CHAPTER OVERVIEW

25: Simple Machines

A given amount of work may often be accomplished with less effort by employing some sort of machine. Classical physics has, since the Renaissance, recognized six basic simple machines. All other machines in use today may be considered as combinations of two or more of these simple machines. The simple machines are:

- inclined plane
- wheel and axle
- pulley
- lever
- wedge
- screw

Each of these simple machines allows work to be performed with less effort, by trading off effort (applied force) for distance. Recall that work is the product of force and distance: $W = Fx$, so that the same amount of work W may be accomplished by applying a smaller force F over a greater distance x. This is what simple machines do.

We define the mechanical advantage of a simple machine to be the ratio of the resistance (resistive force) F_R to the effort (effort force) F_E :

$$M.A. = \frac{F_R}{F_E} \tag{25.1}$$

For example, the resistive force F_R may be the weight of a body, and the effort force F_E may be the force required to lift it. Suppose, for example, that we have a body of mass m, and we wish to lift it onto the top of a table. In this case, the resistive force is the weight of the body, mg; the force required to lift it directly onto the table is equal to also its weight mg, so the mechanical advantage for lifting the body directly (with no machine) is $M.A. = mg/mg = 1$. If one uses a simple machine such as an inclined plane or pulley, the same body may be lifted with less force, and therefore a mechanical advantage greater than 1 . In the sections below, we'll see how to compute the mechanical advantage for each of the simple machines.

We may also define the efficiency of a simple machine to be the ratio of the output work W_o to the input work W_o. Since work is force times distance,

$$\eta = \frac{W_o}{W_i} = \frac{F_R x_R}{F_E x_E} \tag{25.2}$$

where $W_o = F_R x_R$ is the output work-the resistive force times the distance over which the resistive force moves, and $W_i = F_E x_E$ is the input work-the input effort force times the distance over which the effort force is applied. In the absence of friction, the efficiency of a simple machine will be 1 , or 100%, and the input and output work are equal. If friction is present, then a larger input effort force F_E will be required to overcome friction, and the efficiency will be less than 1.