Physics

Basic Kinematics

Distance, speed and acceleration

In kinematics, the basic measurements we can know are **distance**, **speed** and **acceleration**. And their vector counterparts **displacement**, **veloocity** and **acceleration**.

Distance is simply how much an object has moved in any direction, **displacement** or **position** is how far an object is away from the origin. It is represented as d or alternatively $x - x_0$ or Δx

Speed is the rate of change of distance over time, **velocity** is speed with direction (negative means going the other way around). It is represented as v

Finally, **acceleration** is the rate of change of **velocity**, if its negative it means the object is either slowing down or speeding up the other way.

Relationship between the measurements

Displacement

Displacement from constant velocity:

$$\Delta x = d = vt$$

Instantaneous Displacement from velocity function:

$$\Delta x = d = \int_{t_0}^{t} vdt$$

Velocity

Velocity from constant acceleration:

$$v = v_0 + at$$

Average Velocity:

$$v_{avg} = \frac{\Delta x}{\Delta t}$$

Average Velocity from 2 velocities:

$$v_{avg} = \frac{v_0 + v}{2}$$

Velocity function from given displacement function:

$$v = \frac{dx}{dt}$$

Instantaneous velocity from given acceleration function:

$$v = \int_{t_0}^{t} adt$$

Acceleration

Acceleration function from given displacement equation:

$$a = \frac{d^2x}{dt^2}$$

Acceleration function from given velocity equation:

$$a = \frac{dv}{dt}$$

Average acceleration from velocities:

$$a_{avg} = \frac{dv}{dt}$$

Uniform acceleration

Uniform kinematics

The equations below only apply if we know the acceleration does not change.

Likely, you will find yourself missing 2 variables, one which you need to find. To find that, select the equation with a missing quantity you do not need to find yet.

Velocity accelerating constantly. *Missing quantity:* Δx

$$v = v_0 + at$$

Displacement between 2 instant velocities. *Missing quantity:* a

$$x - x_0 = \frac{v_0 + v}{2} t$$

Displacement of the initial velocity accelerating. *Missing quantity:* v

$$x - x_0 = v_0 t + \frac{1}{2} a t^2$$

Displacement using a final accelerated velocity. *Missing quantity:* v_0

$$x - x_0 = vt - \frac{1}{2} a t^2$$

Square of final velocity from initial squared velocity and acceleration and distance. *Missing quantity:* t

$$v^2 = v_0^2 + 2a(\Delta x)$$

Falling in earth's gravity

As an object falls on earth, there is an accelration caused by gravity:

$$a = -g = -9.8 m/s$$

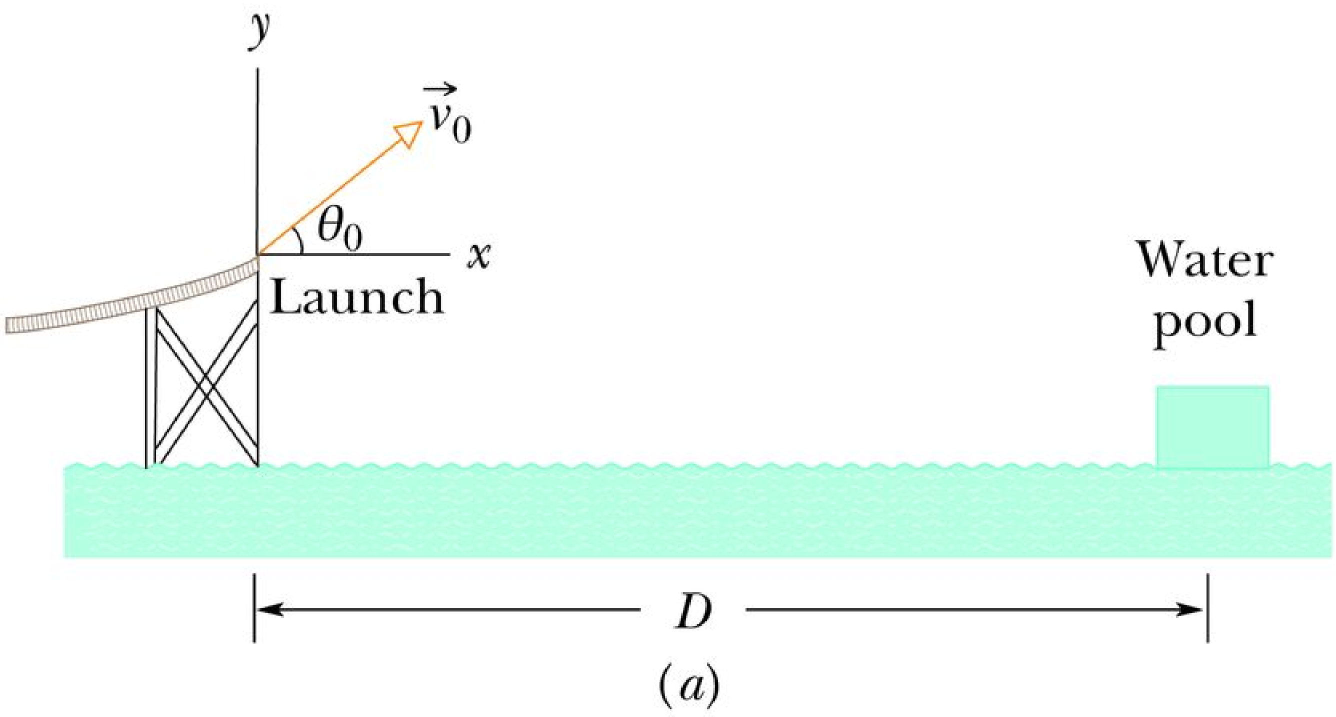
When an object is air with a given velocity, we can assume its velocity to be -9.8 m/s.

