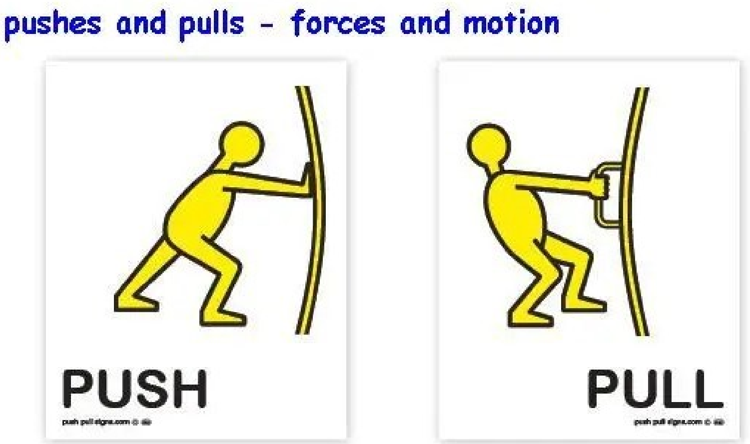
Newtons Laws of Motion

Force

Definition: **Force** A push or pull acting on a body. Force usually causes:

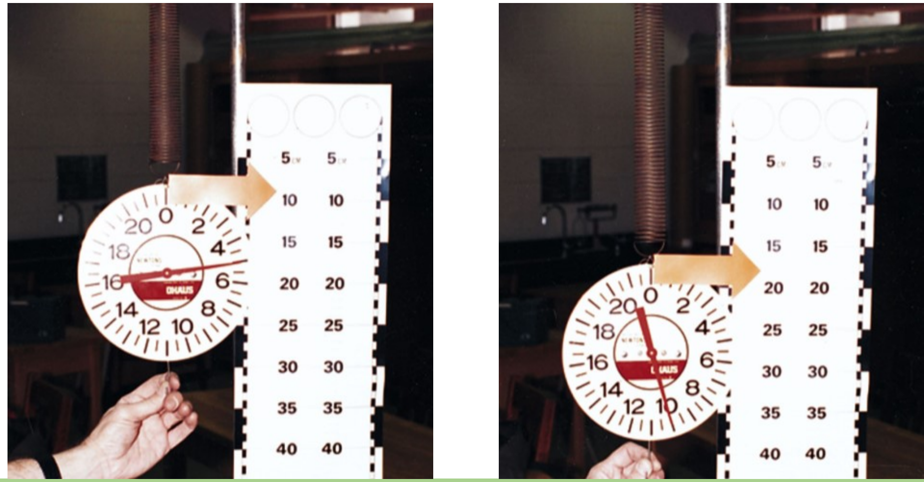
- Change in Velocity
- Distortion of the Object
- Both

Force is a VECTOR



Newton started with Galileo motion, then he wanted to make systematic rules about motion (v) and most importantly ***change in motion***. i.e. quantize and link motion and forces.

Everyday force: Push, Pull, Drag, Lift, Shove…

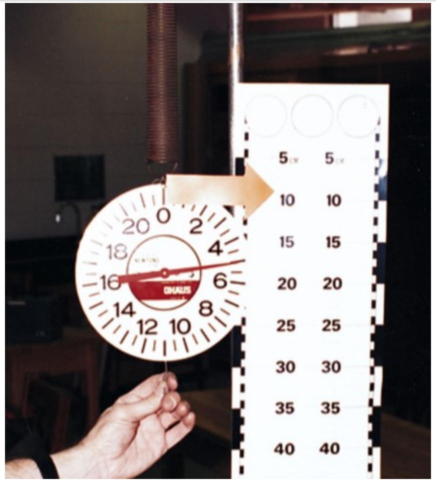


Units: Force (N), (Lb), (oz), (Ton)

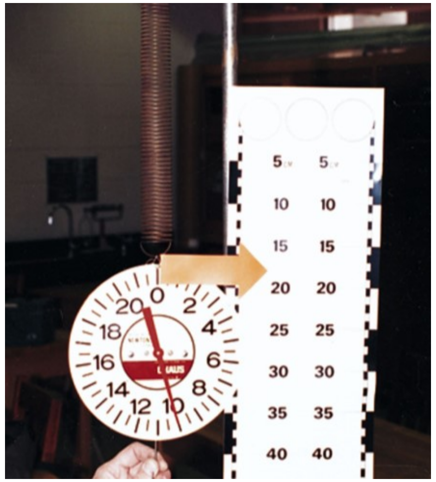
Force Quantization

The picture shows **one** of the method of quantizing a force.

