Study of Stored Energy and Simple Machines

Ben Hammond

December 13, 2020

1 Simple Machines

The following six simple machines were invented by humankind in ancient times and are still in use today: the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw. Using your knowledge of forces and energy describe the physics behind each of these simple machines (use free-body diagrams, Newton's Laws, and equations for work and mechanical energy) and explain why they are so useful. The minimum answer requires one illustration and a paragraph explanation.

1.1 The Lever

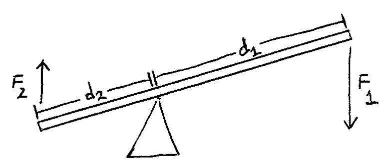

Figure 1: A diagram of a lever.

Description The lever provides a mechanical advantage the same way all simple mechanisms do: by translating distance into force. In the lever, a force F_1 exerted downward over distance d_1 is translated into a force F_2 over distance d_2. When distance d_1 is larger than distance d_2, less force is required to lift an object distance d_2, though it is over a longer distance. In this way levers maintain the amount of work done by reducing force and increasing distance.

1.2 The Wheel and Axle

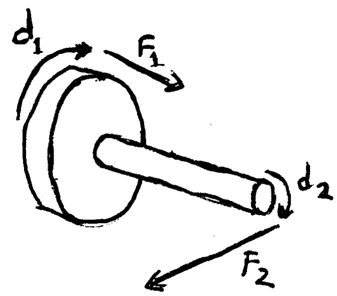

Figure 2: A diagram of a wheel and axle.

Description The wheel and axle converts distance into force through the use of differently sized cylinders. Because the larger cylinder has to move a larger distance d_1 than the smaller cylinder's distance d_2, it's force must be smaller. Thus, when a force F_1 is applied on the larger cylinder over distance d_1, a larger force F_2 is applied on the smaller cylinder over a smaller distance d_2. In these diagrams the works on each "end" of the mechanism are equal, meaning $F_1 * d_1 = F_2 * d_2$.

1.3 The Pulley

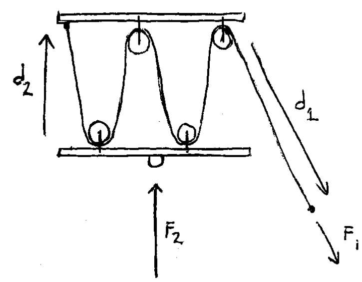

Figure 3: A diagram of a pulley.

Description The pulley, or block and tackle, is often used to lift heavy objects with little force. As with all other simple mechanisms, this is achieved by increasing the distance over which a smaller force is exerted. The block and tackle does this by increasing the number of pulleys through which the rope passes between the top and the object. This means that to lift the object distance d_2, a distance of rope d_1 equal to $_2$ multiplied by the number of times the rope loops back and forth, minus one if the end of the rope goes down. For example, in this diagram d_1 is equal to $4 * d_2$, because the rope has four lengths connected to the bottom, excluding the one being directly pulled on. As with before, this increase in distance means a corresponding decreasing in force produces the same amount of work.

1.4 The Inclined Plane

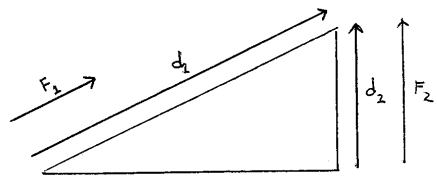

Figure 4: A diagram of an inclined plane.

Description Inclined planes are also often used to lift objects, but, unlike with pulleys, they decrease the amount of force necessary to lift an object a height d_2 by moving the object in a vertically diagonal line over a longer distance d_1. Similarly though, by increasing the distance d_1 they decrease the force F_1 required to do the same amount of work.

1.5 The Wedge

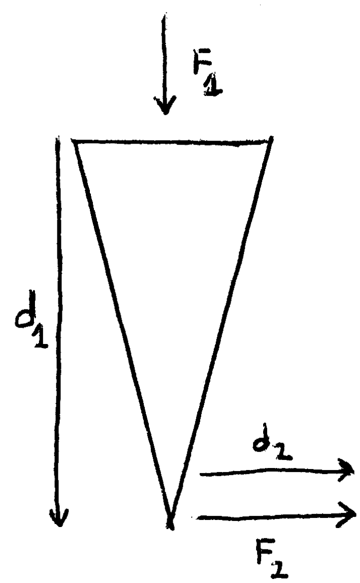

Figure 5: A diagram of a wedge.

1.6 The Screw

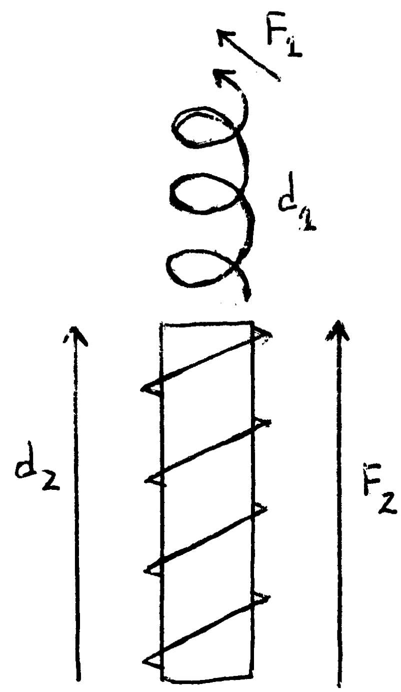

Figure 6: A diagram of a screw.

2 Energy Storage

We have learned that energy can take a number of different forms. In this activity you will design and perform experiments to determine the amount of energy stored in several devices.

2.1 Mouse Trap

For this device, also estimate the velocity of the end of the bar when the trap is triggered.

Experimental Design:

Data:

Calculations:

2.2 Constant Acceleration Cars

For this device determine both the energy required to fully "charge" the car and the kinetic energy of the car when it is released. The percent efficiency of the device is the energy released divided by the energy required to charge it multiplied by 100.

Experimental Design:

Data:

Calculations:

2.3 Household Item

Experimentally determine the energy stored in the device and the device's efficiency.

Experimental Design:

Data:

Calculations:

2.4 Nerf Gun

Experimentally determine the work required to fully charge the Nerf Gun, the kinetic energy of the projectile, and the Nerf Gun's efficiency.

Experimental Design:

Data:

Calculations: