Force, Pressure and Friction

A **FORCE** can be defined as "*A push or a pull on an object".* The FORCE (push or pull) may result from a contact between two objects, or from an influence in which no contact takes place, such as magnetism or gravitation. A FORCE can cause a change in motion of the object. If the object is not acted upon by other pushes and / or pulls which combine to form an equal and opposite counteracting action, then the FORCE will change the motion of the object to which it is applied.
Force is a vector quantity, meaning that it has both **magnitude** and **direction**. Forces are sometimes described in terms of magnitude only, and in many of those cases, the direction is self-evident.
Sir Isaac Newton, the 17th century English mathematician, formulated a series of observations about the basic behavior of forces on objects. Those observations have become known as "Newton's Laws of Motion", and are fundamental to the study of forces acting on objects. They are:

1. Every object continues in a state of rest or of uniform motion until it is compelled by a force to change its state of rest or motion.
2. The change in motion of an object is proportional to the net magnitude of the combination of the applied forces, and takes place along the straight line in which the ombination of the applied forces acts (sometimes stated as: F = MA, or force = mass x acceleration).
3. For every action, there is an equal and opposite reaction. In other words, when two objects exert forces on each other, the forces are equal in magnitude, opposite in direction, and collinear.

The equation "F = MA" is a simplification of Newton's second law, but it has extreme significance. It means that the force required to accelerate an object is equal to the *mass* of the object multiplied by the desired *acceleration*. This simple equation forms the basis for determining the loads applied to objects as the result of motion ("dynamics").
Another common example of Newton's second law is the calculation of the force required to lift an object (its weight) The *weight* of an object is the acceleration of gravity (32.2 ft-per-second-per-second average on earth; quite different on other planets) times the mass of the object.

PRESSURE

A **PRESSURE** is the result of a FORCE being applied to a specific cross-sectional area, and is defined as FORCE per unit AREA, as in POUNDS per SQUARE INCH. For example, if a downward FORCE of 1000 pounds is applied evenly to a square plate of steel which measures 2" by 2" (4 square inches of area), then the PRESSURE applied to that block (Force per unit AREA) is determined by dividing the FORCE (1000 pounds) by the AREA (4 square inches), which is 250 pounds per square inch *("psi")*.

If the **same** 1000 pound FORCE was applied to a plate which measured 2" x 4" (8 square inches), then the PRESSURE would be reduced to 125 psi because the area of the plate doubled. The same force is being applied over a greater area, resulting in a LOWER force per unit area.

Taking it a step further, suppose you have a hydraulic cylinder with a 1/2" diameter piston. The area of that piston = diameter x diameter x 0.785, or in this case, 0.5 x 0.5 x 0.785 = 0.196 square inches. Now, if you apply 1000 pounds to the rod of that cylinder, the 1000 pound FORCE is applied by the rod to the piston, which acts against the oil in the cylinder to produce a pressure in the oil of 5102 (1000 / 0.196 = 5102) *psi*. If that oil is routed through some tubing to another hydraulic cylinder which has a 2.5 inch diameter piston, then the 5102 *psi* will be applied to the 4.91 square inch piston (2.5 x.2.5 x .785 = 4.91) and results in a 25, 050 pound force being available at the end of the rod on that cylinder.

FRICTION

FRICTION is an especially interesting example of a force. It is the resistance to motion which takes place when one body is moved upon another. Friction is generally defined as *"that force which acts between two bodies at their surface of contact, so as to resist their sliding on each other"*.

Suppose that a block of metal, weighing 40 pounds, is resting on a flat, horizontal table top. If, using an accurate tension scale, you exert a small horizontal force on the block, the block will not move. Now suppose you increase the horizontal force until the block moves, and you notice that the value of the force is 8 pounds.

You now have enough data to calculate an important friction parameter known as the *coefficient of friction* (μ), which defines the nature of the resistance to motion these two bodies exert on each other. The value of the coefficient of friction (m) is the horizontal force needed to move the block (8 lbs.) divided by the vertical force pressing the block and the table together (40 lbs.) $\mu = 8 / 40 = 0.20$)

There are several interesting properties of friction between dry, unlubricated surfaces, summarized as follows:

1. At low velocities, the friction is independent of the velocity of rubbing. As the velocity increases, the friction decreases. In other words, the force

the force required to overcome friction and start a body into motion is greater than the force required to sustain the resulting motion. That fact is reflected in the existence of two different coefficients of friction for each material pair: the ***static*** coefficient and the ***dynamic*** coefficient.

2. For low contact pressures (***normal*** {perpendicular} force per unit area), friction is directly proportional to the normal force between the two surfaces. As the contact pressure increases, the friction does not rise proportionately, and when the pressure becomes very high, friction increases rapidly until seizing takes place.
3. For a constant normal force, the friction, in both its total amount and its coefficient, is independent of the surface area in contact (as long as the pressure is not high enough to enter the seizing region).

Now suppose you apply a thin film of oil on the table under the block. The oil reduces the coefficient of friction to somewhere in the neighborhood of 0.025, so the block can now be moved with a horizontal force of about 1 pound (0.025 * 40 = 1).

The properties of friction between well-lubricated surfaces are considerably different from those above for dry surfaces.

1. The frictional resistance is almost independent of the contact pressure if the surfaces are flooded with oil.
2. For low contact pressures, the friction varies directly with velocity. For high contact pressures, the friction is very high at low velocities, dropping to a minimum at about 2 feet-per-second, then increasing as the square root of velocity.
3. For well-lubricated surfaces, the friction decreases dramatically with increasing temperature, from the influence of (a) rapidly-decreasing oil viscosity and (b) for a journal bearing, increasing diametral clearance.
4. If the bearing surfaces are flooded with oil, the friction is almost independent of the nature of the materials of the contact surfaces. As the lubrication diminishes, the coefficient of friction becomes more dependent on the materials.

Source:

http://www.epi-eng.com/mechanical_engineering_basics/force_and_friction.htm