AS Physics – Revision Notes
Unit 2 – Electricity And Thermal Physics

Electricity

1. Electric current is the rate of flow of charge:
$$Q = It$$
2. Current originates in the movement of charged particles – usually electrons around a circuit:
   a. In a conductor, free electrons drift in a negative to positive direction under the influence of an external emf (electromotive force).
   b. In an insulator no current can flow, as there are no free electrons (most non-metals).
   c. A semiconductor will produce limited numbers of electrons.
3. A potential difference in a circuit is the difference in voltage between two points
4. Ohm's law:
$$V = IR$$
5. For a filament bulb, increasing the voltage across the bulb will increase the resistance of the bulb, as the temperature of the filament increases.
6. Kirchoff's laws for electric circuits:
   a. The algebraic sum of the currents meeting at any point in a circuit is zero.
   b. In a closed electric circuit, the algebraic sum of voltages in each part of the circuit is equal to the algebraic sum of the emfs in the circuit.
7. All batteries have an inbuilt internal resistance due to the chemical processes taking place:
$$V_t = E - Ir$$
8. The maximum power from a battery is obtained when the load resistance, ***R***, is equal to the internal resistance, ***r***.
9. For the drift velocity of electrons:
$$I = nAve$$
10. Where ρ is the resistivity of the material, with units Ωm, then:
$$R = \rho \frac{l}{a}$$
11. A potential divider is basically a division of a potential difference in a circuit. The ratio of pds across resistors connected in series to a pd is equal to the ratio of resistances:
$$\frac{R_1}{R_2} = \frac{V_1}{V_2}$$
12. The resistance of a thermistor will decrease with increasing temperature.
13. The resistance of an LDR (light dependant resistor) will decrease with increasing light intensity.
14. There are three power formulae:
$$P = VI$$
$$P = \frac{V^2}{R}$$
$$P = I^2 R$$
15. A voltage is the number of joules that are converted into another energy form for every coulomb of charge supplied to the circuit.
16. There are alternative units for current and voltage:
   a. Current = Cs^{-1}.
   b. Voltage = JC^{-1}.
17. For resistors in series:
$$R_T = R_1 + R_2 + R_3 + \ldots + R_n$$
18. For resistors in parallel:
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n}$$
19. The change in resistivity in a material is proportional to the change in temperature. Where α is the temperature coefficient of resistivity for the material with units K^{-1} then:
$$\frac{R_\theta - R_0}{R_0} = \alpha\theta$$
20. Metals will have positive values for α, because the resistance increases for an increase in temperature.

21. The resistance of non-metals and semiconductors will decrease for an increase in temperature, and so α will be negative. This is called a negative temperature coefficient of resistivity.
22. For a semiconductor diode, the resistance will be close to infinity for a negative current, and will become close to zero for a positive current. The point at which the resistance changes from very high to very low will be the turning point on the graph, and is the knee voltage.

Thermal Physics

1. The heat capacity of an object is the energy needed to produce a temperature rise of 1K in the object.
2. The specific heat capacity of a substance is the thermal energy needed to raise 1kg of the substance by a temperature of 1K.
3. Energy can be calculated using:
$$E = mc\Delta T$$
4. To measure the specific heat capacity of an aluminium block:
    a. Have two holes in the block – one for a thermometer, and one for an emersion heater.
    b. Measure the voltage and current through the heater to give the power.
    c. Measure the mass of the block.
    d. Measure the temperature rise in the block, and the time taken for that temperature rise.
    e. Use a range of temperature rises and times to plot a graph.
    f. From this, $c = \dfrac{VIt}{m\Delta T} = \dfrac{VI}{m} \div \dfrac{dT}{dt}$.
5. The latent heat of fusion is the energy required to convert 1kg of a substance in its solid phase to 1kg of the substance in its liquid phase at its melting point.
6. The latent heat of vaporisation is the energy required to convert 1kg of a substance in its liquid phase to 1kg of the substance in its gaseous phase at its boiling point.
7. Energy in a state change can be calculated using:
$$E = mL$$
8. Hydraulic systems can be used to multiply forces, as liquids will transmit pressure. A small area is used to give a pressure to the liquid, which will be transferred over a larger area to give a greater force than was applied to begin with.
9. The three gas laws link temperature, pressure and volume in a gas:
    a. Boyle's Law – For a fixed mass of gas at constant temperature, the product of pressure and volume is constant, i.e. $P_1V_1 = P_2V_2$.
    b. Charles' Law – For a fixed mass of gas at constant pressure, the volume is directly proportional to the temperature, i.e. $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$.
    c. The Pressure Law – For a fixed mass of gas at constant volume, the pressure is directly proportional to the temperature, i.e. $\dfrac{P_1}{T_1} = \dfrac{P_2}{T_2}$.
10. To demonstrate Boyle's Law:
    a. A fixed mass of gas is trapped in a glass cylinder surrounded by water kept at a constant temperature.
    b. This is connected to a larger gas container, with a pressure gauge, and between the two will be oil to transmit the pressure.
    c. Air from a pump is forced into the container to increase the pressure.
    d. Time is allowed for the system to settle.
    e. Readings of pressure and volume (from a scale) are taken and plotted on a graph of P against V^{-1}. This will be linear.
11. To demonstrate the Pressure Law:
    a. A large glass sphere containing a fixed mass of gas is submerged in water. A thin glass tube connects this to a pressure gauge.
    b. The water is heated using an emersion heater.
    c. Time is allowed for the system to settle.
    d. Readings of temperature and pressure are taken and plotted on a graph of P against T. this will be linear.
12. The ideal gas equation, where the universal gas constant is R = 8.31 $\text{Jmol}^{-1}\text{K}^{-1}$:
$$PV = nRT$$

13. There are a number of different types of thermometer:
    a. A mercury thermometer is simple and cheap, but fragile and not suitable for small quantities – $T = \frac{L_\theta - L_0}{L_{100} - L_0} \times 100$.
    b. A resistance thermometer is accurate, reliable, has a wide range, and is suitable for small temperature differences, but is slow, and bad for small quantities – $T = \frac{R_\theta - R_0}{R_{100} - R_0} \times 100$.
    c. A constant volume thermometer is accurate, gives an absolute scale and has a wide range, but is bulky, slow and inconvenient.
    d. A thermistor is easy to use, but needs to be calibrated and is not very accurate.
    e. A thermocouple can measure small differences and quantities, has a wide range, and is very fast and accurate, but signal amplification is needed.
14. The kinetic theory of gases states that where $<c^2>$ is the mean square velocity of the molecules, p is the pressure of the gas, and ρ is the density of the gas:
    $$p = \tfrac{1}{3}\rho < c^2 >$$
15. The following assumptions are made in the kinetic theory of gases:
    a. An ideal gas obeys the ideal gas equation (there is no such thing as an ideal gas).
    b. The energy of the particles in the gas is all KE.
    c. All particles are identical, and interact elastically.
    d. All particles move randomly and in straight lines.
    e. There are a many particles, and their size is small compared with their separation.
    f. The gas will not liquefy – it is well above its critical temperature.
16. The distribution of molecular speeds in an ideal gas is approximately normal, but will pass through the origin and be asymptotic towards the '*x*-axis' for high speeds. Increasing the temperature will cause the curve to shift to the right and downwards.
17. Kinetic energy is given as follows, where k is Boltzman's constant (1.38×10^{-23} JK^{-1}):
    $$KE = \tfrac{3}{2}kT$$
18. The First Law of Thermodynamics states that the increase in internal energy of a system is the sum of the work done on the system and the energy supplied thermally to the system, i.e. $\Delta Q = \Delta U + \Delta W$:
    a. ΔQ is the heat energy supplied to the system.
    b. ΔU is the internal energy of the system, and is the sum of the KE and PE of every particle in the gas (for ideal gases, PE = 0, so ΔU = KE).
    c. ΔW is the work done by the gas on its surroundings. If a gas expands and pushes a piston out by x metres, then $\Delta W = P \times A \times x$ (P is the pressure of the gas, A is the piston area).
19. A heat engine is any device for converting heat into work, i.e. by doing work on its surroundings:
    a. Energy is transferred from a hot source to a cold sink through the heat engine.
    b. The heat engine converts some of this thermal energy into mechanical energy.
    c. Some heat must always be lost to the cold sink as wasted heat though, and so this process is never perfect.
20. A thermocouple converts thermal energy into electrical energy:
    a. An emf is produced depending on the difference between the hot and the cold object.
    b. Two wires of different metals are junctioned together at cold source and the hot source.
    c. Work is transferred to the circuit, in moving charges.
    d. Wasted energy will heat up the cold sink.
21. If Q_1 is the energy put into the heat engine from an object at temperature t_1, and Q_2 is the wasted energy put into an object at temperature t_2, then:
    $$\text{Efficiency} = \frac{Q_1 - Q_2}{Q_1} = \frac{t_1 - t_2}{t_1}$$
22. The efficiency depends on the temperature difference, so 100% efficiency is impossible, as t_2 would have to be at absolute zero.
23. A heat pump (e.g. a fridge) will take an input of energy into the engine, and extract heat from one object into another. For a fridge, electrical energy is used to extract heat from the interior, and eject it into the surroundings – so more energy is given to the surroundings than is put in electrically!