- When the scale is pulled to 5N, the ruler dialed displaced to show 9 Centimeters.
- When the scale is pulled to 10N, the ruler dial is displaced to 18 Centimeters



When we doubled the pull we doubled the displacement of the dial – this relationship is called proportionality.



Can you guess what would be displacement when we pull the string to 15, 16, 20, N?

Units: Force (N), (Lb), (oz), (Ton)

Weight Force

Definition: **Weight** it is the downward force of gravity acting on an object

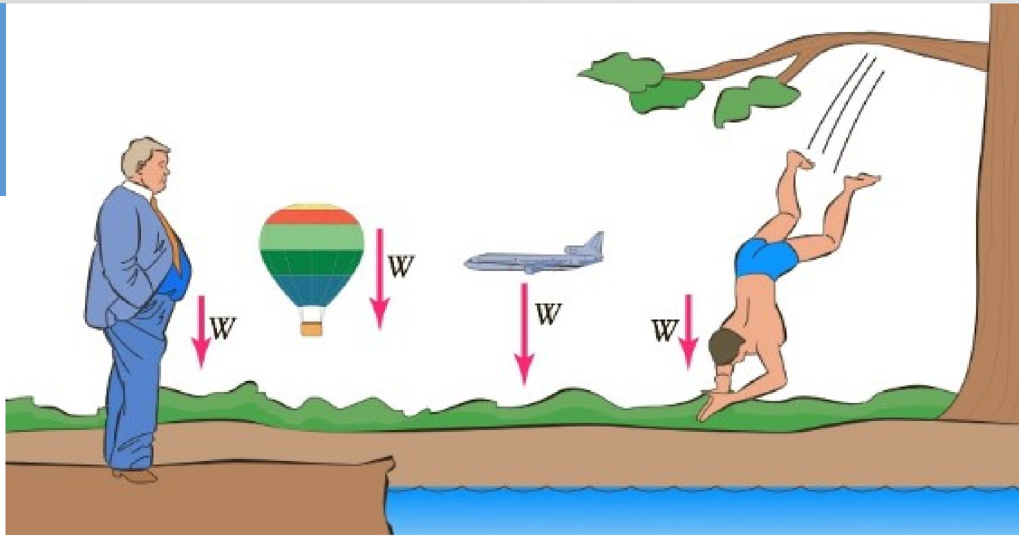
Weight force depends on 2 quantities

1. Mass
2. Gravitational field

The book notation of weight force: $F = W$

Usually the force is represented by an Arrow simulating a vector. Weight force in particular is pointing downwards.

- Units of Mass (g , kg , slug)
- Gravitational fields (earth surface, deep space, moon, sun, Jupiter



The weight force of an object is always there whether the object is

- Stationary or in motion
- Upward, Downward, Horizontally, or at an angle

Arrows are NOT to scale.

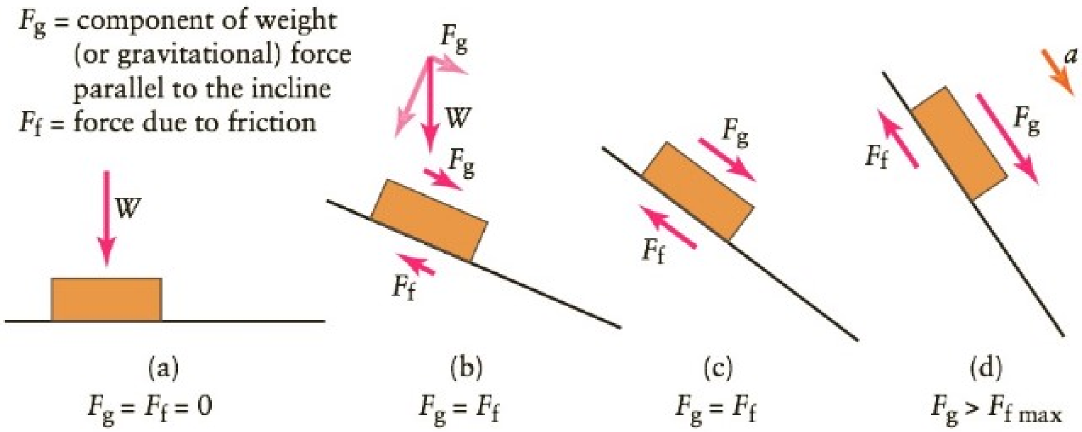
Units: Force (N), (Lb), (oz), (Ton)

