NPL

Measurement At Home

Report on ‘Candle power’

1. Overview

This challenge investigates how much energy a candle flame transforms from a chemical store into heating and lighting. The joule unit describes the amount of energy and the watt is the unit of power (where 1 watt is 1 joule transferred in 1 second).

Thank you **Alastair, Amber, Elizabeth, Gordon, Oliver and Richard** for sharing results with us in the first few weeks.

The measured total candle power ranged from 15 W to 86 W. Compare this with domestic LED lightbulbs that transfer electrical energy at a rate of between 4 W to 18 W, with 4 W lightbulbs producing much, much more visible light than a candle, and the 18 W lightbulb being the brightest lightbulb you can easily buy.

The method used was to measure the mass of candle wax used over time, and multiplying this by a number representing joules of energy transferred per gram of wax. The method assumes this number is suitable for all candles.

The range of results may be due to variations in the amount of chemical energy stored in the wax, or how different wicks burn wax at different rates.

2. Measured candle power

Candle	Experimenter	Measured total candle power (watts)	Comments
1	Amber	15	Dim brightness
2	Amber	35	Middle brightness
3	Gordon	43	Tea light
4	Richard	46	Candle in third hour
5	Elizabeth	48	
6	Oliver	48	(measured two candles)
7	Oliver	48	(measured two candles)
8	Alastair	54	
9	Amber	57	Brightest of 3 candles
10	Gordon	64	Advent candle
11	Richard	74	Candle in first hour
12	Richard	86	Candle in second hour

Looking at the results in the table:

- Amber commented on the brightness of her candles (1, 2 and 9) which are also in the same order as the measured power – which makes sense.
- Richard reported results from one candle for hours 1, 2 and 3. It did not burn at a constant rate – it was very dim in the final hour.
- There is a surprisingly large range in results showing that to have a ‘standard’ candle we must carefully control the type of wax and the wick.

3. Specific Energy

Specific energy describes how many joules of energy are available from a given mass of substance and has units joules per kilogram (j/kg), or kilojoules per gram (kj/g).

This activity was inspired by an entertaining lecture called ‘Christmas Candles’ (https://youtu.be/HcdlksvHWZs). The speaker (NPL scientist Michael de Podesta) describes how candles typically contain ten times more energy than a stick of dynamite, and more energy than 250 AA batteries. Of course, (in contrast to dynamite) they transfer chemical energy to heating and lighting very, very slowly, which Michael describes using the word: “booooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooom”

The table below compares the specific energies of candle wax (item 5) with other substances.

Item	Substance	Application	Specific energy (kJ/g)
1	Deuterium	Fusion reactor	570 000
2	Uranium	Nuclear power station (breeder reactor)	81 000
3	Hydrogen gas	Fuel in a hydrogen powered car	142
4	Petrol	Vehicle fuel	46
5	**Candle wax**	**This investigation**	**43**
6	Cow dung	Fuel (burning)	16
7	Chocolate	Food	22
8	Dynamite	High explosive	4
9	Lithium Ion Battery	Mobile phone	2.5
10	NCA batteries	Vehicles	1

The table values are for indication only as they depend much on substance purity and the method of energy release and use. They show – in our energy demanding lifestyle – why people:

- are so excited about fusion reactors which have been in experimental stage for many years (item 1)
- have used petrol fuelled vehicles for many years (item 4)
- argue about using hydrogen or battery powered electric cars (items 3 and 10)
- use readily available cheap energy sources like cow dung (item 6).

4. What is meant by energy efficient lighting?

The proportion of energy candles transfer to light is tiny compared with electric light bulbs. Over the years people have introduced new technologies that use less and less electrical power to make light:

Light bulb type	How it works	Efficacy (lumens of light produced per watt of electricity)
Incandescent	Electric current heats a thin metal filament to about 3000 °C (white hot)	12
Fluorescent tube	Electric current transfers energy to mercury vapour causing narrow spectral bands of radiation to be emitted, some of which is converted to visible light using fluorescent chemicals	60
Light emitting diode (LED)	Semiconductor materials convert electrical power to heat and light	69

Less electricity being used in lighting means less environmental pollution. Also, the LEDs (if used properly) last longer than the other technologies (less landfill) and contain less harmful waste products than fluorescent tubes so as well as cheaper running costs, they are ‘greener’.

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