

1 The response time of thermistors

The following graph shows the results of an experiment set up to investigate the response time of three thermistors when they were exposed to the same sudden change in temperature. A potential divider circuit is set up so that a rise in temperature gives an increase in output p.d. across the thermistor. The thermistors at room temperature were all plunged into hot water at time $t = 0$ and the output p.d. (across the thermistor) and time were measured. A graph of the results for the first 10 seconds is shown in Fig. 1.

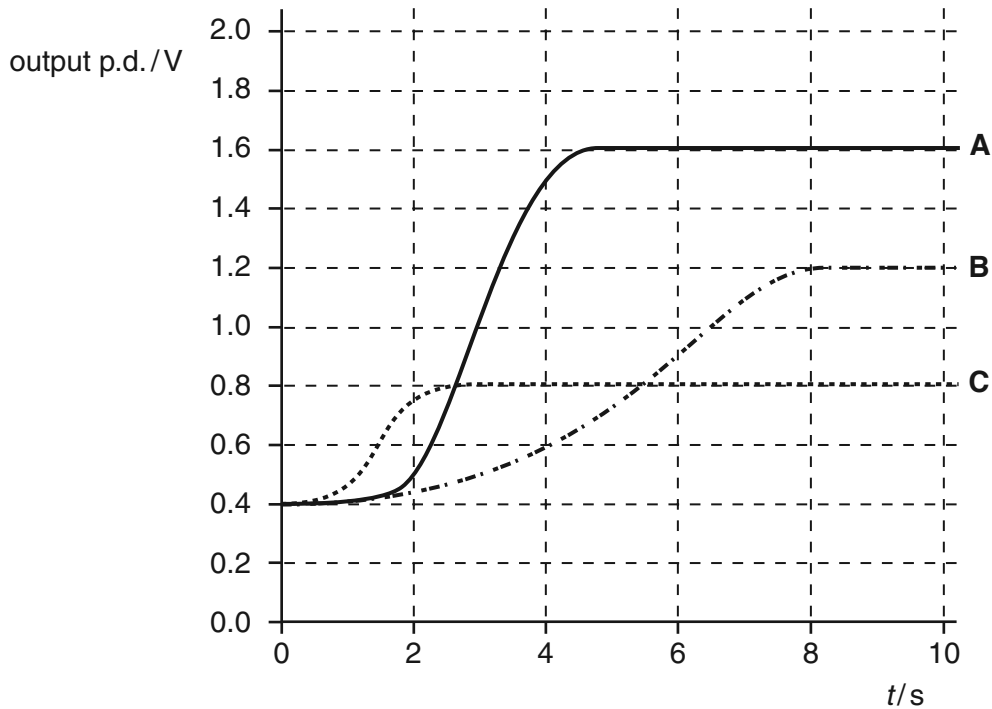


Fig. 1

These data allow both the response time and sensitivity of the thermistors to be compared.

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2 Electricity consumption in an American home

Table 1 shows the electricity consumed, for each month of the year, by an American home in the year 1996. Table 2 shows the same data four years later, for the year 2000, after changes were made to the heating system.

The house was all-electric, using only electricity as the source of power for heating in winter, cooling in summer, cooking, lighting, etc.

Month in 1996	Number of people living in house	Electricity used /kWh	Electricity used per day /kWh	Energy per person per day /kWh
Jan	4	11644	376	94
Feb	4	13784	475	119
Mar	4	12544	405	101
Apr	4	10463	349	87
May	4	5280	170	43
Jun	4	3371	112	28
Jul	4	2898	94	23
Aug	4	3567	115	29
Sep	4	1992	66	17
Oct	4	1784	57	14
Nov	4	2105	70	18
Dec	4	5975	192	48

Table 1 Electricity consumption in an American home in 1996

Month in 2000	Number of people living in house	Electricity used /kWh	Electricity used per day /kWh	Energy per person per day /kWh
Jan	3	3658	118	39
Feb	3	4681	161	54
Mar	3	3455	112	37
Apr	3	5805	194	65
May	4	3311	107	27
Jun	3	2062	69	23
Jul	3	2434	79	26
Aug	3	2253	73	24
Sep	2	1320	44	22
Oct	2	1182	38	19
Nov	2	1055	35	18
Dec	2	1462	47	24

Table 2 Electricity consumption in the same home in 2000

In 1998, the occupiers, worried that their electricity bills were too large, replaced their existing electrical heating and air conditioning system with heat pumps. A heat pump heats a house (rather like a refrigerator in reverse) by cooling the ground outside the house a little and pumping the energy extracted from the ground into the house, at a higher temperature. The reverse process operates during hot summer weather. Heat pumps can be very efficient and the occupiers hoped in this way to reduce their electricity consumption.

