Mon: HW by 5pm

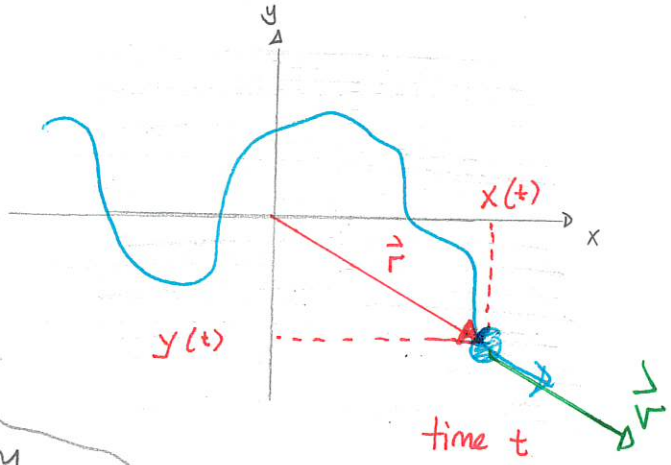
Ex: 91, 93ab, 95, 96, 97, 98, 99, 100

Tues: Warm Up 5 D2L

## Classical Kinematics

Classical kinematics describes an object's motion via its trajectory ~ a map of position versus time.

The hierarchy of definitions is:




Given position at all times:

$x(t)$, $y(t)$

$\vec{r}(t) = x(t)\hat{\imath} + y(t)\hat{\jmath}$

→ differentiate →

Form velocity ~ rate of change of position

$v_x = \frac{dx}{dt}$ $v_y = \frac{dy}{dt}$

$\vec{v} = v_x\hat{\imath} + v_y\hat{\jmath}$

→ differentiate →

Form acceleration ~ rate of change of velocity

$a_x = \frac{dv_x}{dt}$ $a_y = \frac{dv_y}{dt}$

$\vec{a} = a_x\hat{\imath} + a_y\hat{\jmath}$

In physics this usually happens in reverse.

Physics gives acceleration $\vec{a}$ at all times

→ integrate →

Obtain velocity at all later times $\vec{v}(t)$

→ integrate →

Obtain position at all later times

Know velocity at one time, $\vec{v}_0$

Know position at one moment, $\vec{r}_0$

So for constant acceleration $a_x$, $a_y$

⇒

$v_x = v_{ox} + a_x t$

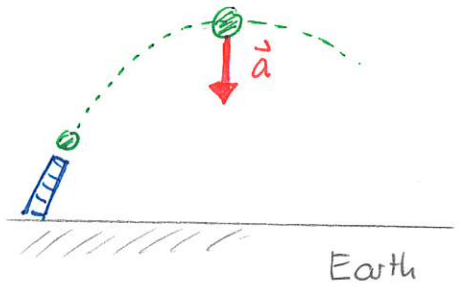
$v_y = v_{oy} + a_y t$

... etc...

# Dynamics

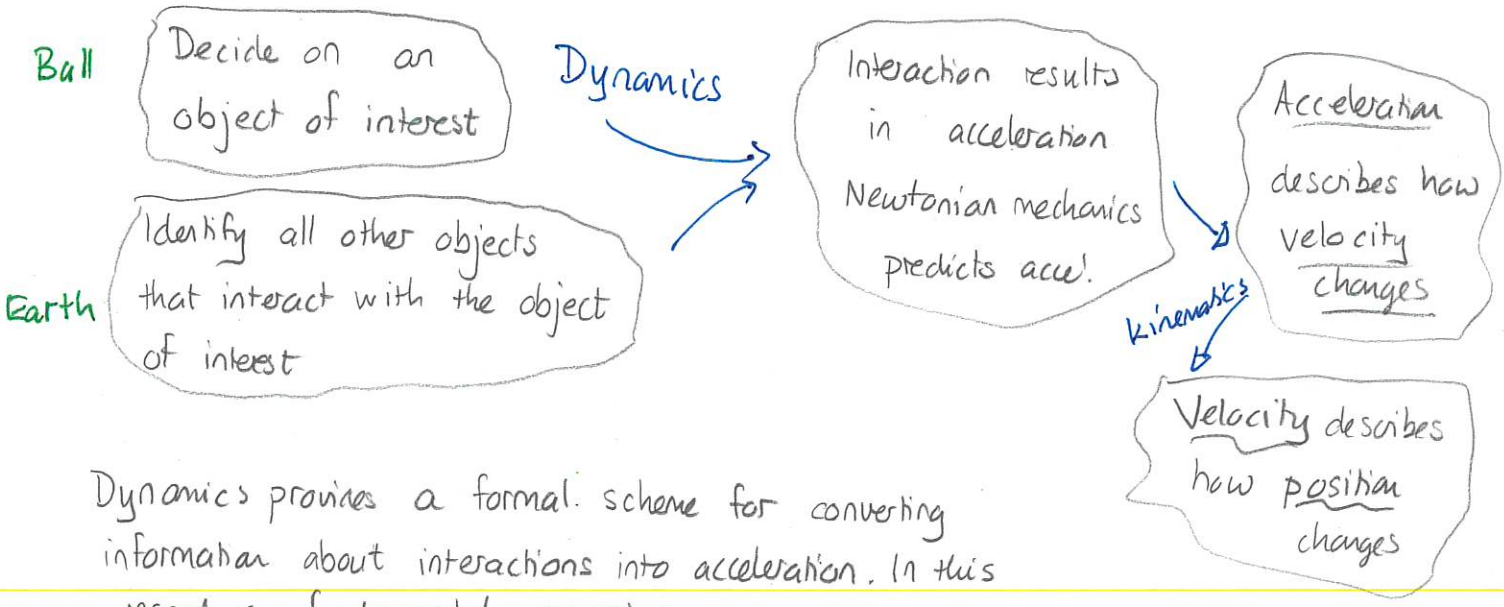
We need a method for finding the acceleration of any object prior to knowing its position and velocity. The part of classical physics that addresses this is called dynamics.