Friction

Definition: **Friction** it is a **force** of resistance to relative motion between two objects in physical contact.

Defined as a force of resistance to relative motion between 2 objects in contact

- Static Friction (object at rest)
- Dynamic (Kinetic) Friction (object in motion)



Newtons Law of Motion

Newton 1st Law of Motion: An object will remain at rest or in uniform motion with constant velocity unless acted on by a net external force.

Newton 2nd Law of Motion: An object is accelerated whenever a net external force acts on it. The net force equals the object's mass times its acceleration.

$$\vec{F} = m.\vec{a}$$

Newton 3rd Law of Motion: Forces always come in pairs: when one object exerts a force on a second object, the second exerts an equal and oppositely directed force on the first.

Newtons 1st Law of Motion

Newton 1st Law of Motion: An object will remain at rest or in uniform motion with constant velocity unless acted on by a net external force.

In deep space

An object at rest will always remain at rest unless it is acted on by an external force

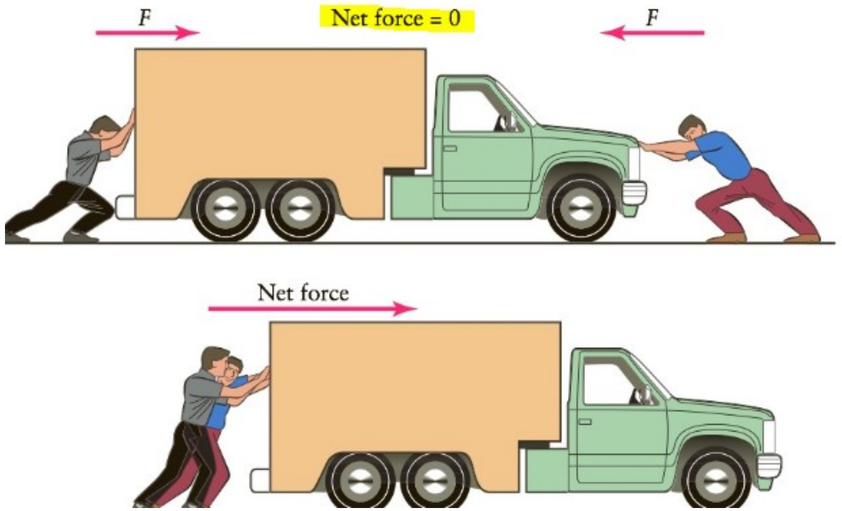
An object in uniform motion (constant speed) will always remain in uniform motion (constant speed) with same velocity unless it is acted on by a force $\sum \vec{F} \neq 0$.

A force does not cause motion it causes change in motion!

A force is not required to maintain motion it is only require to accelerate

Keep in mind that a force is vector, which has a magnitude and direction.

So a change in direction will break the law and cause change of velocity – case in point Centripetal Motion.



Mass

The property of mass that makes it resist to acceleration is called Inertia

- The units of Mass are (g, kg, slug) mass is a scalar
- The terms lb, oz, ton refer to the concept of **weight force**.

1kg = 2.2lbm hold true only on earth surface.

The gravitational acceleration on Earth is 9.8 m/s^2

The gravitational acceleration on the is 1.6 m/s^2

The gravitational acceleration in deep space is 0 m/s^2

Newtons 2nd Law of Motion

Newton 2nd Law of Motion: An object is accelerated whenever a net external force acts on it. The net force equals the object's mass times its acceleration.

