Lecture 13

Tues: Review for Class Exam I

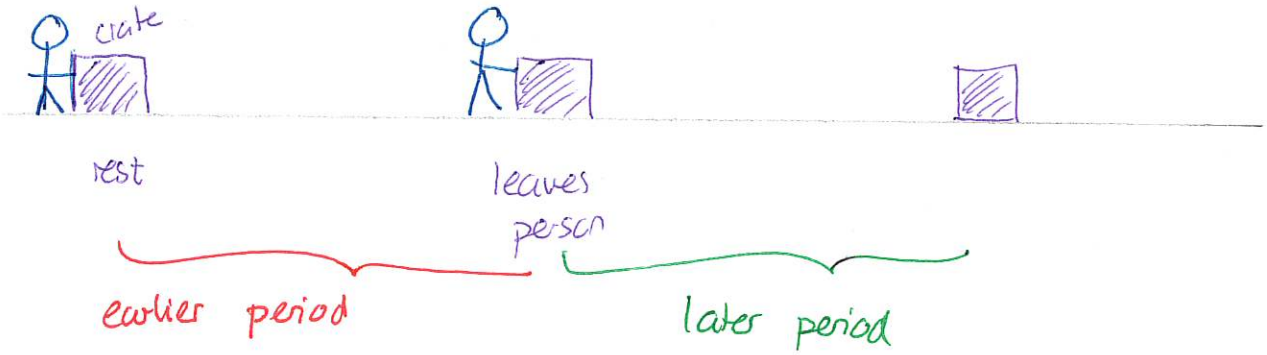
Thurs: Class exam I

Forces and Motion

The interaction between one object and another is described by a force. Consider the animation where a person pushes on a crate.

PhET: Forces in ~~One Dimension~~ and Motion — no friction, crate

— force ~~200N~~ ~~50N~~ 40N for 4s — show applied force graph



During the earlier period the person interacts with the crate. We say the person exerts a force on the crate.

Quiz! 100%

During the earlier period:
* the man exerts a force on the crate
* the state of motion of the crate changes (velocity changes)

During the later period
* the man does not exert a force on the crate
* the crate moves with constant velocity.

We cannot say that: "the crate only moves because there is a force acting on it." If we only observed the later period we would see that there is no force but the crate does move. We always have to assess during a period or at an instant

In general:

> Forces describe how velocity changes at the moment that the forces act on an object (not earlier or later)

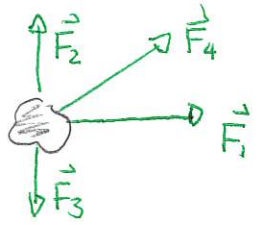
Net force

In general many forces act on an object at any instant. We can combine these into a single collective net force.

PhET: Forces and Motion – no friction ~~crate~~ cabinet
– apply ~~300 750 N 400~~ 200 N

We see that, in the absence of friction there are three forces. We then define net force via

> Consider an object and suppose that forces $\vec{F}_1, \vec{F}_2, \vec{F}_3, \ldots$ act on the object. Then the net force on the object is a single vector
>
> $$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots$$ ADD VECTORS



Quiz 2 70% – 90%

Newton's First Law

The simplest situation to consider is that where the net force on an object is zero. Here Newton's First Law states:

> The net force on an object is zero $\Leftrightarrow$ the object's acceleration is zero
>
> moves in a straight line with constant velocity.

Warm Up!

Quiz 3 – 40% – 80%
Quiz 4 – 90%

DEMO: Hoop / ball

Dynamical effects of forces

If the net force on an object is non-zero then Newton's First Law suggests that the object's acceleration is non-zero. How can we predict the acceleration? This requires:

1) a method for quantifying force and determining the magnitude of a force
2) a method for relating non-zero force to acceleration.

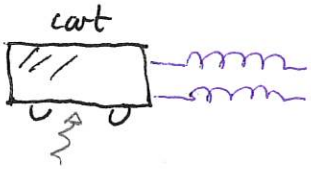
The scheme is

Decide on a special object that produces the same (standard) force

standard spring stretched standard length

length always same

↳ Apply variable numbers of such standard springs to various objects



two standard springs

can vary mass

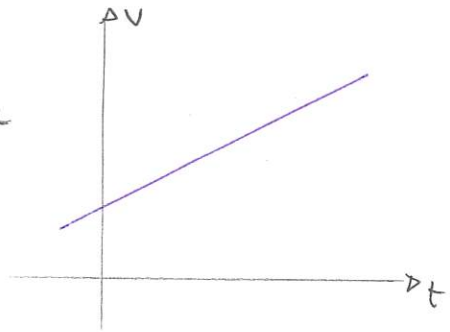
↳ Observe motion of object by tracking its position

Observations indicate

If there are no other interactions then

1) graph of v vs t ⇝ straight line
   ⇒ constant acceleration
2) the acceleration is constant and:
   a) inversely proportional to mass
   b) directly proportional to force.

   ⇒ $a = \text{constant} \times F/M$



Warm Up 2

The constant can be fixed to 1 by deciding on the units of force

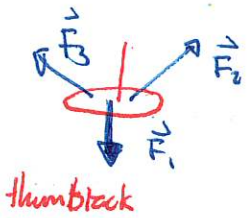
> A force of 1 Newton N acting on an object with mass 1kg will produce an acceleration of $1 m/s^2$ in the absence of other forces

Then $F = ma$.

Newton's Second Law

If multiple forces act on an object then Newton's Second Law predicts the acceleration via:

1) Consider an object of interest. Let m be the mass of the object



2) List all forces on the object. Form the net force

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots$$

3) Then the acceleration of the object satisfies

$$\vec{F}_{net} = m\vec{a}$$

Thus in Newtonian mechanics

> Force provides acceleration $\Rightarrow$ forces are related to changes in velocity

We will see that forces are not immediately connected to motion. Consider

1) Is the direction of the net force the same as the direction of motion?

Quiz 5 90%

> Sometimes the net force is along the direction of motion
> Sometimes " " " " not along the direction of motion

2) Is the velocity of an object determined by the net force?

Quiz 6

> The velocity of an object can differ even for the same net force applied for the same time.