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Problem 25.11 (RHK)

A chef, awaking one morning to find the stove out of order decides to boil water for coffee by shaking it in a thermos flask. Let us suppose that the chef uses $560\ \text{cm}^3$ *of tap water at* 59^0F, *and the water falls* $35\ \text{cm}$ *each shake, the shape making* 30 *shakes each minute. Neglecting any loss of energy, we have to estimate how long the flask must be shaken before the water boils.*

Solution:

We first calculate the temperature equivalent in Celsius to 59^0F. We use the relation

$$T_F - 32 = \frac{9}{5}T.$$

We find that 59^0F is equal to

$$T = \frac{5}{9}(59-32) = 15^0\text{C}.$$

Volume of water to be boiled by shaking is

$$V = 560\ \text{cm}^3 = 560\times10^{-6}\ \text{m}^3 = 5.6\times10^{-4}\ \text{m}^3.$$

Mass of the water to be boiled is

$M = 5.6 \times 10^{-4} \times 10^{3}$ kg $= 0.56$ kg,

as the density of water $\rho = 10^{3}$ kg m^{-3}.

Amount of energy gained by the water to be boiled in each shake will be the change in gravitational potential energy in 0.35 m. It is $\Delta E = 0.56 \times .35 \times 9.81$ J $= 1.923$ J.

Specific heat of water, $c = 4190$ J kg^{-1} K^{-1}.

Amount of heat required to raise the temperature of water from $15\,^{0}$C to $100\,^{0}$C will be

$Q = 0.56 \times 4190 \times (100 - 15)$ J $= 1.99 \times 10^{5}$ J.

As 30 shakes are imparted in a minute, the time required for obtaining mechanical energy equal to Q will be

$t = \dfrac{1.99 \times 10^{5}}{1.923 \times 30}$ min $= 57.6$ hour $= 2.4$ day.