Several way to rewrite Newton 2nd Law of Motion

$$\vec{F} = m.\vec{a}$$

$$\sum \vec{F} = m.\frac{\Delta\vec{v}}{\Delta t}$$

$$\vec{F}_{Net} = m.\frac{\Delta\vec{v}}{\Delta t}$$

Think carefully: Force does NOT cause motion, force causes motion to **change**.

Mathematically: $F \neq v, F \approx \Delta v$

Wrong

$$\vec{F} = m.\vec{v}$$

Correct

$$\vec{F} = m.\frac{\Delta\vec{v}}{\Delta t}$$

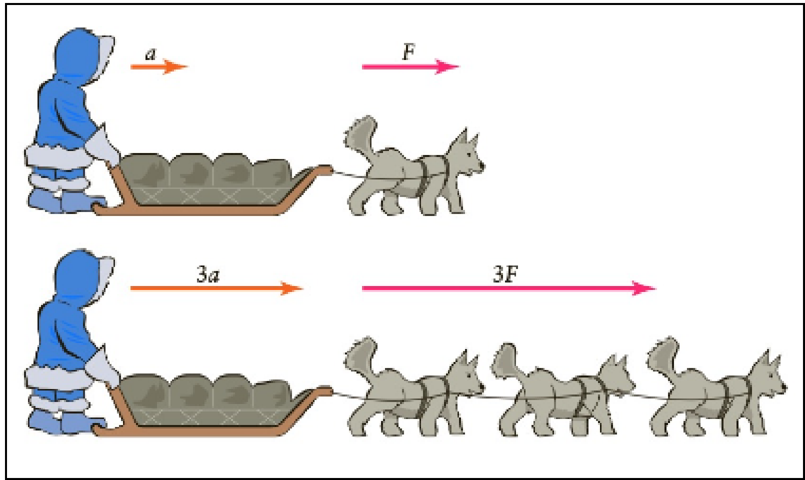
Newtons 2nd Law of Motion

Newton 2nd Law of Motion: An object is accelerated whenever a net external force acts on it. The net force equals the object's mass times its acceleration.

The force is proportional to the mass and acceleration and vice versa.

It is safe to claim that 3 dogs will have the 3 times the force of 1 dog and such 3 dogs will induce 3 times the acceleration of 1 dog.

$$\vec{F} = m.\vec{a}$$



Practice – Newtons 2nd Law

A Boing 737 with a mass of 41,145kg is observed to be accelerating at a rate of $4m/s^2$. What is the net force acting on it?