For a projectile, after launch, we know that there is non-zero constant acceleration. The questions are:




* "Why is the acceleration constant?"
* "Is there some fundamental machinery that predicts a constant acceleration?"
* "How does the interaction between Earth + projectile affect its motion or acceleration?"

Newtonian or classical mechanics provides a scheme for addressing such questions. The scheme will be:

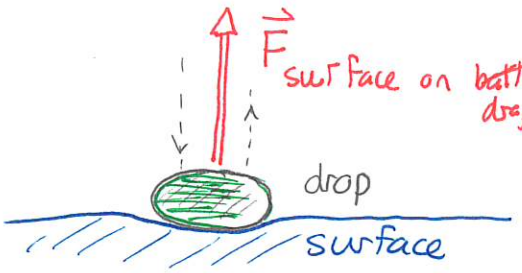



Dynamics provides a formal scheme for converting information about interactions into acceleration. In this regard a fundamental concept is

> Interactions determine acceleration (how velocity changes)

Interactions will not determine why an object has a particular velocity at any instant.

# Forces




We will need a conceptual and mathematical framework for describing interactions between objects.

Demo: Juggling water drops video (Second video)

Consider a water drop bouncing off a surface (e.g. a water surface). During the impact the surface interacts with the drop. We use the scheme:

Drop

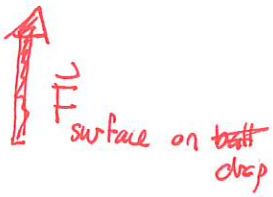
Identify object of interest

Identify another object that interacts with the object of interest.

Surface.

Specify a force (vector) that describes the interaction. This has:

a) magnitude = strength of push/pull in interaction
b) direction = direction of push/pull in interaction.




This force vector will be constructed so as to capture all physical aspects of the interaction. The syntax of this is:

Object exerts a (type of) force on object of interest

other object — object of interest

e.g. Surface exerts a contact force on drop

different!

If we can specify such force vectors then the question is:

How do the forces on an object relate to its motion?

In order to explore the effects of forces, we can consider a variety of idealized experiments

**Demo: PhET Forces in One Dimension**

- Friction: Off.
- Show person pushing
- Uncheck: all forces

**Quiz 1** 100% | 100%

**Quiz 2** 95%

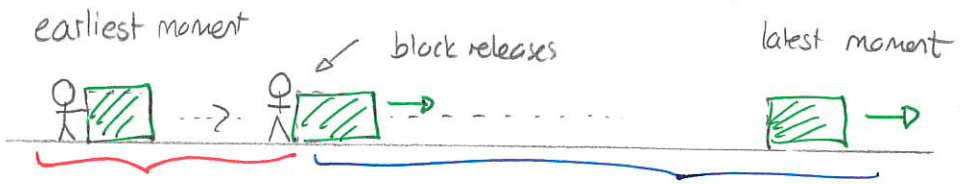
These suggest that

> An object could be moving even though there is no force acting on the object while it moves.

and

> During any period when a force acts on an object its state of motion changes.

So for the motion above, we would need to analyze this in parts




**During earlier period**

* Force on block
* Motion changes

Force during earlier period relevant. (include in analysis)

**During later period**

* No force on block.
* State of motion constant.

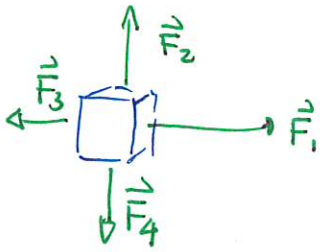
Force during earlier period irrelevant. (exclude from analysis)

## Net force:

In general any object of interest will interact with multiple other objects. Thus there will be multiple forces acting on the object of interest.

**Demo: Forces in One Dimension PhET.**

- turn friction on
- apply larger force
- observe force vectors




In these situations, define a net force via.

> If multiple forces $\vec{F}_1, \vec{F}_2, \vec{F}_3, \ldots$ act on an object then the net force on the object is:
>
> $$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \ldots = \sum_{\text{all forces } i} \vec{F}_i$$

Quiz 3 80% → ≲ 80% – 95%

The net force must be determined at each instant during the objects motion.

Quiz 4 60% → 70% ≲ 95%

In general the net force represents the cumulative effects of all the interactions between the object and its surroundings.

## Newton's First Law

The first step in address the connection between forces and motion regards the case where the net force is zero. Then Newton's First Law states:

> The net force on an object is zero
>
> $\Leftrightarrow$ the velocity of the object is constant

Alternatively

> The net force on an object is zero $\Leftrightarrow$ the acceleration of the object is zero

Quiz 5 90% } 50% – 90%

Quiz 6 90%

Demo: Ball / hoop