2.5 × 105 J 5. A spring constant k = 100 Nm is stretched to a distance of 20 cm. calculate the work done by the spring. Solution Work = ½ ks2 = ½ × 100 × 0.22 = 2 J Power Power is the time rate of doing work or the rate of energy conversion. Power (P) = work done / time P = W / t The SI unit for power is the watt (W) or joules per second (J/s). Examples 1. A person weighing 500 N takes 4 seconds to climb upstairs to a height of 3.0 m. what is the average power in climbing up the height? Solution Power = work done / time = (force × distance) / time = (500 ×3) / 4 = 375 W 2. A box of mass 500 kg is dragged along a level ground at a speed of 12 m/s. If the force of friction between the box and floor is 1200 N. Calculate the power developed. Solution Power = F v = 2,000 × 12 = 24,000 W = 24 kW. Machines A machine is any device that uses a force applied at one point to overcome a force at another point. Force applied is called the effort while the resisting force overcome is called load. Machines makes work easier or convenient to be done. Three quantities dealing with machines are;- a) Mechanical advantage (M.A.) – this is defined as the ratio of the load (L) to the effort (E). It has no units. M.A = load (L) / effort (E) b) Velocity ratio – this is the ratio of the distance moved by the effort to the distance moved by the load V.R = distance moved by effort/ distance moved by the load c) Efficiency – is obtained by dividing the work output by the work input and the getting percentage Efficiency = (work output/work input) × 100 = (M.A / V.R) × 100 = (work done on load / work done on effort) × 100 Examples 1. A machine; the load moves 2 m when the effort moves 8 m. If an effort of 20 N is used to raise a load of 60 N, what is the efficiency of the machine? Solution Efficiency = (M.A / V.R) × 100 M.A = load/effort =60/20 = 3 V.R =DE/ DL = 8/2 = 4 Efficiency = ¾ × 100 = 75% Some simple machines a) Levers – this is a simple machine whose operation relies on the principle of moments b) Pulleys – this is a wheel with a grooved rim used for lifting heavy loads to high levels. The can be used as a single fixed pulley, or as a block-and-tackle system. Example A block and tackle system has 3 pulleys in the upper fixed block and two in the lower moveable block. What load can be lifted by an effort of 200 N if the efficiency of the machine is 60%? Solution V.R = total number of pulleys = 5 Efficiency = (M.A /V.R) × 100 = 60% 0.6 = M.A/ 5 = 3, but M.A = Load/Effort Therefore, load = 3 × 200 = 600 N c) Wheel and axle– consists of a large wheel of big radius attached to an axle of smaller radius. Example A wheel and axle is used to raise a load of 280 N by a force of 40 N applied to the rim of the wheel. If the radii of the wheel and axle are 70 cm and 5 cm respectively. Calculate the M.A, V.R and efficiency. Solution M.A = 280 / 40 = 7 V.R = R/r = 70/5 = 14 Efficiency = (M.A/ V.R) × 100 = 7/14 × 100 = 50 % d) Inclined plane; V.R = 1/ sin θ M.A = Load/ Effort Example A man uses an inclined plane to lift a 50 kg load through a vertical height of 4.0 m. the inclined plane makes an angle of 300 with the horizontal. If the efficiency of the inclined plane is 72%, calculate; a) The effort needed to move the load up the inclined plane at a constant velocity. b) The work done against friction in raising the load through the height of 4.0 m. (take g= 10 N/kg) Solution a) V.R = 1 / sin C = 1/ sin 300 = 2 M.A = efficiency × V.R = (72/100)× 2 = 1.44 Effort = load (mg) / effort (50×10)/ 1.44 = 347.2 N b) Work done against friction = work input – work output Work output = mgh = 50×10×4 = 2,000 J Work input = effort × distance moved by effort 347.2 × (4× sin 300) = 2,777.6 J Therefore work done against friction = 2,777.6 – 2,000 = 777.6 J e) The screw: - the distance between two successive threads is called the pitch V.R of screw = circumference of screw head / pitch = 2πr / P Example A car weighing 1,600 kg is lifted with a jack-screw of 11 mm pitch. If the handles 