Practice – Newtons 2nd Law

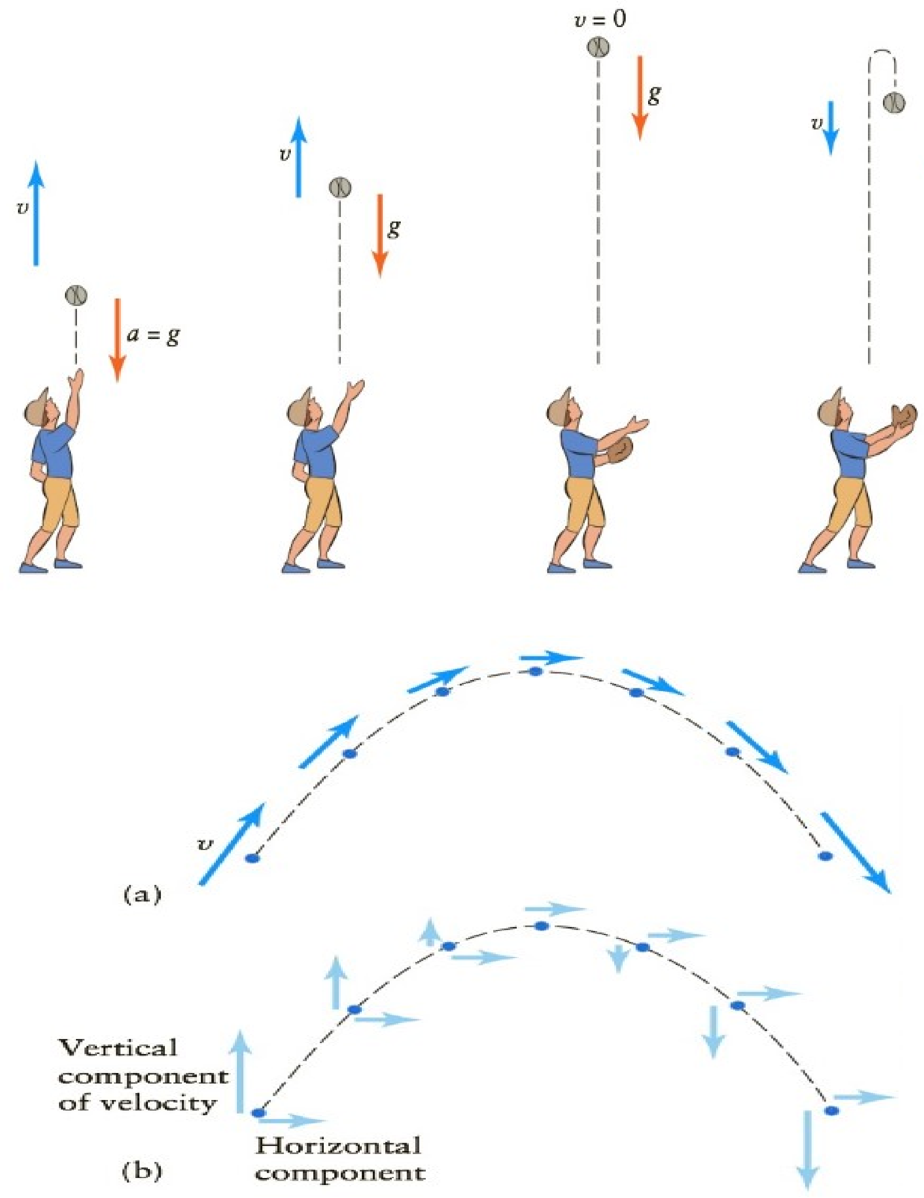
A car manufacturer needs to build a car that accelerates from 0 to 60mph in 10s. The cars mass is 1000kg. What is the force required?

Practice – Newtons 2nd Law

The centripetal acceleration of car going 10m/s around a curve with a radius of 20m. What would be the centripetal force if the car mass is 1000kg?

Projectile Motion

- Free falling object vs projectile motion
- Projectile motion is a confusing free fall and could be broken into vertical and horizontal velocities. What causes motion? The horizontal velocities are constant, however the vertical components change due to the constant gravitational acceleration (weight force)

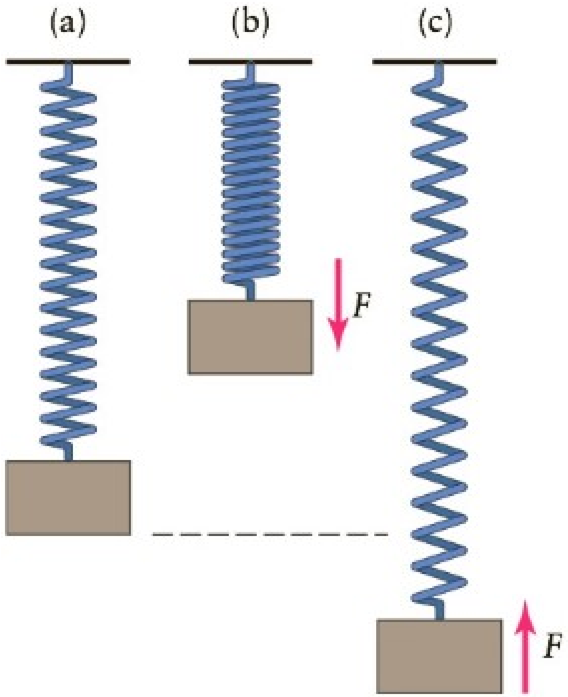


Simple Harmonic Motion

When the block is at rest and not moving it is called equilibrium pic (a), position 0.

If the block is lifted by a distance d, pic (b), it experiences a Downward force $\vec{F}$ toward position 0, upon releasing the force $\vec{F}$ accelerates the block toward position 0.

If the block is lowered by a distance d, pic (c), it experiences an Upward force $\vec{F}$ toward 0, upon releasing the block, the force $\vec{F}$ accelerates the block toward position 0.



