Question: Factors Affecting The Heating Effect Of A Current.

Planning Stage

Introduction

"Electricity can produce for effects:
HEAT: Hairdryers/kettles, LIGHT: light bulbs, SOUND: speakers, MOTION: motors.

All resistors produce heat when a current flows through them. Whenever a current flows through anything with electrical resistance then electrical energy is converted into heat energy. The more current that flows, the more heat is produced. Also, a bigger voltage means more heating, because it pushes more current through. However, the higher you make the resistance, the less heat is produced. This is because a higher resistance means less current will flow, and that reduces the heating. The amount of heat produced can be measured by putting a resistor in a known amount of water or inside a solid block and measuring the increase in temperature." (*Parsons, 2000*)

"Current flow is accompanied by the transfer of electrical energy and it is often necessary to know the rate at which a device brings about this transfer. The power of a device is the rate at which it transfers energy. If the p.d. across a device is V and the current through it is I, the electrical energy W transferred from it in time t is $W = ItV$

The power P of the device will be $P = \frac{W}{t} = \frac{ItV}{t}$

$$P = IV$$

The unit of power is the watt (W) and equals an energy transfer rate of 1 joule per second, i.e. $1W = 1J\ s^{-1}$. In the expression P=IV, P will be in watts if I is in amperes and V in volts. A larger unit is the kilowatt (kW) which equals 1000 watts.
If all the electrical energy is transformed into heat by the device it is called a 'passive' resistor and the rate of production of heat will also be called IV. The resistance is R.

$$P = IV$$
$$= \frac{V}{R} \longrightarrow \frac{V^2}{R}$$
$$= I \longrightarrow IR = I^2R$$
$$\text{So } P = IV = I^2R$$

There are thus three alternative expressions for power but the last two are only true when all the electrical energy is transferred into heat. The first, P=IV, gives the rate of production of all forms of energy. For example, if the current in an electric motor is 5A when the applied p.d. is 10V then 50W of electric power is supplied to it. However, it may only produce 40W of mechanical power, the other 10W being the rate of production of heat by the motor windings due to their resistance.

The expression $P = V^2/R$ shows that for a fixed supply p.d. of V, the rate of heat production by a resistor increases as R decreases. Now $R = pl/A$, therefore $P = V^2A/pl$ and so where a high rate of heat production at constant p.d. is required, as in an electric fire on the mains, the heating element should have a large cross-section area A, a small resistivity p and a short length l. It must also be able to withstand high temperatures without oxidizing in air (and becoming brittle). Nichrome is the material that best satisfies all these requirements.

Electric lamp filaments have to operate at even higher temperatures in order to emit light. In this case, tungsten, which has a very high melting-point (3400ºC), is used either in a vacuum or more often in an inert gas (nitrogen or argon). The gas reduces evaporation of the tungsten and prevents the vapour condensing on the inside of the bulb and blackening it. In projector lamps there is a little iodine which forms tungsten iodide with the tungsten vapour and remains as vapour when the lamp is working, thereby preventing blackening." (*Duncan, 1973*)

"An effect of electrical current is that it heats the wire through which it is flowing. If a wire of suitable resistance is chosen it will glow red-hot when the current flows, and this heating effect is used in electric ovens, cookers, fires and irons. The same effect is used in an electric light bulb, which has a length of very thin wire called a filament which is made white-hot by the current and emits light. The stronger the current, the greater the heat produced." (*Encyclopaedia Britannica*)

Possible Variables

The factors that affect the heating effect of a current are the volume of water, the mass of water, the amount of current in the heater, the insulation of the container, the charge in the heating element, the initial temperature, the amount of time the water is heated, the resistance of heater, the size of the heater and whether the water is hard or soft.

Chosen Variable

I am selecting the amount of current in the heater as my dependant variable. I am selecting current because it can be varied easily using a variable resistor or rheostat. The current will be varied but the other factors will be kept constant to ensure a fair test. (See *Workable Method* section.) It also features in these equations, which shows that it will affect the heating effect of a current.

