Journal of Physics Special Topics

A4_6 Heating a cold room

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November 09, 2011

Abstract

This paper compares the time taken to heat a room using a central heating system radiator and an open wood fire. The calculations show that the open fire heats the room in the shortest time.

Introduction

Although central heating system radiators and open fires are both commonly used methods for heating, they provide heat energy in very different ways. This paper aims to discuss how the time taken in heating a room varies for radiators and wood fires.

How much heat energy is required?

To compare the time taken to heat a room using different methods, it is necessary to determine the amount of heat that is needed. This requires some initial assumptions about the room. It is assumed that the room volume, V, is approximately 85 m^3, the initial temperature, T_i, is 10°C and the final temperature, T_f, after heating will be 25°C. Therefore the change in temperature, ΔT, is 15°C. It is also assumed that the room is sufficiently insulated so that the heat lost from the room can be neglected.

The heat energy required to heat the air at constant volume, Q_V, as the size of the room does not change, can be found from the heat capacity at constant volume, C_V, and the change in temperature. This relationship is shown below [1]:

$$Q_V = C_V \Delta T. \qquad (1)$$

It is assumed that the air can be approximated as consisting of identical diatomic molecules with a mass, m, of 5.6x10^{-26} kg, as this is the average mass of an air molecule [2]. Therefore, C_V can be expressed as

$$C_V = \frac{5}{2}\frac{\rho V}{m} k_B, \qquad (2)$$

where ρ is the average density of air, taken as 1.29 kgm^{-3}, and k_B is Boltzmann's constant, which is 1.38x10^{-23} JK^{-1}[1]. By substituting equation (2) into equation (1), the total heat energy required to increase the temperature of the room by 15°C is found to be 1.02 MJ.

Heating a room by radiator

The time taken for a central heating radiator to provide the total amount of heat energy can be found. Despite their name, radiators provide heat energy through convection as the heated water flows through copper pipes at an average temperature, T_W, of 70°C [3]. The time taken for the radiator, t_R, to convect the heat energy required, Q_V, can be determined from

$$\frac{Q_V}{t_R} = hA_R(T_W - T_{ROOM}), \qquad (3)$$

where A_R is the radiator area, T_{ROOM} is the average temperature of the room, and h is the convective heat transfer coefficient [4]. It has been assumed that the average temperature of the room can be used as the difference in temperature is comparatively large.

The radiator area, A_R, is approximated as 1m^2, and an average of the initial and final temperatures is used for T_{ROOM}. The convective heat transfer coefficient, for heat convection from water to air through copper, is taken as 13.1 Wm^{-2}K^{-1} [5]. By rearranging equation (3) for t_R and substituting in the relevant values, the time taken to heat the room by a radiator is found to be approximately 25 minutes.

Heating a room by open fire

Finally, the time taken to heat the room through the combustion of wood can be examined. The relationship between the energy released with time can be found from Janssens equation [6]:

$$\frac{Q_V}{t_F A_W} = q_{cr} + 0.73 q_{cr} \left(\frac{k\rho c}{h_{ig}^2 t_F}\right)^{0.547}, \quad (4)$$

which depends on the total time taken to heat the room by fire, t_F, surface area of the wood, A_W, critical heat flux for ignition, q_{cr}, thermal conductivity of wood, k, wood density, ρ, specific heat capacity of wood, c, and heat transfer coefficient at ignition, h_{ig}.

The second term on the right hand side of equation (4) represents the heat flux at ignition [6]. As the wood will be assumed to be in equilibrium, this term is neglected. Therefore equation (4) becomes:

$$\frac{Q_V}{t_F A_W} = q_{cr}. \quad (5)$$

By using experimental values for the combustion of pine wood and some assumptions, this equation can be used to determine t_F. The surface area of the wood can be approximated as 0.2 m^2. An experimental study into the combustion of pine wood [6] measured the critical heat flux for ignition, q_{cr}, as (10.68×10^3) Wm^{-2}.

By substituting the relevant values into equation (4), the time taken to heat the room through combustion of wood is found to be approximately 8 minutes.

Discussion

The results show that the time taken to heat a room by 15°C is approximately 25 minutes for a radiator, and 8 minutes for an open fire. This is as expected because the combustion of wood occurs at a much higher temperature compared to the temperature of the water. Therefore, the rate of energy transfer would be increased for the open fire.

It is important to note that the resulting values are approximations only, and have not taken into account some important factors. The radiator calculation neglected the time taken to heat the water, which means that the actual time would be longer than the calculated time. The wood combustion calculation also neglected the initial excess heat flux at ignition, which would slightly decrease the time. However, with these changes, the results would still show that the radiators take longer to heat the room.

It was also assumed that all the energy emitted by the systems has been converted to the air molecules' heat energy, and that no heat energy is lost from the room. By considering energy losses, the time taken for both the radiator and the open fire would be increased.

Conclusion

This paper has found that the time taken to heat a room is shorter for an open fire burning wood compared to a central heating radiator. Although the heat transfer rate is longer for radiators they do have advantages over open fires, for example they are more environmentally friendly and more suitable for heating houses with many rooms. It is important to consider these factors when comparing the benefits of different heating systems.

In conclusion, this paper was successful in determining that open fires take less time to heat a room when compared radiators. The method used could be improved by accounting for heat losses from a room and considering the initial heat fluxes when the radiator is heating the water and when the wood is ignited. Further investigations could also include examining the differences in different types of open fires, such as coal fires.

References

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