Notice the force $\vec{F}$ is proportional to the displacement d and always tries to bring the block toward position 0, kind of restoring force.

Notice the force will always act to bring the block to position 0 and is always opposing the displacement, this explains the negative sign

$$\vec{F} = -k\,d$$

Simple Harmonic Motion

Robert Hook, 1635 England, discovered the proportional relationship. As such Hook’s Law, where the spring constant k is called Hooks constant.

$$\vec{F} = -k\,d$$

Remember Proportional → straight line equation

Example of springs (human flesh, tires, phone cases, veins)

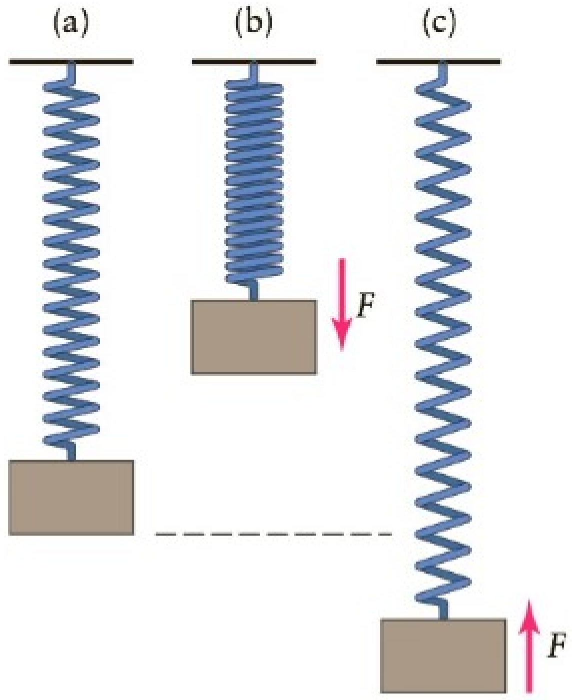
What are the units of F?

What are the units of d?

Can you guess the units of k?

Simple Harmonic Motion – Lets investigate

If the block is pulled down then released, the upward $\vec{F}$ will cause it to accelerate. It will pick up speed as it moves upward, but the $\vec{F}$ & acceleration will decrease as it nears position 0. When it reaches position 0, the $\vec{F}$ is zero, and it stops accelerating but continues its upward motion **(Newton's 1st law)**.



Once it has moved past position d, $\vec{F}$ is downward. The block will slow down, stop at an instant, and then gain speed downward.

This process is repeated over and over: the block oscillates up and down.

$$\vec{F} = -k\,d$$

So how does this motion behave over time?

Simple Harmonic Motion – Lets investigate

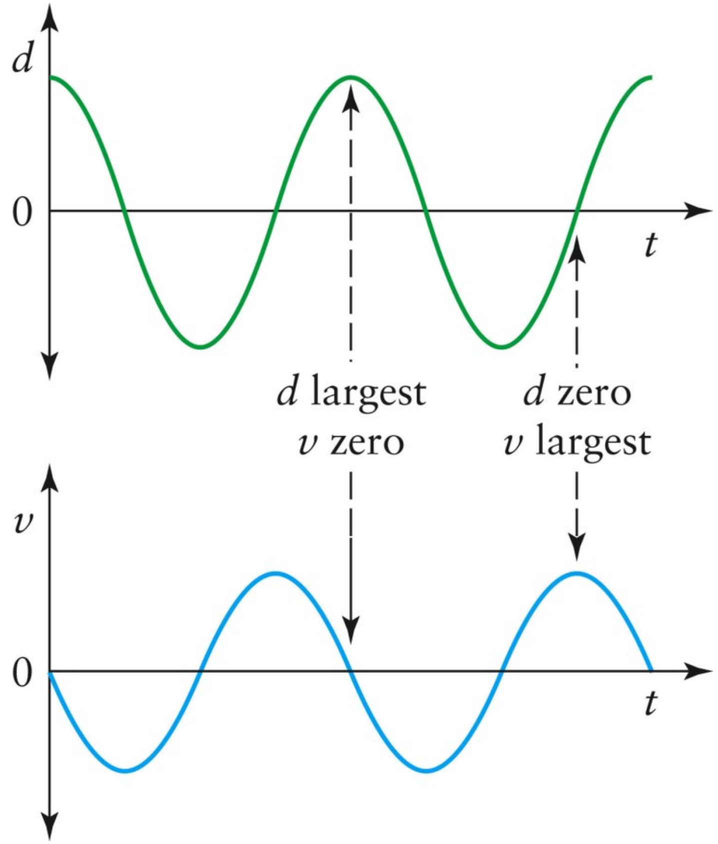
Simple harmonic motion is very common for example air molecules vibrating with the sound from a tuning fork.

