## QUESTION

A refrigerator with a coefficient of performance (COP) of 1.4 has a faulty switch so that the light in the refrigerated space remains on when the door is closed. If the light has a 20W bulb and the cost of electricity is 1.2 pence per kWh, then determine the increase in energy consumption of the refrigerator and its cost per year if the switch is not repaired. Assume the refrigerator is opened an average of 20 times per day for 30 seconds on average.

[Answer: 298 kWh/yr, £3.57/yr]

SOLUTION
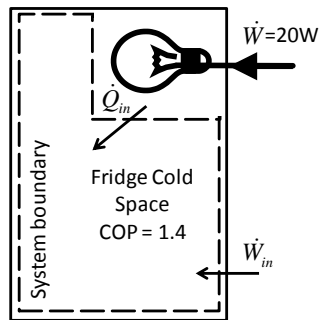
Electricity price = 1.2p/kWh

Fridge opened 20 times/day for 30s

Using the first law of thermodynamics applied to the fridge-space, excluding the light bulb,

$$(Q_{in} - Q_{out}) + (W_{in} - W_{out}) + (E_{mass,in} - E_{mass,out}) = \Delta U + \Delta KE + \Delta PE$$

There is no mass transfer, no change in KE or PE. Assume the temperature remains constant so that there is no change in internal energy. The fridge is insulated so $\dot{Q}_{out} = 0$ and there is no work done by the fridge-space, so $\dot{W}_{out} = 0$, i.e.

$$\dot{Q}_{in} + \dot{W}_{in} = 0$$

Hence, the additional work that must be done on the fridge-space is equal to the heat transfer in from the light bulb, i.e. $\dot{Q}_{in} = 20$W

and by definition $\qquad COP = \dfrac{\dot{Q}}{\dot{W}} = 1.4$

Work done to remove additional heat, $\dot{W}_{in} = \dfrac{\dot{Q}_{in}}{COP} = \dfrac{20}{1.4} = 14.3$W

Now additional power is required for the fridge work and the light bulb, i.e.

$$\Delta \dot{W}_{elect} = \dot{Q}_{in} + \dot{W}_{in} = 20 + 14.3 = 34.3\text{W}$$

Total number of hours in a year is 365 days/year × 24 hours/day = 8760 hrs/year

Assuming fridge is opened 20 times per day for an average of 30 seconds, then the light would normally be on for 20 /day × 30 seconds × (1h/3600s) × 365 days/yr = 61 hrs/year

So, additional hours on for lamp is = 8760 – 61 = 8699 hrs/year

Hence, additional power consumption = $W_{total} \times 8699 = 298$ kWh/yr

And, additional cost = 298×0.012 =£3.57/yr