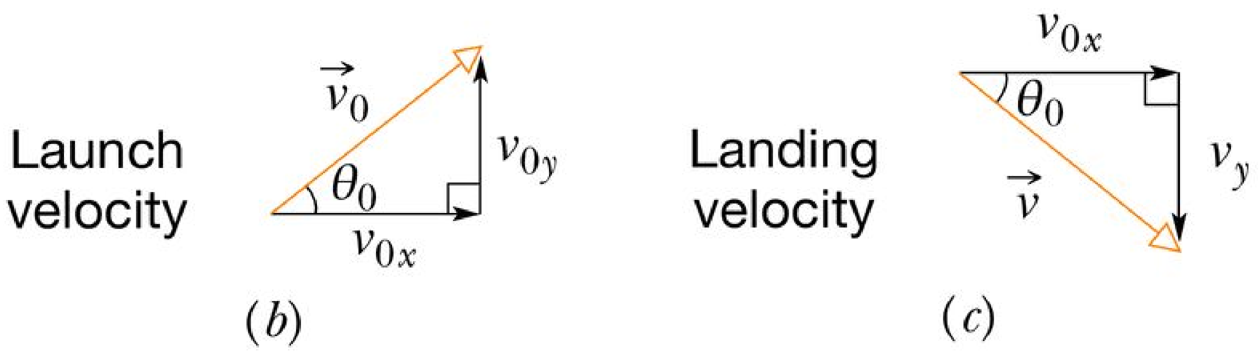
Additionally, the typical turning point where the object starts to fall after having been launched up into the air can be found when the velocity is 0.

Projectile motion

In projectile kinematics, we need to assume the horizontal and vertical motion of the particle seperately.

Here, θ_0 represents the launch angle or the landing angle





Motion Equations

Horizontal displacement due to velocity

$$\Delta x = (v_0 cos\theta_0)t$$

Vertical displacement due to velocity and gravity

$$y_1 - y_0 = \Delta y = (v_0 sin\theta_0)t - \frac{1}{2}gt^2$$

Vertical velocity influenced by gravity

$$v_y = v_0 sin\theta_0 - gt$$

Vertical velocity calculated from vertical displacement

$$v_y^2 = (v_0 sin\theta_0)^2 - 2g(\Delta y - y_0)$$

Trajectory

$$y = (tan\theta_0)x - \frac{gx^2}{2(v_0 cos\theta_0)^2}$$

Horizontal Range R

R is the horizontal distance from the launch point to the point at which the particle returns to the launch height

$$R = \frac{v_0^2}{g} sin2\theta_0$$

Circular motion

Circular velocity

If a particle travels along a circular path of radius r, it is said to be at **uniform circular motion** if the velocity v is constant, and it has an acceleration a of constant magnitude $\overrightarrow{a}$.

$$a = \frac{v^2}{r}$$

$$a = \frac{2\pi v}{T} \; or \; a = \frac{4\pi^2 r}{T^2}$$

Period

This acceleration $\overrightarrow{a}$ is directed towards the center, it is **centripetal**, the time needed for the particle to complete the circle is:

$$T = \frac{2\pi r}{v}$$

Centripetal force

$$F = \frac{mv^2}{r}$$

Newton's motions

Mass and force

$$F = ma$$

> The SI units for calculating F is kilograms for mass, and meters per second squared for acceleration. Force itself is represented as newtons, N.

Equilibrium

A body is set to be in translational equilibrium if all the vectors summed up equals zero.

