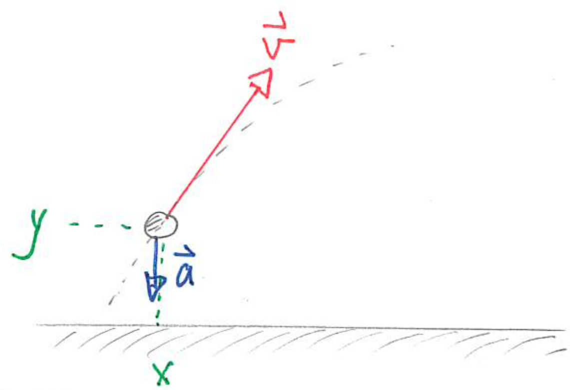
Thurs Discussion quiz Ex 112, 113, 114, 115, 116, 118, 119

Next HW due Monday

Thurs: Physics Seminar

Kinematics

Kinematics provides a way to describe the motion of any object. The system of definitions proceeds from position to acceleration



position ~ describes location via co-ordinates x, y → velocity vector $\vec{v}$ = rate of change of position → acceleration vector $\vec{a}$ = rate of change of velocity $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$

Mathematically the system can be reversed

Known acceleration a_x, a_y → Obtain velocity at later times: v_{fx}, v_{fy} → Obtain position at later times x_f, y_f

Known initial velocity v_{ix}, v_{iy} → Obtain velocity at later times

Known initial position x_i, y_i → Obtain position at later times

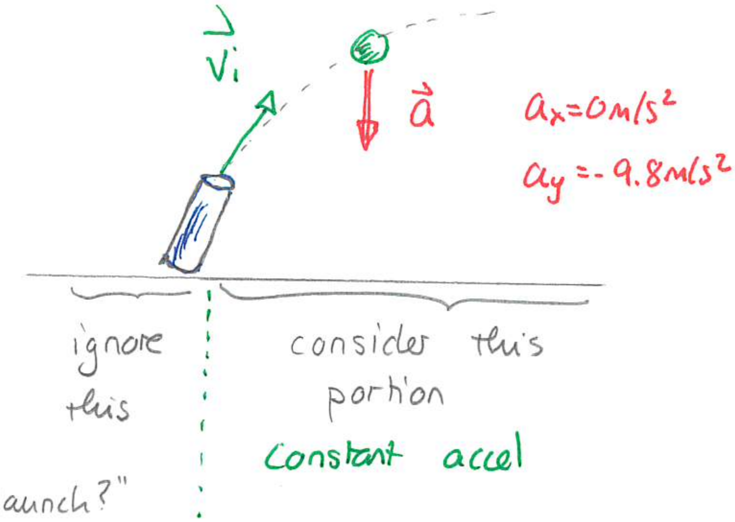
Example: Constant Acceleration

$$v_{fx} = v_{ix} + a_x \Delta t$$
$$v_{fy} = v_{iy} + a_y \Delta t$$

$$x_f = x_i + v_{ix} \Delta t + \tfrac{1}{2} a_x \Delta t^2$$
$$y_f = y_i + v_{iy} \Delta t + \tfrac{1}{2} a_y \Delta t^2$$

Dynamics

We now address questions about why particular motion occurs the way it does. Consider a ball launched. We can use kinematics to analyze the motion after launch, provided we know the initial velocity. Then we ask



"Why is acceleration constant after launch?"

"How does velocity change?"

"Is the a fundamental system that could predict the acceleration?"

Classical physics can answer such questions.

Classical Physics CAN answer

* how velocity changes
* what is the acceleration
* why state of motion changes

Classical Physics CANNOT answer

* why does an object move?
* why is the object's velocity at some initial instant what it is.

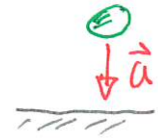
Interactions and Forces

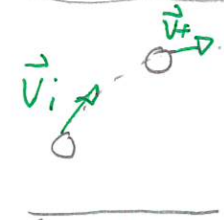
In the case of the ball after launch we suspect that Earth influences the motion. Classical physics describes this:

Ball → Choose an object of interest →

Earth → Identify each other object that interacts with object of interest →

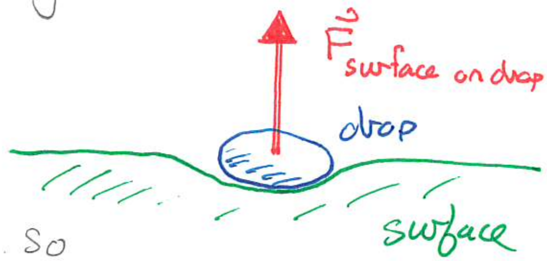
Interactions result in acceleration. Newton's Laws predict acceleration → Acceleration describes how velocity changes.





Forces

The mathematical tool for describing interactions in classical physics will be a force. Consider a bouncing object



DEMO: Juggling Water Drops Videos

Second video gives more detail.

We want to consider the drop's motion. So

Object of interest: drop

Other object that interacts with object of interest: surface

→ Interaction described by a force vector, $\vec{F}_{label}$. This has

a) magnitude, measured in Newtons (N)

b) direction ≈ direction of push pull in interaction

We will say that

Object A exerts a (type) force on object B

(Object A = Other object; object B = Object of interest)

Forces and Motion

We now ask how force affects motion.