28 cm from the screw, find the force applied. Solution Neglecting friction M.A = V.R V.R = 2πr /P = M.A = L/ E 1,600 / E = (2π × 0.28) / 0.011 E = (1,600 × 0.011 × 7) / 22×2×0.28 =10 N f) Gears: - the wheel in which effort is applied is called the driver while the load wheel is the driven wheel. V.R = revolutions of driver wheel / revolutions of driven wheel Or V.R = no of teeth in the driven wheel/ no. of teeth in the driving wheel Example g) Pulley belts: -these are used in bicycles and other industrial machines V.R = radius of the driven pulley / radius of the driving pulley h) Hydraulic machines V.R = R2 / r2 where R- radius of the load piston and r- radius of the effort piston Example The radius of the effort piston of a hydraulic lift is 1.4 cm while that of the load piston is 7.0 cm. This machine is used to raise a load of 120 kg at a constant velocity through a height of 2.5 cm. given that the machine is 80% efficient, calculate; a) The effort needed b) The energy wasted using the machine Solution a) M.A = V.R = R2 / r2 = (7×7) / 1.4 × 1.4 = 25 Efficiency = M.A / V.R = (80 /100) × 25 = 20 But M.A = Load/ Effort = (120×10) / 20 = 60 N b) Efficiency = work output / work input = work done on load / work done by effort (80 / 100) = (120 × 10 × 2.5) / work input Work input = (3,000 × 100) / 80 = 3,750 J Energy wasted = work input – work output = 3,750 – 3,000 = 750 J Chapter Five Current Electricity Electric potential difference and electric current Electric current Electric potential difference (p. d) is defined as the work done per unit charge in moving charge from one point to another. It is measured in volts. Electric current is the rate of flow of charge. P. d is measured using a voltmeter while current is measured using an ammeter. The SI units for charge is amperes (A). Ammeters and voltmeters In a circuit an ammeter is always connected in series with the battery while a voltmeter is always connected parallel to the device whose voltage is being measured. Ohm's law This law gives the relationship between the voltage across a conductor and the current flowing through it. Ohm's law states that "the current flowing through a metal conductor is directly proportional to the potential difference across the ends of the wire provided that temperature and other physical conditions remain constant" Mathematically V α I So V /I = constant, this constant of proportionality is called resistance V / I = Resistance (R) Resistance is measured in ohms and given the symbol Ω Examples 1. A current of 2m A flows through a conductor of resistance 2 kΩ. Calculate the voltage across the conductor. Solution V = IR = (2 × 10-3) × (2 × 103) = 4 V. 2. A wire of resistance 20Ω is connected across a battery of 5 V. What current is flowing in the circuit? Solution I = V/R = 5 / 20 = 0.25 A Ohmic and non-ohmic conductors Ohmic conductors are those that obey Ohms law(V α I) and a good example is nichrome wire i.e. the nichrome wire is not affected by temperature. Non-ohmic conductors do not obey Ohms law i.e. bulb filament (tungsten), thermistor couple, semi-conductor diode etc. They are affected by temperature hence non-linear. Factors affecting the resistance of a metallic conductor 1. Temperature – resistance increases with increase in temperature 2. Length of the conductor- increase in length increases resistance 3. Cross-sectional area- resistance is inversely proportional to the cross-sectional area of a conductor of the same material. Resistivity of a material is numerically equal to the resistance of material of unit length and unit cross-sectional area. It is symbolized by ρ and the units are ohmmeter (Ωm). It is given by the following formula; ρ = AR /l where A- cross-sectional area, R – resistance, l – length Example Given that the resistivity of nichrome is 1.1x 10-6Ωm, what length of nichrome wire of diameter 0.42 mm is needed to make a resistance of 20 Ω? Solution ρ = AR /l, hence l = RA/ ρ = 20 × 3.142 × (2.1×10-4) / 1.1 × 10-6 = 2.52 m