Some Heat Revision Questions:

1. Block A is twice the size of block B
   a. block A has twice as much energy as block B
   b. neither, as both are the same temperature, both has the same average kinetic energy
   c. A as this has more potential energy than B
   d. From B to A as heat flows from hotter to cooler
   e. B as it is now hotter

2. a. 35 + 273 = 308 K   b. 123 – 273 = -150^{0}C

3. Convection is mass movement of particles in a substance from a more dense to a less dense area. Particles in a solid are fixed in position and therefore large numbers of the particles can't move to a less dense area.

4. Radiation is energy travelling in waves and can travel through a vacuum so doesn't need particles for the heat to be transferred. Conduction and convection, on the other hand, do need particles.

5. Radiation – all hot bodies radiate heat and humans are usually hotter than the surroundings.
   Convection – the human body heats the air around it and this heated air rises up
   Conduction – the very thin layer of air which touches the human body is heated from the body by contact and this is conduction.

   Evaporation calls by phase change of liquid on body
   a. body sweats (liquid on skin)
   b. sweat evaporates
   c. evaporation is a phase change which needs energy (latent heat)
   d. energy taken from the body so the body cools.

6. All has to do with conduction. Carpet is a poor conductor and while some of the heat from your hand will go to the top of the carpet, it can't conduct away so the heat stays around your hand and it doesn't feel cold. The tiles, on the other hand, are good conductors of heat. When your hand is on the tiles, the heat goes into the tile and is conducted away from the surface. This transfer continues until the tile and your hand reach the same temperature, which is much lower than the initial temperature of your hand so your hand feels cold.

7. When steam hits your body, the steam must condense which releases latent heat into your body, this is a great deal of energy. Once the steam has condensed, it is now water at 100^{0}C and it then releases heat to your hand to cool. So while the water and steam may be the same temperature, the steam releases more energy as it must first change phase to water.

8. N/A

9. 750 g of water at 80.0^{0}C is cooled to 10.0^{0}C. How much heat energy is removed?

$$\begin{aligned}\mathbf{Q} &= \mathbf{mc\Delta T}\\ &= \mathbf{0.75 \times 4180 \times (80 - 10)}\\ &= \mathbf{219450}\\ \mathbf{Q} &= \mathbf{2.2 \times 10^5\ J}\end{aligned}$$

10. The human body can secrete a maximum of 700 mL of sweat per hour. How much energy will this remove from the body?

$$\begin{aligned}\mathbf{Q} &= \mathbf{mL}\\ &= \mathbf{0.7 \times 2.26 \times 10^6}\\ &= \mathbf{1582000}\\ \mathbf{Q} &= \mathbf{1.6 \times 10^6\ J}\end{aligned}$$

11. 0.50 kg of ice at –15.0^{0}C is heated to steam at 105^{0}C. How much heat energy is added to the ice?

$$\begin{aligned}\mathbf{Q} &= \textbf{heat ice } (\mathbf{\Delta T = 15}) + \textbf{melt ice} + \textbf{heat water } (\mathbf{\Delta T = 100}) + \textbf{boil water} + \textbf{heat steam } (\mathbf{\Delta T = 5})\\ &= \mathbf{(0.5 \times 2100 \times 15) + (0.5 \times 3.34 \times 10^5) + (0.5 \times 4180 \times 100) + (0.5 \times 2.26 \times 10^6) + (0.5 \times 2000 \times 5)}\\ &= \mathbf{15750 + 16700 + 209000 + 113000 + 5000}\end{aligned}$$

$Q = 509750$
$Q = 5.1 \times 10^5$ J

12. 0.25 kg of water at 100^{0}C is placed in an insulated glass cup of mass 0.40 kg which is at 20.0^0. What is the specific heat of the glass cup if the final temperature is 80.0^{0}C?

Heat lost = heat gained
0.15 kg water = 0.4 kg glass
$\Delta T = (100 - 80)$ $\Delta T = (80 - 20)$
$mc\Delta t$ (water) = $mc\Delta T$ (glass
$0.25 \times 4180 \times 20 = 0.4 \times c \times 60$
$20900 = 24c$
$c = 871$ J kg kg^{-1} K^{-1}

13. 34.0 g of steel at 355^{0}C is placed in a large insulated copper calorimeter (mass 500 g) which contains water at a temperature of 10^{0}C. The final temperature of the water and steel is 15.0^{0}C. What mass of water was in the calorimeter?