DEMO: PhET Forces in One Dimension

Friction: Off

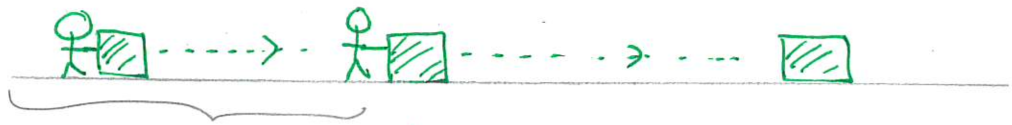
Uncheck: All forces

Show person pushing

Quiz 1 100

Quiz 2 100

The animation suggests different features between the two segments of motion.



* Person exerts force on crate
* Crate accelerates
  - velocity changes

* No force exerted on crate
* Velocity is non-zero but constant
  - velocity does not change.

These suggest:

> An object can move (during some period) even though no force acts on the object during that period.

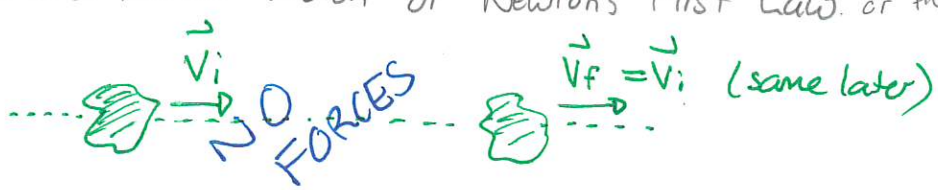
and

> A force acting on an object tends to produce acceleration.

We first answer the question of exactly how forces affect motion for the simple situation where either no forces or else one force act on an object. First

> If no forces act on an object then the object has zero acceleration ⇒ either the object is at rest or else it moves with constant velocity

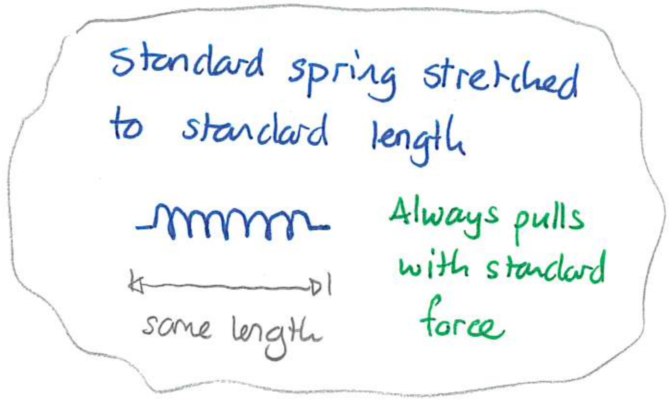
This is a limited version of Newton's First Law or the Law of Inertia



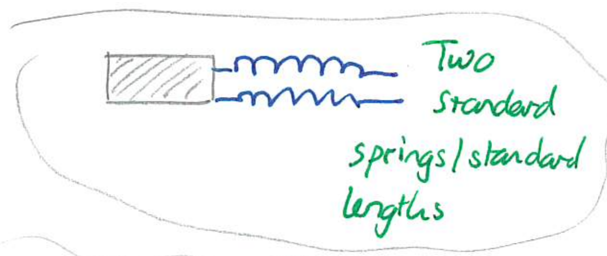
Newton's Second Law (Simplest Case)

Suppose that only one force acts on an object. What effects would this have on the motion? We can answer this quantitatively via the following scheme

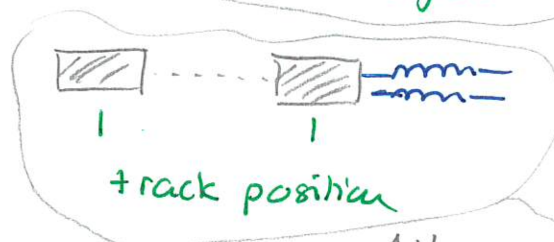
1) Select a special object that always exerts a standard force. We can have multiple copies of this object.

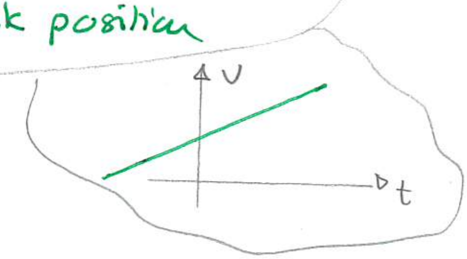


2) Apply varying numbers of these to objects with various masses



3) Observe motion of object





DEMO: Cart / springs

Observations would show

> With only one force:
> 1) acceleration of object is constant
> 2) acceleration is
>   a) directly proportional to force
>   b) inversely proportional to mass
>
> $\Rightarrow a = \text{constant} \times F/m$

Warm Up 1

The constant can be set equal to 1. This effectively fixes the units of force. Then

$$a = F/m \implies F = ma \qquad N = kg\,m/s^2$$

The meaning of one Newton is.

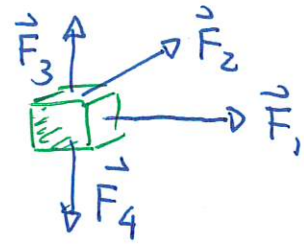
> Suppose that a 1 Newton force acts on an object with mass 1 kg. Then the acceleration of this object will be $1\,m/s^2$.

Multiple forces

In general there may be many forces acting on an object of interest.

DEMO: PhET Forces in One Dimension.

- turn friction on
- vary forces...



In such situations we form a net force via

> Suppose forces $\vec{F}_1, \vec{F}_2, \vec{F}_3, \ldots$ act on an object. Then the net force on the object is
>
> $$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 \quad \text{(all forces on object)}$$

Next class Quiz 3

Newton's First Law

We now arrive at a complete statement of Newton's First Law

> The net force on an object is zero $\iff$ velocity of the object is constant
>
> $\iff$ acceleration of object is zero.

Warm Up 2