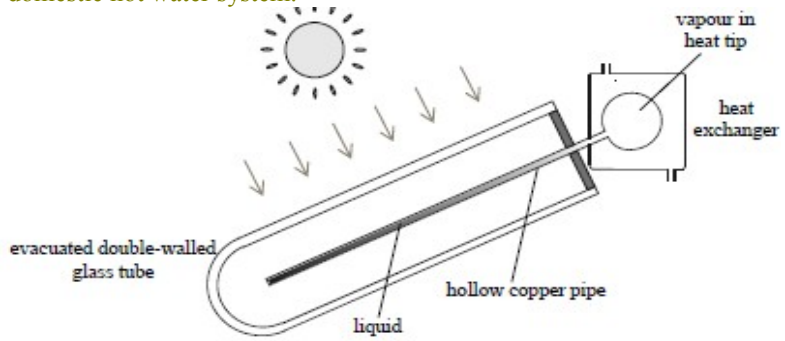
State Examination Commission – Physics Higher Level, 2009

Question 11

Read the following passage and answer the accompanying questions.
The sun is a major source of 'green' energy. In Ireland solar heating systems and geothermal systems are used to get energy from the sun.
There are two main types of solar heating systems, flat-plate collectors and vacuum-tube collectors.
A flat-plate collector is usually an aluminium box with a glass cover on top and a blackened plate on the bottom. A copper pipe is laid on the bottom of the box, like a hose on the ground; water is passed through the pipe and transfers the absorbed heat to the domestic hot water system.



In a vacuum-tube collector, each tube consists of an evacuated double-walled silvered glass tube in which there is a hollow copper pipe containing a liquid. The liquid inside the copper pipe is vaporised and expands into the heat tip. There the vapour liquefies and the latent heat released is transferred, using a heat exchanger, to the domestic hot water system. The condensed liquid returns to the copper pipe and the cycle is repeated. In a geothermal heating system a heat pump is used to extract solar energy stored in the ground and transfer it to the domestic hot water system.

(*a*) What is the maximum energy that can fall on an area of 8 m^2 in one hour if the solar constant is 1350 W m^{-2}? (7)
(*b*) Why is the bottom of a flat-plate collector blackened? (7)
(*c*) How much energy is required to raise the temperature of 500 litres of water from 20 C to 50 C (7)
(*d*) The liquid in a vacuum-tube solar collector has a large specific latent heat of vaporisation. Explain why. (7)
(*e*) Name the three ways that heat could be lost from a vacuum-tube solar collector. (7)
(*f*) How is the sun's energy trapped in a vacuum-tube solar collector? (7)
(*g*) Describe, in terms of heat transfer, the operation of a heat pump. (7)
(*h*) Give an advantage of a geothermal heating system over a solar heating system. (7)

(specific heat capacity of water = 4200 J kg^{-1} K^{-1}; density of water = 1000 kg m^{-3}; 1 litre = 10^{-3} m^3)

(*a*) What is the maximum energy that can fall on an area of 8 m^2 in one hour if the solar constant is 1350 W m^{-2}? (7)

1350 W m^{-2} = 1350 J s^{-1} m^{-2} ≡ 1350 x 60 x 60 J h^{-1} m^{-2} ≡ 8 x 1350 x 60 x 60 = 38.9 MJ over 8 m^2 /h

(*b*) Why is the bottom of a flat-plate collector blackened? (7)

For better absorption of radiation

(*c*) How much energy is required to raise the temperature of 500 litres of water from 20 C to 50 C (7)

$E = mc\Delta\theta = 500 \times 4180 \times 30 = 62.7$ MJ

(*d*) The liquid in a vacuum-tube solar collector has a large specific latent heat of vaporisation. Explain why. (7)

So that, when the vapour liquefies there will be a large amount of latent heat transferred to the domestic hot water system

(*e*) Name the three ways that heat could be lost from a vacuum-tube solar collector. (7)

conduction, convection, radiation

(*f*) How is the sun's energy trapped in a vacuum-tube solar collector? (7)

The silvered wall prevent heat loss by radiation, while the evacuated space between the double walls prevents heat loss by conduction and convection.

(*g*) Describe, in terms of heat transfer, the operation of a heat pump. (7)

Heat pumps take heat from a cold place (making it colder) and move it into warmer place (making it even warmer still).

(*h*) Give an advantage of a geothermal heating system over a solar heating system. (7)

Solar heating will only occur during daylight hours. Geothermal heating is not restricted like this.