Heat lost = heat gained
0.034 kg steel = 0.5 kg copper + x kg water
$\Delta T = (355 - 15)$ $\Delta T = (15 - 10$ $\Delta T = (15 - 10)$
$= 340$ $= 5$ $= 5$

$(mc\Delta T)$ steel = $(mc\Delta T)$ copper + $(mc\Delta T)$ water
$0.034 \times 445 \times 340 = (0.5 \times 390 \times 5) + (m \times 4180 \times 5)$
$5144.2 = 962.5 + 20900m$
$4181.7 = 20900m$
$m = 0.20$ kg

14. Ice at -10.0^{0}C is placed in an insulated aluminium container which has a mass of 90.0 g. The container contains 50.0 mL of water and both are at a temperature of 80.0^{0}C. How much ice is needed to bring the temperature down to 50.0^{0}C?

Heat lost = heat gained
Cool 0.09 kg Al + cool 0.05 kg water = ice + melt ice + heat water
ΔT for both = 80 – 50 = 30 $\Delta T = 10$ $\Delta T = 50$

$(0.09 \times 900 \times 30) + 0.05 \times 4180 \times 30) = (m \times 2100 \times 10) + (m \times 3.34 \times 10^5) + (m \times 4180 \times 50)$
$2430 + 6270 = 21000m + 334000m + 20900m$
$8700 = 564000m$
$m = 0.0154$

$m = 1.54 \times 10^{-2}$ kg.

15. An insulated copper calorimeter (mass 43.0 g) contains 40.0 mL of water at a temperature of 65.0^{0}C. 15.0 g of ice at -15.0^{0}C is added to the water and the mixture stirred until the ice has dissolved. What is the final temperature of the water?

Heat lost = heat gained
0.043 kg copper + 0.04 kg water = 0.015 kg ice + melt ice + heat ice
$(0.043 \times 390 \times (65 - T_f)$ + $(0.04 \times 4180 \times (65 - T_f)$ = $(0.015 \times 2100 \times 15) + (0.015 \times 3.34 \times 10^5)$
$+ (0.015 \times 410 \times T_f)$
$1076.075 - 16.77T_f + 10868 - 167.2T_f = 472.5 + 5010 + 62.7\ T_f$
$1076.075 + 10868 - 472.5 - 5101 = 16.77Tf + 167.2T_f + 62.7T_f$
$6461.575 = 246.67\ T_f$
$T_f = 26.2^0C$

Written Type questions:

1. Heat — flow of energy from a hotter to a cooler body.
   Temperature — measure of the average kinetic energy of a body
   Internal energy — potential and kinetic energy a body contains.

2. The raised hair traps air within it. Air is a good insulator and helps prevent the flow of heat from the cat's body to the cooler temperature of the room.

3. This is evaporation:
   a. tongue has moisture on it.
   b. Moisture evaporates into the air
   c. In evaporating, there is a change in phase as liquid goes to gas.
   d. Change of phase need energy and this energy is taken from the tongue.
   e. Cooler tongue cools the blood vessels in the tongue which in turn cool the body of the dog

4. Water has a very high specific heat which means that it takes a lot of energy to change the temperature of water by one degree Celsius. This then means that as a liquid in a cooling system, it will take a lot more energy from the engine before it changes temperature.

5. Two reasons for this, but the second causes the greater temperature change.
   a. Spraying can causes the pressure to decrease of gas leaves container. A decrease in pressure (without a change in volume) causes a lowering of the temperature.
   b. The substance in the can exists both as a liquid and as a vapour in the can. When the aerosol is sprayed, some of the substance leaves as vapour and therefore the vapour pressure of the can is reduced. This means that some of the liquid will then turn into vapour and to do this it needs energy. The energy is taken from the liquid, the can and your hand and so the can feels cooler.

6. All has to do with conduction. Carpet is a poor conductor and while some of the heat from your feet will go to the top of the carpet, it can't conduct away so the heat stays around your feet and they don't feel cold. The tiles, on the other hand, are good conductors of heat. When your feet are on the tiles, the heat goes into the tile and is conducted away from the surface. This transfer continues until the tile and your feet reach the same temperature, which is much lower than the initial temperature of your feet so your feet feel cold.

Short answer type questions:

1. A 100 g lump of copper (c = 390 J kg^{-1} K^{-1}) has 6.0 x 10^3 J of energy added to it. If it was initially at 20^0C, what is its final temperature?

$$\mathbf{Q = mc\Delta T}$$
$$\mathbf{6 \times 10^3 = 0.1 \times 390 \times (T_f - 20)}$$
$$\mathbf{6 \times 10^3 = 39 \times (T_f - 20)}$$
$$\mathbf{153.85 = T_f - 20}$$
$$\mathbf{T_f = 174^0C}$$

2. An emersion heater heats 2.5 L of water which was initially at 15^0C. If it takes 3.5 minutes to bring the water to boiling point (100^0C), at what rate (in joules per second) is the water gaining heat energy?