The 2 graphs of distance & velocity versus time show a *sinusoidal* shape a wave oscillation with a characteristic wavelength, period and frequency – next slide.

Waves are the building block of sonography and CVS.

Helpful Observation:

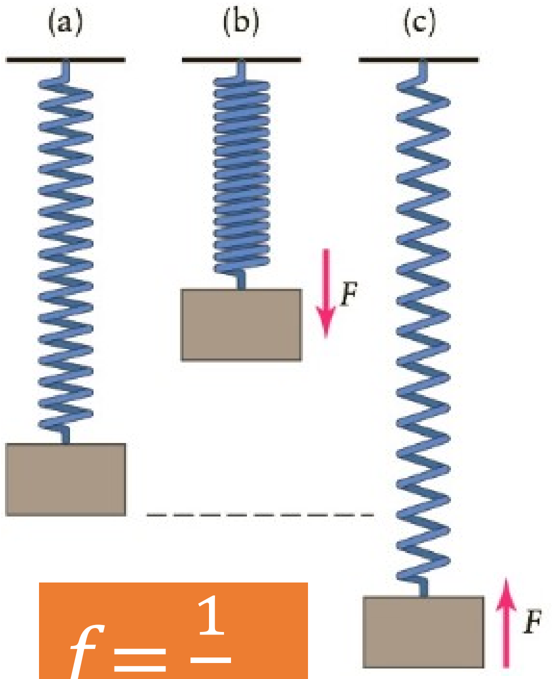
- when d is largest max, v is zero
- when d is zero, v is at it's max



Simple Harmonic Motion

Simple harmonic motion is cyclical motion with a constant **frequency**. In our example, the frequency of oscillation depends only on the mass of the object and the strength of the spring. Higher or lower k & m will change the frequency.

$$f = \frac{1}{2\pi}\sqrt{k/m}$$



The easiest would be by making plots $f(k)$, $f(m)$

As stated in chapter 1: $f = \frac{1}{T}$,

Frequency: The number of cycles of periodic process that occur per unit of time f (1/s) or (s^{-1}) or hertz (Hz)

$$f = \frac{1}{T}$$

Period: The time for one complete cycle of a process that repeats T (s)

$$T = \frac{1}{f}$$

Units: Period (s), frequency (Hz)

Practice – Proportionality

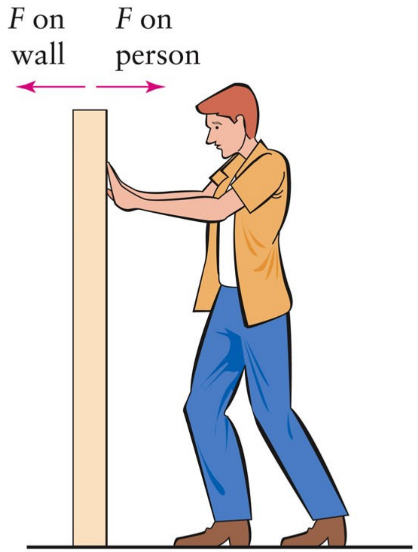
Make a plot of f(m) and f(k)

Practice – Simple Harmonic & Newtons 2nd Law

A ball with a mass of 0.25kg is connected to a spring and displaced by 0.30 m from the origin. Given a spring constant 2.4 N/m find the restoring force acting on the mass? What is the period of the oscillation?

