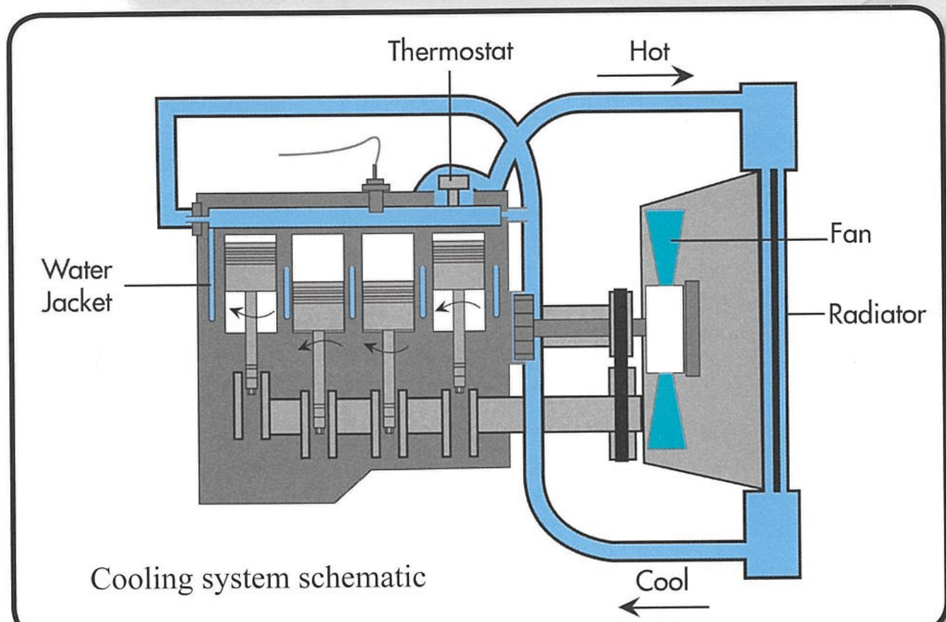
Heating Processes Context 1: Heating and Cooling in Motor Vehicles

Motor vehicles use internal combustion engines. Internal combustion means that a fuel, usually a hydrocarbon such as petrol or diesel oil, burns inside the engine. As fuel molecules react with oxygen molecules, they release a great deal of energy.
The engine absorbs most of this energy as thermal energy. Each time the air-fuel mixture burns in a combustion chamber, the temperature of the gases in the chamber may briefly reach 2200 °C. Normal operating temperatures for most engines range between 80 °C and 95 °C. To prevent overheating, the engine needs mechanisms to help it lose excess thermal energy,

The vehicle's cooling system transfers excess heat from the engine to its surroundings. It must keep the engine at or near its most efficient operating temperature under all weather conditions. The cooling system must also let the engine reach its optimum temperature as quickly as possible after starting.



Cooling system schematic

There are two main types of cooling systems; liquid cooling and air cooling. In either case, a fluid coolant circulates around the hot engine parts, absorbing heat and so cooling the engine. Note that 'fluid' means 'able to flow' and includes both gases and liquids.
Most car and boat engines are liquid cooled. Air cooling is more common in motor cycles, lawn mowers and aeroplanes, although a few car manufacturers use air cooled engines.
Some high-performance engines use evaporative cooling. This process loses coolant to the atmosphere.

The energy produced when the fuel-air mixture burns all ends up as thermal energy in the car's surroundings. However, some of this energy does useful work in the process, to push the pistons down and make the vehicle move. About one third of the total energy released when the fuel burns leaves the engine in the hot exhaust gases. These enter the atmosphere through the exhaust pipe, and we have no way to use the wasted energy that they take with them.
The car uses another third of the energy released by the burning fuel to overcome friction and air resistance. Half of this energy, or one sixth of the total, overcomes friction in the car's moving parts, such as the shafts that connect the engine to the wheels.
The energy needed to overcome air resistance and friction with the road is about one sixth of the total available from the fuel. This is the useful output of the engine that propels the car along the road.
Parts of the engine, such as the cylinder walls, pistons, and cylinder head, absorb most of the remaining third as thermal energy.

Without a cooling system, the engine temperature would increase rapidly, leading to a variety of problems. If some part of an engine gets too hot, its oil film no longer protects it. Such parts wear quickly.
Very high temperatures may soften some components and may crack others. Some engine parts would melt. Eventually the pistons would expand so much they could not move in the cylinders; they would seize.
Conversely, an engine running at too low a temperature is inefficient. Some of the unburnt carbon from fuel burning at a too-low temperature remains in the engine. The circulating oil picks up some of this carbon, increasing wear and reducing the engine power. Dirty oil also moves solid residues around the engine, creating deposits in previously clean places. This increases both fuel consumption and exhaust emissions.
Thus, the cooling system only starts working when the engine temperature is high enough for efficient running.

Questions:

1. A 200 kg metal engine's temperature increases by 60 °C.
   [a] Calculate the heat absorbed by the engine if it is made of aluminium.
   [b] Calculate the heat absorbed by the engine if it is made of cast iron.
   [c] Based on your answers to the previous questions, which of these would be easier to cool? Explain.

2. The useful power output of a steel engine is 100 kW.
   [a] Estimate the rate at which energy is being released by the fuel. Show all your working and list any assumptions you make.
   [b] Estimate the amount of thermal energy absorbed by the engine in a 10 minute period. Show all your working and list any assumptions you make.
   [c] Hence, estimate the temperature rise of the engine in this 10 minute period, if the engine cooling system stopped working. Show all your working and list any assumptions you make.

3. A 200 kg aluminium engine at 95 °C is cooled by 2.00 kg of ethylene glycol that is initially at 25 °C. Calculate the final temperature of the engine and coolant.

4. [a] Calculate the energy absorbed by 10 kg water heating from 20 °C to 100 °C.
   [b] Calculate the energy absorbed by 10 kg of water boiling at 100 °C.
   [c] Why is evaporative cooling rarely used in motor vehicles?

5. The graph (right) shows the 'cooling curve' for 1.00 kg of naphthalene. Naphthalene is a liquid at 100 °C. Use the curve, and any necessary calculations, to determine:
   [a] The freezing point of naphthalene;
   [b] The specific heat capacity of liquid naphthalene;
   [c] The latent heat of fusion of naphthalene;
   [d] Whether the specific heat capacity of solid naphthalene is less than, equal to or greater than the specific heat capacity of liquid naphthalene.
   [e] Naphthalene is not used as a coolant in motor vehicles. Suggest a reason why.