On thermal energy

A.C. Norman
ACN.Norman@radley.org.uk

Questions 4 & 5 are adapted from *Ordinary Level Physics*, A.F. Abbott; questions 6–10 are adapted from *Thermal Physics*, C.J. Adkins.

Warm-up problems

1. Define *heat capacity* and *heat of vaporization*.
2. *Specific* is a word that crops up in a number of places in physics, e.g. specific latent heat, specific charge, specific gravity, specific heat capacity. What does it mean?
3. What is mean by the term 'specific latent heat of fusion'? What does *latent* mean and why is it used in this phrase?

Regular problems

4. (a) How much heat is given out when a piece of iron of mass 50 g and specific heat capacity 460 J/kg K cools from 80 °C to 20 °C?
   (b) What is the specific heat capacity of gold if 108 J is required to raise the temperature of 9 g of the metal from 0 °C to 100 °C?
   (c) i. 160 g of molten silver at its melting point, 960 °C, is allowed to solidify at the same temperature and gives out 16 800 J of heat. What is the specific latent heat of silver?
   ii. If the mean specific heat capacity is 230 J/kg K, how much additional heat does it give out in cooling to −40 °C?
5. (a) Calculate the quantity of heat required to melt 4 kg of ice and to raise the temperature formed to 50 °C. Take the specific latent heat of ice to be 3.4×10^5 J/kg and the specific heat capacity of water to be 4200 J/kg K
   (b) Why are pieces of ice at 0 °C, added to a drink at room temperature, more effective in cooling the drink than an equal mass of water at 0 °C?
6. Criticize the following statement:

   > The heat capacity of a body is a measure of how much heat the body can hold.

7. (a) A shower is supplied with hot water by a unit in which the water is heated electrically as it flows through from the water main to the shower. What is the maximum rate at which the hot water can be supplied if the heater is rated at 7 kW, the temperature of the water from the mains is 5 °C and the temperature of the shower water is to be 45 °C?

   (b) $7 \times 10^{-2}\,\mathrm{m}^3$ of hot water at 60 °C are run into a bath. How much cold water at 7 °C has to be added to lower the temperature to 42 °C? (Neglect the heat capacity of the bath.)

8. An electric kettle of negligible thermal capacity and fitted with a 2.6 kW heating element contains $1.7 \times 10^{-3}\,\mathrm{m}^3$ of water at 10 °C

specific heat capacity of water	$4200\,\mathrm{J\,kg^{-1}\,K^{-1}}$
latent heat of vaporization of water	$2.3 \times 10^6\,\mathrm{J\,kg^{-1}}$

   (a) How long will it take for the kettle to come to the boil?

   (b) How long will it take for the kettle to boil dry?

Extension problems

9. A 10 W electric heater of negligible thermal capacity is inserted into an unlagged metal block which is initially at room temperature. When the heater is switched on, the block warms up and eventually reaches a steady temperature. The heater is then switched off and the block cools at an initial rate of $1.5\,^\circ\mathrm{C\,min^{-1}}$.

   (a) What is the heat capacity of the metal block?

   (b) What was the initial rate of rise of temperature when the heater was first switched on?

10. A copper cylinder of mass 2.0 kg and radius 30 mm is attached coaxially to the horizontal shaft of an electric motor. A cord is wound a few times around the cylinder. One end is attached to a spring balance and the other supports a mass of 0.1 kg. The electric motor is run at 3000 rpm for one minute, during which time the spring balance registers 6.9 kg. At the end of the minute the temperature of the copper is found to have risen by 47 K. Estimate the specific heat capacity of copper. What assumptions are you making?