Tables 1 and 2 show that there were fewer people living in this house after the changeover, so perhaps some reduction should be expected anyway, for this reason. Tables 1 and 2 therefore show, as well as the total energy consumed each month, the energy consumed per person per day.

Unfortunately the monthly average temperatures for these two years were not available. Table 3 shows the average monthly temperature data over a thirty-year period, including the years in question.

Month	Thirty-year average monthly temperature / °C
Jan	-1.6
Feb	-0.3
Mar	5.5
Apr	11.9
May	17.6
Jun	22.7
Jul	24.9
Aug	23.9
Sep	20.2
Oct	13.8
Nov	6.3
Dec	0.3

Table 3 Monthly average temperatures for the environment of the home studied

The data in Tables 1 to 3 can be expressed graphically and used to explore whether the heat pumps did indeed reliably reduce energy consumption. The data are limited and could be improved.

3 Thomas Young's double slit experiment

"The experiments I am about to relate ... may be repeated with great ease, whenever the Sun shines, and without any other apparatus than is at hand to everyone."



This is how Thomas Young, speaking in 1803 to the Royal Society, began his description of his historic experiment. His audience, an august gathering of notables in science, was steeped in Isaac Newton's idea that light is made of tiny bullet-like particles, because it is always observed (or so Newton thought) to travel in straight beams, in contrast to the ripple-spreading behaviour which Christiaan Huygens had linked with wave motion. Young's talk was published in 'Philosophical Transactions'. The journal became a classic, still reprinted and read today; it gave for the first time the decisive evidence which clearly demonstrated that light has the properties of waves. This conflicted with Newton's view and gave rise to the issue of whether light behaves as a wave or a particle.

Fig. 2

"...It will not be denied by the most prejudiced," Young chided his sceptical listeners, *"that the fringes are produced by the interference of two portions of light."*

It is a little-known fact that the original, historic "double slit" experiment, demonstrating that light can be diffracted, was not done with a double slit at all. This first light interference experiment used a different method which Young claimed was so simple that it could be easily reproduced in the classroom. The double slit experiment historically came later.

A narrow beam of sunlight was split with what Young described as *"a slip of card, about one thirtieth of an inch in breadth (thickness)"* (1 inch = 2.54 cm). The slip of card was held edgewise into the sunbeam, which was made to enter the room horizontally and through a tiny hole in a "window shutter". The sunbeam had a diameter slightly greater than the thickness of the card. The card was then placed to split the beam into two slivers, one passing on each side of the slip of card.

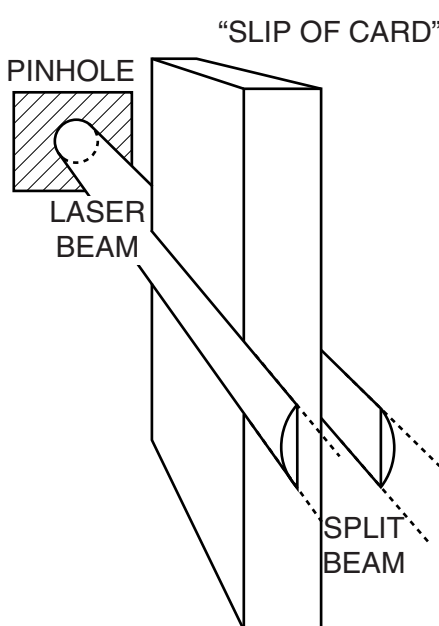


Fig. 3

You can try this experiment in the laboratory using a room-length projection distance. The card should not be reflective, or extra paths of light may be introduced confusing the interference pattern. It is also important to use a card or slip of stiff paper as thin as possible or the interference maxima will be too close together. It is possible to produce a pattern of interference fringes, with measurable separation using a laser. There are several advantages of using a laser but health and safety requirements must be followed.

Demonstration of the wave nature of light – Thomas Young's original purpose – can be achieved with this experiment, although errors in aligning the card parallel to the laser beam make accurate measurement of the wavelength difficult. The systematic error introduced by placing the card at an angle to the beam could considerably exceed the uncertainties in measurements of the fringe separation and the thickness of the card.

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