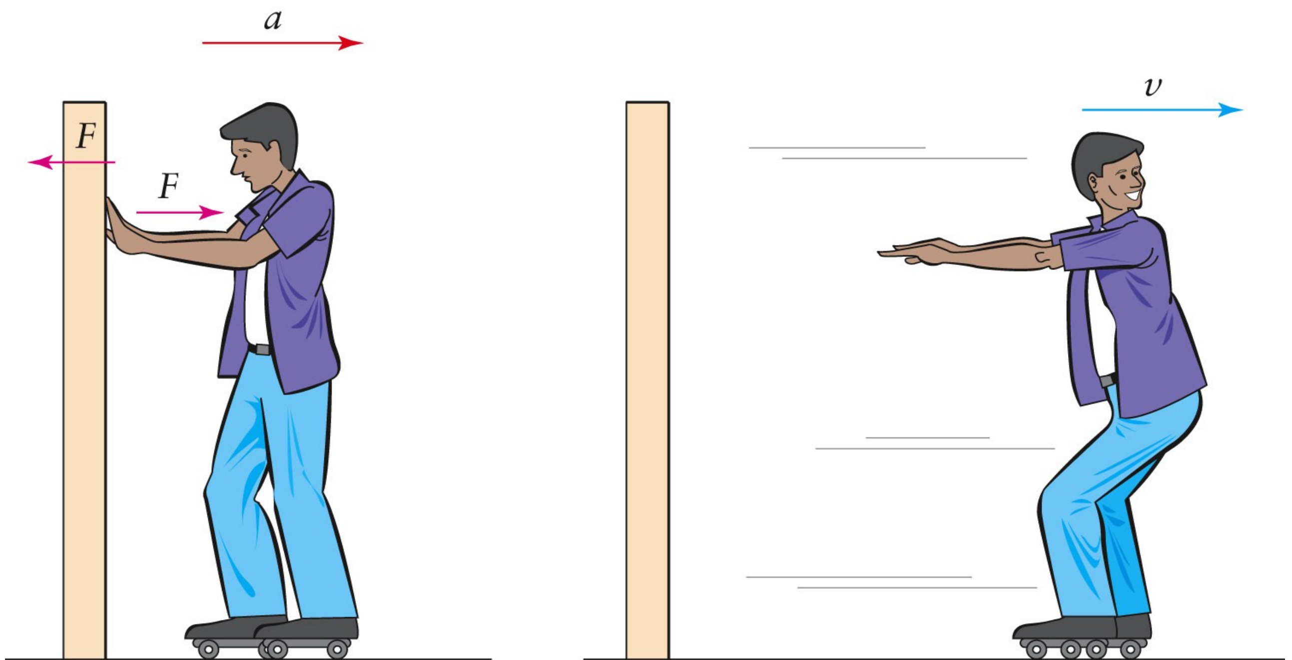
Newtons 3rd Law of Motion

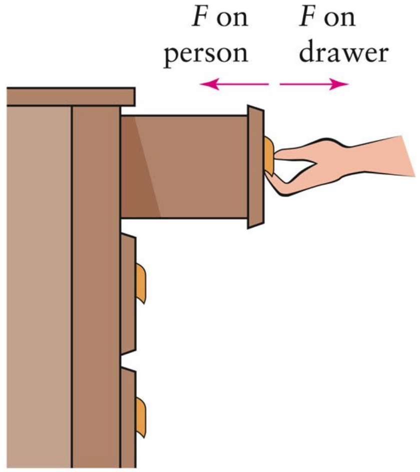
Newton 3rd Law of Motion: Forces always come in **pairs**: when one object exerts a force on a second object, the second exerts an **equal and oppositely** directed force on the first.



Keep it simple but remember, the 3rd law gives an insight into what actually happens in many real systems.

On roller skates if push against a wall, you accelerate backward.





Summary of Force Motion Relation

Nature of Net Force	Description of Motion
Zero net force	Constant velocity: stationary or motion in straight line with constant speed
Constant net force Force parallel to velocity Force opposite to velocity Force perpendicular to velocity	Constant acceleration Motion in a straight line with increasing speed Motion in a straight line with decreasing speed Motion in a circle: radius depends on speed and force
Restoring force proportional to displacement	Simple harmonic motion (oscillation)
Net force decreases as speed increases	Acceleration decreases: velocity reaches a constant value

An updated version is pending.