FBD Notes

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1 What are Forces?

Definition 1 (Force)**.** A field or body applies a push or pull on another body. One object by itself *cannot* generate a force.

Forces *can* change the velocity of an object. However, if forces are balanced, there will be no net change in velocity.

Definition 2 (Balanced Forces)**.** Forces that cancel each other out; there is no net force acting on the object.

Note knowing the forces acting on an object does *not* inherently tell you its velocity. An object may have zero net force yet be moving at a constant velocity (due to inertia).

2 Types of Forces

Forces fall into one of two types: *active* versus *reactive* forces.

2.1 Active Forces

Active forces are forces that are actively done by another object. The following are active forces.

Definition 3 (Force of Gravity: F_g, W)**.** How hard a planet pulls on an object. Equals mass (m) times the gravitational constant (g):

$$F_g = mg$$

Definition 4 (Dynamic Friction Force: F_{fr})**.** The force of a surface colliding against an object. Equals the coefficient of dynamic friction (μ_k) multiplied by the normal force (F_N):

$$F_{fr} = \mu_k F_N$$

Definition 5 (Force of Tension: F_T, T)**.** The force exerted by a long object (chain, string, rope, etc). This does not apply to "bouncy" objects, most notably springs.

Definition 6 (Spring Force: F_{spr})**.** The force exerted by a spring. Equals the spring constant (k, varies on string) times the change from the resting position (the negative indicates opposite from the applied force):

$$F_{spr} = -k\Delta x$$

Definition 7 (Applied Force, F_a)**.** A force applied by another object, typically unspecified.

2.1.1 Archimedes' Principle / Buoyant Force

Definition 8 (Buoyant Force, F_{buoy})**.** An upward force applied to an object submerged in a fluid or gas, against gravity.

Buoyant Force is caused by the differences in pressure between the top and bottom of the submerged object. Because pressure increases the farther an object goes within the fluid, this pressure difference causes the buoyancy force. It can be shown that buoyancy force is equal to the weight of the displaced water: that is,

$$F_{buoy} = \rho g V_f$$

This is known as *Archimedes' Principle*, where ρ = fluid density, g = the gravitational constant, and V_f = the volume of the displaced fluid. See the Khan Academy article on buoyant force for more information.

2.2 Reactive Forces

Reactive forces are forces that are caused by other forces. The following are reactive forces.

Definition 9 (Normal Force, F_N, N)**.** The "reaction" force caused by the pressure of an object being pulled down on a surface due to gravity. Normal force is always perpendicular to the surface that an object is on.

Definition 10 (Static Friction Force: F_{fr})**.** The "reaction" force that prevents stationary objects on surfaces from accelerating. Note that static friction force is (typically) stronger than dynamic friction; think about the grooves on a surface lining up with the grooves of an object. Equals the coefficient of static friction (μ_s) multiplied by the normal force (F_N):

$$F_{fr} = \mu_s F_N$$

Definition 11 (Air Resistance Force: F_{air})**.** The "reaction" force that counteracts gravity (on earth) and causes falling objects to reach a maximum *terminal velocity* (versus infinitely accelerating in a vacuum). Is proportional to velocity:

$$F_{air} \propto v$$

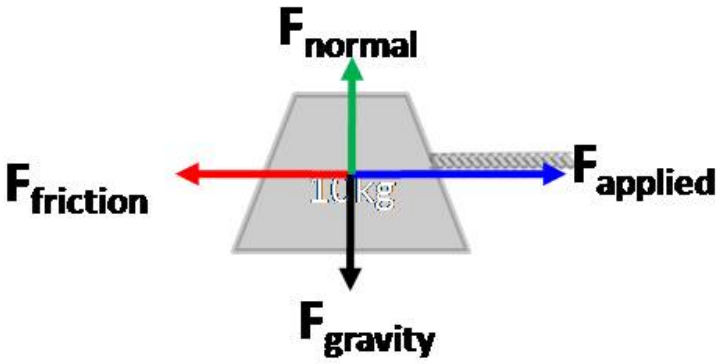

Figure 1: An example FBD. Forces shown are the normal force (F_N), the application force (F_a), the force of gravity (F_g), and the force of friction (F_{fr}).

3 Free Body Diagrams (FBDs)

Definition 12 (Free Body Diagrams)**.** Diagrams that show the different forces on an object and their relative directions and magnitudes. In FBDs, forces are shown coming out of its center of mass (for convenience; this does not literally happen, although the influence is rarely important.)

Although Newton's Third Law suggests that all forces will have a reaction force, these reaction forces are often applied to other objects, and as such are not considered in the FBD. See Figure 1 for an example of a FBD.

3.1 FBD Problems

Problems involving many forces can be simplified by drawing a FBD of the situation. To solve these types of problems, break forces down into pure x and y components to try to find equations relating some variables to each other, and then solve from there. For some problems (notably those with objects on inclines), it maybe helpful to redefine the x and y directions for your problem.