Electrical Power = IV/I^2R

Electrical Energy = ItV/I^2Rt

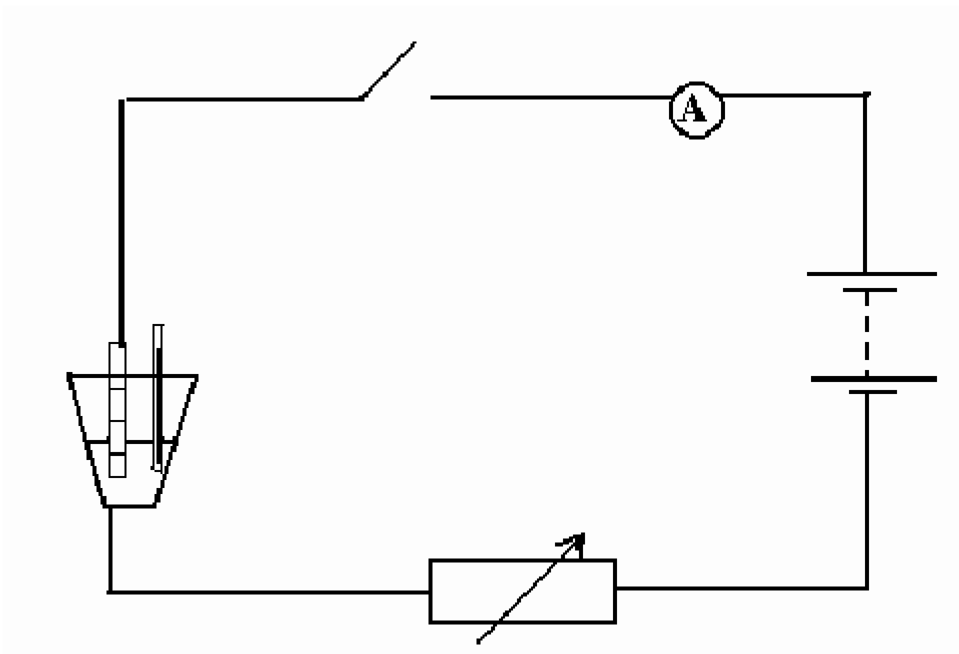
Electrical Energy Supplied = *Thermal Energy Gained*

$$ItV = mc\Delta T$$

$$\Delta T = \frac{I^2Rt}{mc}$$

ΔT = change in temperature (ºC)
m = mass of water (kg.)
c = specific heat capacity (J/kg/ºC)
R = resistance of heater (Ω ohms)
t = time (seconds)
I = current in heater (A amperes)

Diagram



Prediction

I think that as the current increases the temperature of the water increases. This is backed up by the quote, "The stronger the current, the greater the heat produced." (*Encyclopaedia Britannica*) The kinetic theory also shows that temperature will increase as the rate of reaction, in this case the current, increases. "At higher temperatures molecules gave a greater kinetic energy and move more rapidly, so they must collide more frequently – and more importantly, with greater energy." (*Lewis, Berry, 2000*) I think the temperature will have a steady rise as the current goes up. The graph should be straight. The graph below from *England, 1989* shows this.

Apparatus List

Ammeter
Power supply
Power Pack
Stopclock
Variable resistor
Heater
Thermometer
Wires
Polystyrene cup
Water
Measuring cylinder
Clamp and Stand

Workable Method

We will set up a circuit like the one in the *Diagram* section. We will connect the power pack into a socket and use the wires to connect it to the heater, variable resistor and ammeter. We will use the 19V option on the power pack. We will then hold the heater in a clamp on a stand. A polystyrene cup will then be filled with 40ml of water using a measuring cylinder to assure accuracy, hence a fair test. The heater will be lowered into the water in the cup by the clamp, making sure that the heater will not be touching any part of the cup. This is so the cup is not heated, only the water, ensuring a fair test. The thermometer will also be placed this way. The variable resistor will be set to one out of the range of nine different currents. The range we will select will be 2.0A, 2.5A, 3.0A, 3.5A, 4.0A, 4.5A, 5.0A, 5.5A and 6.0A. We will then switch on the power pack and immediately start the stopclock. After every thirty seconds we will stir the water a few times. After three minutes we will stop the stopclock, take the thermometer out and take the reading of the temperature. We will read the thermometer by getting at eyes length to it to ensure precision. We will carry this out for all the different currents and record the results in a table. We will then carry out the experiment two more times so we get three replicates. We can then take an average so our results are more accurate. We will then be able to produce a graph.

To make this a fair test, between readings we will cool the thermometer down, back to the original temperature, and we will cool the heater. We will also change the water. We will also make sure we will use the same type of cup, which is polystyrene.

Safety

Do not carry out the experiment near a sink or tap because water and electricity are dangerous when mixed. Carry out the experiment in the centre of the table, not near the edge. Bags should be put out of the way.