Resistors Resistors are used to regulate or control the magnitude of current and voltage flowing in a circuit according to Ohms law. Types of resistors i) Fixed resistors – they are wire-wound or carbon resistors and are designed to give a fixed resistance. ii) Variable resistors – they consist of the rheostat and potentiometer. These can be varied by sliding a metal contact to generate desirable resistance. Resistor combination a) Series combination Consider the following loop Combining those in series then this can be replaced by two resistors of 60 Ω and 40 Ω. Current through 10 Ω = (p.d. between P and R)/ (30 + 10) Ω p.d between P and R = 0.8 × Req. Req = (40 × 60)/ 40 + 60 = 2400/ 100 = 24 Ω p.d across R and P = 0.8 × 24 (V=IR) therefore, current through 10 Ω = 19.2 / 10 + 30 = 0.48 A Electromotive force and internal resistance Electromotive force (e.m.f.) is the p.d across a cell when no current is being drawn from the cell. The p.d across the cell when the circuit is closed is referred to as the terminal voltage of the cell. Internal resistance of a cell is therefore the resistance of flow of current that they generate. Consider the following diagram; The current flowing through the circuit is given by the equation, Current = e.m.f / total resistance I = E / R + r where E – e.m.f of the cell Therefore E = I (R + r) = IR + Ir = V + Ir Examples 1. A cell drives a current of 0.6 A through a resistance of 2 Ω. if the value of resistance is increased to 7 Ω the current becomes 0.2 A. Calculate the value of e.m.f of the cell and the internal resistance. Solution Let the internal resistance be 'r' and e.m.f be 'E'. Using E = V + Ir = IR + Ir For the two sets of values for I and R E = 0.6 × (2 + 0.6 r) = 1.2 + 0.36r E = 0.6 × (7 × 0.2 r) = 1.4 + 0.1 r Solving the two simultaneously, we have, E = 1.5 v and R = 0.5 Ω 2. A battery consists of two identical cells, each of e.m.f 1.5 v and internal resistance of 0.6 Ω, connected in parallel. Calculate the current the battery drives through a 0.7 Ω resistor. Solution When two identical cells are connected in parallel, the equivalent e.m.f is equal to that of only one cell. The equivalent internal resistance is equal to that of two such resistance connected in parallel. Hence Req = R1 R2 / R1 + R2 = (0.6 × 0.6) / (0.6 + 0.6) = 0.36 / 1.2 = 0.3 Ω Equivalent e.m.f =1.5 / (0.7 + 0.3) = 1.5 A Hence Current through the 0.7 Ω resistor is 1.5 A Chapter Six Waves II Properties of waves Waves exhibit many properties which can be conveniently demonstrated using the ripple tank. It consists of a transparent tray filled with water and a white screen as the bottom. On top we have a source of light. A small electric motor (vibrator) is connected to cause the disturbance which produces waves. The waves fronts represent wave patterns as they move along. Rectilinear propagation This is the property of the waves travelling in straight lines and perpendicular to the wave front. The following diagrams represent rectilinear propagation of water waves. Refraction This is the change of direction of waves at a boundary when they move from one medium to another. This occurs when an obstacle is placed in the path of the waves. The change of direction occurs at the boundary between deep and shallow waters and only when the waves hit the boundary at an angle. Diffraction of waves This occurs when waves pass an edge of an obstacle or a narrow gap, they tend to bend around the corner and spread out beyond the obstacle or gap. Interference of waves This occurs when two waves merge and the result can be a much larger wave, smaller wave or no wave at all. When the waves are in phase they add up and reinforce each other. This is called a constructive interference and when out of phase they cancel each other out and this is known as destructive interference. Interference in sound Two loud speakers L1 and L2 are connected to the same signal generator so that sound waves from each of them are in phase. The two speakers are separated