Physics 1180
Section 1.2.2: Dynamics

Newton’s 2nd Law

FORCE Causes Acceleration

Recall that ACCELERATION is the rate at which velocity changes:

1. How quickly an object *speeds up*.
2. How quickly an object *slows down*.
3. How quickly an object *changes direction*.

What is a FORCE?

Any “push” or “pull” that tend to change the state of motion of an object.

Experiments show:

Acceleration is *directly proportional* to (net) force.

MASS Resists Acceleration

What is a MASS?

- A quantitative measure of an objects inertia.
- The amount of matter or “stuff” that an object contains.

Experiments show:

Acceleration is *inversely proportional* to mass.

For example:

Three time the mass gives one-third the acceleration and

half the mass gives twice the acceleration (for the same net force).

Newton's 2nd Law of Motion

Combining these results,
we arrive at Newton's 2nd law of motion:

$$\vec{a} = \frac{\vec{F}_{net}}{m} \quad \text{or} \quad \vec{F}_{net} = m\vec{a}$$

Sometimes $\vec{F}_{net}$ is written as $\sum \vec{F}$,
where the symbol "Σ" means "the sum of…"

Example 1

A 10 kg box is pushed by a horizontal force of 20 N across a floor a flat floor at a constant speed. What is the force of friction between the floor and the box?

Since the speed is constant, the acceleration must be zero. Therefore, the net force on the box must be zero. The opposing force of friction must then be 20 N (in a direction opposite to the push).

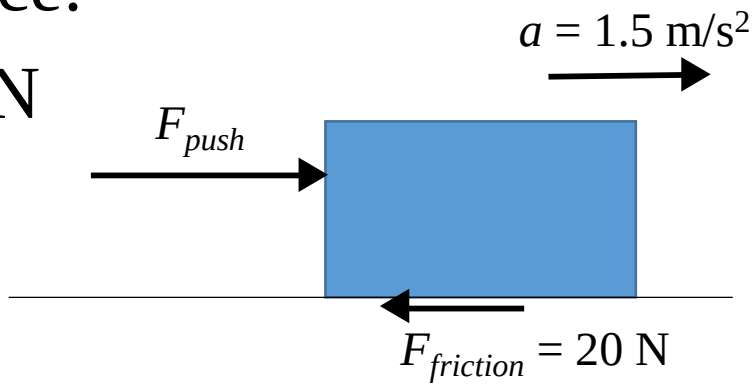
Example 2

Assuming the same frictional force between the floor and the box described in the previous question, what horizontal pushing force will give the box an acceleration of 1.5 m/s^2?

Since the box accelerates, there must be a net force:

$F_{net} = ma = (10\text{ kg})(1.5\text{ m/s}^2) = 15\text{ kg·m/s2} = 15\text{ N}$

where $F_{net} = F_{push} - F_{friction}$.



Therefore, $F_{push} = F_{net} + F_{friction} = 15\text{ N} + 20\text{ N} = 35\text{ N}$

MASS versus WEIGHT

What is a WEIGHT?

For now, weight is a measure of the force of gravity on an object.

(This definition will be refined later.)

$$\text{Weight} = F_{gravity} = mg,$$

where g is the "acceleration due to gravity."

Near the surface of the Earth, $g = 9.8 \text{m/s}^2 \approx 10 \text{ m/s}^2$.

Free Fall

- For an object in “free fall,” only gravity acts. (Air drag is negligible.)
- Free fall acceleration is g ($\approx 10\,\frac{\mathrm{m}}{\mathrm{s}^2}\downarrow$ near the surface of the Earth).
- At a time t after being released rom rest…

The speed attained is $v = gt$

The distance fallen is $d = \frac{1}{2}gt^2$

Example 3

An object is dropped from a certain height hits the ground after 3 seconds.

1. How fast was the object going when it the ground?

$$\text{The speed attained is } v = gt = (10\,\tfrac{\text{m}}{\text{s}^2})(3\text{ s}) = 30\,\tfrac{\text{m}}{s}$$

2. From what height was the object dropped?

$$\text{The distance fallen is } d = \tfrac{1}{2}gt^2 = \tfrac{1}{2}(10\,\tfrac{\text{m}}{\text{s}^2})(3\text{ s})^2 = 45\text{ m}$$

Example 4

An object is tossed upward at 40 m/s.

1. At what time does the object reach its highest point?

Since gravity accelerates the object downward, the object must LOSE 10 m/s of speed each second on the way up. Therefore it takes 4 s to reach the highest point. (On the way down the object GAINS 10 m/s os speed every second.)

2. How high does the object go?

From above, it takes the object 4 s to return to its launch point. So, the distance fallen is $d = \frac{1}{2} g t^2 = \frac{1}{2} (10 \frac{\text{m}}{\text{s}^2})(4 \text{ s})^2 = 80 \text{ m}$