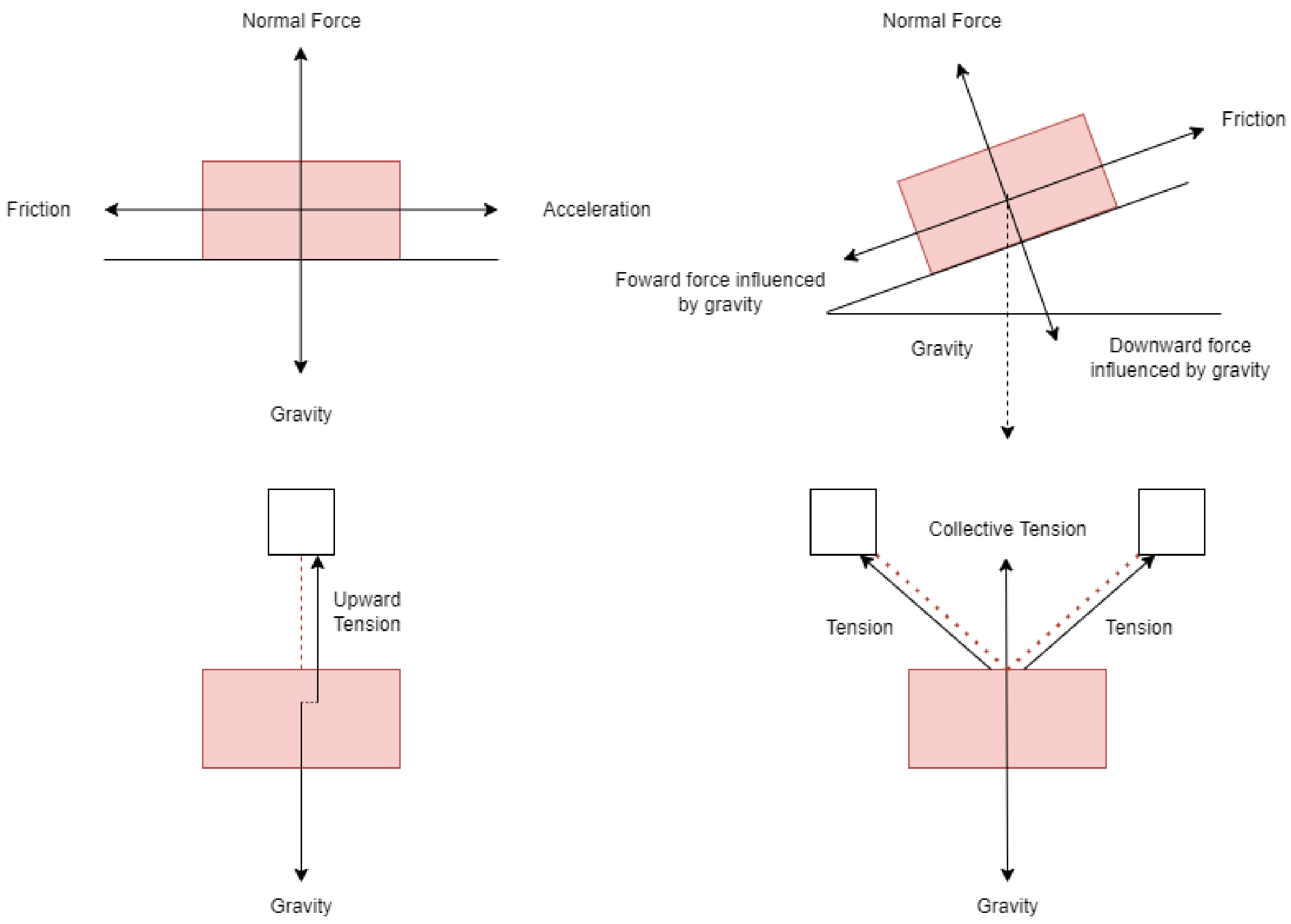
$$\Sigma F_x = 0, \Sigma F_y = 0$$

$$\therefore \sum F = 0$$

In relation to the formula $F = ma$, when the force is 0, that also means acceleration is 0, or when velocity wont change. Mass can also be 0, but that would be pointless to study.

The acting forces

Generally every object has a bunch of forces acting on it. A few examples nad their free body diagrams below illustrate the forces and how they act on a box.



Object on flat ground

For diagram 1, or an object on a flat ground. The object has an opposite force acting upwards. This is the normal force resulting from the surface pushing against the object as the object pushes against the surface. Thats why when you drop an egg, it breaks.

Object on incline

For diagram 2, or an object on an incline. Gravity is always a directly downward vertical force, no matter the incline. This gravity influences 2 other forces, the angle of the incline determines the proportion at which gravity affects these forces.

Object suspended by single rope

For diagram 3, or an object suspended in air. The upward force is instead tension on the rope suspending it. *Note the arrow for upward tension is shifted so you can see the rope, it is still vertically up and centered.*

Object suspended by multiple ropes

For diagram 4, or an object suspended my multiple ropes, the multiple rope that suspend the object contribute to a collective upward force.

When any object is in equilibrium, the opposite forces on one axis always cancel each other out, for example in diagram 1. The normal force and gravity is equal in magnitude and will cancel each other out.

Coefficient of Friction

For an object on ground, the friction force can be found by using the coefficient of friction μ multiplied by the upward normal force F_N.

$$f = \mu F_N$$

However it should be known that there are generally 2 types of friction. **Static friction** μ_s and **Kinetic friction** μ_k.

As the names may imply, static friction applies to objects in rest. Kinetic friction applies when the object is moving.

Tension and pulleys

$$T = mg + ma$$

Gravitational force

$$F = G\frac{m_1 m_2}{r^2}$$

r is the seperated distance between 2 objects, G is the gravitational constant $6.67 \times 10^{-11} N\frac{m^2}{kg^2}$

Application examples

Ferris Wheel Problem

//todo bitch

You have reached the end