by a distance of the order of wavelengths i.e. 0.5 m apart for sound frequency of 1,000 Hz. If you walk along line AB about 2m away from the speakers, the intensity of sound rises and falls alternately hence both destructive and constructive interference will be experienced. Stationary waves They are also known as standing waves and are formed when two equal progressive waves travelling in opposite direction are superposed on each other. When the two speakers are placed facing each other they produce standing waves. A rope tied at one end will still produce stationary waves. Chapter Seven Electrostatics II Electric fields An electric field is the space around a charged body where another charged body would be acted on by a force. These fields are represented by lines of force. This line of force also called an electric flux line points in the direction of the force. Electric field patterns just like in magnetic fields, the closeness of the electric field lines is the measure of the field strength. Their direction is always from the north or positive to the south or negative. Charge distribution on conductors' surface A proof plane is used to determine the charge distribution on spherical or pear-shaped conductors. For an isolated sphere it is found that the effect is the same for all points on the surface meaning that the charge is evenly distributed on all points on the spherical surface. For appear-shaped conductor the charge is found to be denser on the regions of large curvature (small radius). The density of charge is greatest where curvature is greatest. Charges on or action at sharp points A moving mass of air forms a body with sharp points. The loss of electrons by molecules (ionization) makes the molecules positively charged ions. These ions tend to move in different directions and collide producing more charged particles and this makes the air highly ionized. When two positively charged bodies are placed close to each other, the air around them may cause a spark discharge which is a rush of electrons across the ionized gap, producing heat, light and sound in the process which lasts for a short time. Ionization at sharp projections of isolated charged bodies may sometimes be sufficient to cause a discharge. This discharge produces a glow called corona discharge observed at night on masts of ships moving on oceans. The same glow is observed on the trailing edges of aircrafts. This glow in aircrafts and ships is called St. Elmo's fire. Aircrafts are fitted with 'pig tails' on the wings to discharge easily. The lightning arrestors Lightning is a huge discharge where a large amount of charge rushes to meet the opposite charge. It can occur between the cloud and the earth. Lightning may not be prevented but protection from its destruction may be done through arrestors. An arrestor consists of a thick copper strip fixed to the outside wall of a building with sharp spikes. Capacitors and capacitance A capacitor is a device used for storing charge. It consists of two or more plates separated by either a vacuum or air. The insulating material is called 'dielectric'. They are symbolized as shown below. Capacitance C = Q / V where Q- charge and V – voltage. The units for capacitance are coulombs per volt (Coul /volt) and are called farads. 1 Coul/ volt = 1 farad (F) 1 μF = 10-6 F and 1pF = 10-12 Types of capacitors are; a) Paper capacitors b) Electrolyte capacitors c) Variable capacitors d) Plastic capacitors e) Ceramic capacitors f) Mica capacitors Factors affecting the capacitance of a parallel-plate capacitor 1. Distance between the plates:- reducing separation increases capacitance but the plates should not be very close to avoid ionization which may lead to discharge. 2. Area of plates: - reduction of the effective area leads to reduction in capacitance. 