Q = mcΔT
= 2.5 x 4180 x 85
= 888250 J per 3.5 minutes

per second = $\frac{888250}{(3.5 x 60)}$
= 4.23 x 10^3 Js^{-1}

3. 0.5 kg of water at 20^0C is all boiled away to steam at 100^0C. How much heat energy is required?

Q = heat water + boil water
$$Q = (0.5 \times 4180 \times 80) + (0.5 \times 2.26 \times 10^6)$$
$$Q = 167200 + 1130000$$
$$Q = 1297200$$
$$Q = 1.3 \times 10^6 \text{ J}$$

4. How much ice at 0^0C must be added to 250 mL coffee in an insulated cup (assume no loss of heat to the container) to cool the coffee from 95^0C to 65^0C (use $c = 4.18 \times 10^3$ J kg^{-1} K^{-1} for coffee)?

Heat lost = heat gained
$$(0.25 \times 4180 \times [95 - 65]) = (m \times 3.34 \times 10^5) \times (m \times 4180 \times 65)$$
$$31350 = 3.34 \times 10^5 m + 271700m$$
$$31350 = 605700m$$
$$m = 5.18 \times 10^{-2} \text{ kg}$$

5. In a factory, a machine you are using applies a force of 8000 N to push a 30 kg lump of steel ($c = 445$ J kg^{-1} K^{-1}) 10 m across the factory floor. If the stainless steel was initially at 20^0C, what is its new temperature after you have pushed it across the floor?

W = Fs
$$= 8000 \times 10$$
$$= 80000 \text{ J}$$

now work is energy so Q = mcΔT
$$80000 = 30 \times 445 \times (T_2 - 20)$$
$$80000 = 13350 (T_2 - 20$$
$$5.992 = T_2 - 20$$
$$T_2 = 25.992$$
$$T_2 = 26^0 \text{ C}$$

Problem Solving type questions:

1. How much heat energy is needed to change 1.0 kg ice at -5^0C to steam at 100^0C?

Q = heat ice + melt ice + heat water + boil water
$$Q = (1 \times 2100 \times 5) + (1 \times 3.34 \times 10^5) + (1 \times 4180 \times 100) + (1 \times 2.26 \times 10^6)$$
$$Q = 10500 + 334000 + 418000 + 2260000$$
$$Q = 3022500$$
$$Q = 3.02 \times 10^6 \text{ J}$$

2. An insulated calorimeter of mass 41 g has 100 mL of water at 15^0C placed in it. 50 g of iron is heated to 160^0C then carefully lowered into the water. What would be the final temperature of the water? ($c_{iron} = 477$ J kg^{-1} K^{-1}, $c_{copper} = 385$ J kg^{-1} K^{-1}).

Heat lost = heat gained

50g iron = 41g copper + 100g water

$\Delta T = (160 - T_f)$ $\qquad$ $\Delta T = T_f - 15$

$$0.05 \times 440 \times (160 - T_f) = (0.041 \times 390 \times (T_f - 15)) + (0.1 \times 4180 \times (T_f - 15))$$
$$3520 - 22T_f = 15.99T_f - 239.85 + 418T_f - 6279$$
$$3520 + 239.85 + 6279 = 15.99T_f + 22T_f + 418T_f$$
$$10038.85 = 455.99T_f$$
$$T_f = 22^0\text{C}$$

3. A block of an unknown alloy, mass 6 kg, at 25^0C, is placed in an insulated copper calorimeter, mass 10 kg, containing 2 kg of water at 15^0C. If the resulting temperature is 18^0C, what is the specific heat of the unknown alloy?

Heat lost = heat gained

6kg alloy = 10kg copper + 2kg water

ΔT = 7 $\qquad\qquad$ ΔT = 3

$$6 \times c \times 7 = (10 \times 390 \times 3) + (2 \times 4180 \times 3)$$
$$42c = 11700 + 25080$$
$$42c = 36780$$
$$c = 876 \text{ J kg}^{-1} \text{ K}^{-1}$$

4. An insulated aluminium calorimeter with a mass of 154 g, contains 90 mL of water at a temperature of 80^0C. 10 g of ice at -20^0C is added to the water and the mixture stirred until the ice has dissolved. What is the final temperature of the water? (specific heat aluminium = 880 $Jkg^{-1}K^{-1}$)

Heat lost = heat gained

$$(0.154 \times 900 \times (80 - T_f)(+ (0.09 \times 4180 \times (80 - T_f)) = (0.01 \times 2100 \times 20) + (0.01 \times 334000) + (0.01 \times 4180 \times T_f)$$
$$11088 - 138.6\, T_f + 30096 - 376.2\, T_f = 420 + 3340 + 41.8T_f$$
$$11088 + 30096 - 420 - 3340 = 138.6\, T_f + 376\, T_f + 41.8T_f$$
$$37424 = 556.4\, T_f$$
$$T_f = 67^0 \text{ C}$$