3.7: Shaft Work

Shaft work refers to energy transferred across the boundary by a rotating shaft.

The complete apparatus is depicted in Fig. 3.13. In use, two lead weights sank and caused the paddle wheel to rotate. Joule evaluated the stirring work done on the system (the vessel, its contents, and the lid) from the change of the vertical position h of the weights. To a first approximation, this work is the negative of the change of the weights' potential energy: $w = -mg\Delta h$ where m is the combined mass of the two weights. Joule made corrections for the kinetic energy gained by the weights, the friction in the connecting strings and pulley bearings, the elasticity of the strings, and the heat gain from the air surrounding the system.

A typical experiment performed by Joule is described in Prob. 3.10. His results for the mechanical equivalent of heat, based on 40 such experiments at average temperatures in the range $13\,^\circ\mathrm{C}$–$16\,^\circ\mathrm{C}$ and expressed as the work needed to increase the temperature of one gram of water by one kelvin, was $4.165\,\mathrm{J}$. This value is close to the modern value of $4.1855\,\mathrm{J}$ for the "$15\,^\circ\mathrm{C}$ calorie," the energy needed to raise the temperature of one gram of water from $14.5\,^\circ\mathrm{C}$ to $15.5\,^\circ\mathrm{C}$.

The thermochemical calorie (cal), often used as an energy unit in the older literature, is defined as $4.184\,\mathrm{J}$. Thus $1\,\mathrm{kcal} = 4.184\,\mathrm{kJ}$.