3. Dielectric material between plates: - different materials will produce different capacitance effects. Charging and discharging a capacitor When the switch S1 is closed the capacitor charges through resistor R and discharges through the same resistor when switch S2 is closed. Applications of capacitors 1. Variable capacitor: - used in tuning radios to enable it transmit in different frequencies. 2. Paper capacitors: - used in mains supply and high voltage installations. 3. Electrolytic capacitors: - used in transistor circuits where large capacitance values are required. Other capacitors are used in reducing sparking as a car is ignited, smoothing rectified current and increasing efficiency in a. c. power transmission. Example A capacitor of two parallel plates separated by air has a capacitance of 15pF. A potential difference of 24 volts is applied across the plates, a) Determine the charge on the capacitors. b) When the space is filled with mica, the capacitance increases to 250pF. How much more charge can be put on the capacitor using a 24 V supply? Solution a) C = Q/ V then Q = VC, hence Q = (1.5 × 10-12) × 24 = 3.6 × 10-10 Coul. b) Mica C = 250pF, Q = (250 × 10-12) × 24 = 6 × 10-9 Coul. Additional charge = (6 × 10-9) – (3.6 × 10-10) = 5.64 × 10-9 Coul. Capacitor combination Chapter Eight Heating Effect of an Electric Current When current flows, electrical energy is transformed into other forms of energy i.e. light, mechanical and chemical changes. Factors affecting electrical heating Energy dissipated by current on work done or current flows depends on; a) Current b) Resistance c) Time Factors summarises these factors as, E = I V t or E = V2 t / R Examples 1. An iron box has a resistance coil of 30 Ω and takes a current of 10 A. Calculate the heat in kJ developed in 1 minute. Solution E = I2 Rt = 102 × 30 × 60 = 180 kJ 2. A heating coil providing 3,600 J/min is required when the p.d across it is 24 V. Calculate the length of the wire making the coil given that its cross-sectional area is 1 × 10-7 m2 and resistivity 1 × 10-6 Ω m. Solution E = P t hence P = E / t = (3,600 / 60) = 60 W P = V2 / R therefore R = (24 × 24)/ 60 = 9.6 Ω R = ρ l/ A, l = (RA) / ρ = (9.6 × 1 × 10-7) / 1 × 10-6 = 0.96 m Electrical energy and power In summary, electrical power consumed by an electrical appliance is given by; P = VI = I2 R P = V2 / R The SI unit for power is the watt (W) 1 W = 1 J/s and 1kW = 1,000 W. Examples 1. What is the maximum number of 100 W bulbs which can be safely run from a 240 V source supplying a current of 5 A? Solution Let the maximum number of bulbs be 'n'. Then 240 × 5 = 100 × 5n 'n' = (240 × 5)/ 100 = 12 bulbs. 2. An electric light bulb has a filament of resistance 470 Ω. The leads connecting the bulb to the 240 V mains have a total resistance of 10 Ω. Find the power dissipated in the bulb and in the leads. Solution Req = 470 + 10 = 480 Ω, therefore I = 240 / 480 = 0.5 A. Hence power dissipated = I2 R = (0.522 × 470 = 117.5 W (bulb alone) For the leads alone, R = 10 Ω and I = 0.5 A Therefore power dissipated = (0.5)2 × 10 = 2.5 W. Applications of heating effect of electrical current 1. Filament lamp – the filament is made up of tungsten, a metal with high melting point (3,400 0C). It is enclosed in aglass bulb with air removed and argon or nitrogen injected to avoid oxidation. This extends the life of the filament. 2. Fluorescent lamps – when the lamp is switched on, the mercury vapour emits ultra violet radiation making the powder in the tube fluoresce i.e. emit light. Different powders emit different colours. 3. Electrical heating – electrical fires, cookers e.tc. their elements are made up nichrome (alloy of nickel and chromium) which is not oxidized easily when it turns red hot. 4. Fuse – this is a short length of wire of a material with low melting point (often thinned copper) which melts when current through it exceeds a certain value. They are used to avoid overloading. Chapter Nine Quantity of Heat Heat capacity Heat is a form of energy that flows from one body to another due to temperature differences between them. Heat capacity Heat capacity is defined as the quantity of heat required to raise the temperature of a given mass of a substance by one degree Celsius or one Kelvin. It is denoted by 'C'. Heat capacity, C = heat absorbed, Q / temperature change θ. The units of heat capacity are J /0C or J / K. Specific heat capacity. S.H.C of a substance is the quantity of heat required to raise the temperature of 1 kg of a substance by 1 0C or 1 K. It is denoted by 'c', hence, c = Q / m θ where Q – quantity of heat, m – mass andθ – change in temperature. The units for 'c' are J kg-1 K-1. Also Q = m c θ. Examples 1. A block of metal of mass 1.5 kg which is suitably insulated is heated from 30 0C to 50 0C in 8 minutes and 20 seconds by an electric heater coil rated 54 watts. Find; a) The quantity of heat supplied by the heater b) The heat capacity of the block c) Its specific heat capacity Solution a) Quantity of heat = power × time = P × t = 54 × 500 = 27,000 J b) Heat capacity, C = Q / θ = 27,000 / (50 – 30) = 1,350 J Kg-1 K-1 c) Specific heat capacity, c = C / m = 1350 / 1.5 = 900 J Kg-1 2. If 300 g of paraffin is heated with an immersion heater rated 40 W, what is the temperature after 3 minutes if the initial temperature was 20 0C? (S.H.C for paraffin = 2,200 JK -1 K-1). Solution Energy = Pt = m c θ = Q = quantity of heat. P t = 40 × 180 = 7,200 J m = 0.30 kg c = 2,200, θ = ? Q = m c θ, θ = Q / m c = 7,200 / (0.3 × 2,200) = 10.9 0C 3. A piece of copper of mass 60 g and specific heat capacity 390 J Kg-1 K-1 cools from 90 0C to 40 0C. Find the quantity of heat given out. Solution Q = m c θ, = 60 × 10-3 × 390 × 50 = 1,170 J. Determination of specific heat capacity: A calorimeter is used to determine the specific heat capacity of a substance. This uses the principle of heat gained by a substance is equal to the heat lost by another substance in contact with each other until equilibrium is achieved. Heat losses in calorimeter are controlled such that no losses occur or they are very minimal. Examples 1. A 50 W heating coil is immersed in a liquid contained in an insulated flask of negligible heat capacity. If the mass of the liquid is 10 g and its temperature increases by 10 0C in 2 minutes, find the specific heat capacity of the liquid. Solution Heat delivered (P t) = 50 × 2 × 60 = 2,400 J Heat gained = m c θ = 10/1000 × c × 10 J Therefore 'c' = 2,400 / 0.1 = 24,000 J Kg-1 K-1 2. A metal cylinder mass 0.5 kg is heated electrically. If the voltmeter reads 15V, the ammeter 0.3A and the temperatures of the block rises from 20 0C to 85 0C in ten minutes. Calculate the specific heat capacity of the metal cylinder. Solution Heat supplied = heat lost, V I t = m c θ 15 × 3 × 10 × 60 = 0.5 × c × 65 c = (15 × 3 × 600)/ 0.5 × 65 = 831 J Kg-1 K-1 Fusion and latent heat of fusion Fusion is the change of state from solid to liquid. Change of state from liquid to solid is called solidification. Latent heat of fusion is the heat energy absorbed or given out during fusion. Specific latent heat of fusion of a substance is the quantity of heat energy required to change completely 1 kg of a substance at its melting point into liquid without change in temperature. It is represented by the symbol (L), we use the following formula, Q = m Lf Different substances have different latent heat of fusion. Factors affecting the melting point a) Pressure b) Dissolved substances Specific latent heat of vaporization is the quantity of heat required to change completely 1 kg of a liquid at its normal boiling point to vapour without changing its temperature. Hence Q = m Lv The SI unit for specific latent heat of vaporization is J / Kg. Example An immersion heater rated 600 W is placed in water. After the water starts to boil, the heater is left on for 6 minutes. It is found that the mass of the water had reduced by 0.10 kg in that time. Estimate the specific heat of vaporization of steam. Solution Heat given out by the heater = P t = 600 × 6 × 60 Heat absorbed by steam = 0.10 × L v Heat gained = heat lost, therefore, 600 × 6 × 60 = 0.10 × L v = 2.16 × 106 J / Kg Evaporation Factors affecting the rate of evaporation a) Temperature b) Surface area c) Draught (fan and dry surrounding) d) Humidity Comparison between boiling and evaporation Evaporation Boiling 1. Takes place at any temperature – takes place at a specific temperature 2. Takes place on the surface (no bubbles formed) – takes place throughout the liquid (bubbles formed) 3. Decrease in atmospheric pressure increases the rate –decreases as atmospheric pressure lowers Applications of cooling by evaporation a) Sweating b) Cooling of water in a porous pot c) The refrigerator Chapter Ten The Gas Laws Pressure law This law states that "the pressure of a fixed mass of a gas is directly proportional to the absolute temperature if the volume is kept constant". The comparison between Kelvin scale and degrees Celsius is given by; θ0 = (273 + θ) K, and T (K) – (T – 273) 0C. Examples 1. A gas in a container has a pressure of 1.6 × 105 Pa at a temperature of 27 0C. What will be the pressure of the gas if the container is heated to a temperature of 2770C? Solution Since we apply for Kelvin scale, convert the temperature to kelvin T1 = 270C = (273 + 27) K = 300 K T2 = 2270C = (273 + 277) = 550 K P1 / T1 = P2 / T2, therefore P2 = (1.6 × 105) × 550 / 300 = 2.93 × 105 Pa. 2. At 200C, the pressure of a gas is 50 cm of mercury. At what temperature would the pressure of the gas fall to 10 cm of mercury? Solution P1 / T = constant, P1 / T1 = P2 /T2, therefore T2= (293 × 10) / 50 = 58.6 K or (−214.4 0C) Charles law Charles law states that "the volume of a fixed mass of a gas is directly proportional to its absolute temperature (Kelvin) provided the pressure is kept constant". Mathematically expressed as follows, V1 / T1 = V2 / T2. Examples 1. A certain mass of hydrogen gas occupies a volume of 1.6 m3 at a pressure of 1.0 cm at 27 0C and normal atmospheric pressure. Calculate the new volume of the gas if it is heated to 5480C at the same pressure. Solution Using, V1 / T1 = V2 / T2, then V2 =(20 × 327) / 300 = 21.8 cm3. 2. 0.02m3 of a gas is at 27 0C is heated at a constant pressure until the volume is 0.03 m3. Calculate the final temperature of the gas in 0C. Solution Since V1 / T1 = V2 / T2, T2 = (300 × 0.03) / 0.02 = 450 K or 1770C Boyle's law Boyle's law states that "the pressure of a fixed mass of a gas is inversely proportional to the volume provided the temperature of the gas is kept constant". Mathematically expressed as, P1 V1 = P2 V2 Examples 1. A gas in a cylinder occupies a volume of 465 ml when at a pressure equivalent to 725 mm of mercury. If the temperature is held constant, what will be the volume of the gas when the pressure on it is raised to 825 mm of mercury? Solution Using, P1 V1 = P2 V2, then (725 × 465) / 825 = 409 ml 2. The volume of air 26 cm long is trapped by a mercury thread 5 cm long as shown below. When the tube is inverted, the air column becomes 30 cm long. What is the value of atmospheric pressure? Solution Before inversion, gas pressure = atm. Pressure + h p g After inversion, gas pressure = atm. pressure - h p g From Boyle's law, P1 V1 = P2 V2, let the atm. Pressure be 'x', So (x + 5) 0.26 = (x – 5)0.30 0.26x + 1.30 = 0.3x – 1.5, x = 2.8/ 0.04 = 70 cm. A general gas law Since we have the three gas laws we can then derive a general gas law as follows; P1 V1 / T1 = P2 V2 / T2 or P V / T = constant – equation of state for an ideal gas. Examples 1. A fixed mass of gas occupies 1.0 × 10-3 m3 at a pressure of 75 cmHg. What volume does the gas occupy at 17 0C if its pressure is 72 cmHg? Solution P1 V1 / T = constant so V1 = (76 × 1.0 × 10-3 × 290) / 273 ×72 = 1.12 × 10-3 m3 2. A mass of 1,200 cm3 of oxygen at 270C and a pressure 1.2 atmosphere is compressed until its volume is 600 cm3 and its pressure is 3.0 atmosphere. What is the Celsius temperature of the gas after compression? Solution Since P1 V1 / T1 = P2 V2 / T2, then T2 = (3 ×600 × 300) / 1.2 × 1,200 = 375 K or 102 0C. 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