Acceleration and forces



Which hits the ground first?

Day 4:
What causes acceleration?
Gravity

Reminders:
HW 2 due Monday
Reading for Tues:2.2 Bloomfield
Visit Help sessions today
Next up: forces

Tuesday:

Motion at constant velocity:
- $x = x_0 + vt$

Motion at constant acceleration:
- $v = v_0 + at$

- Velocity is the gradient of a position time graph
- Acceleration is the gradient of a velocity versus time graph

Today:

Motion at constant acceleration (cont):
- $x = x_0 + v_0 t + ½ at^2$

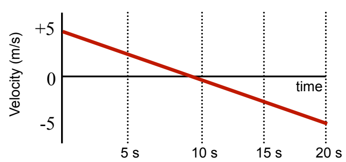
But what causes acceleration? → Forces

Motion with constant force and acceleration
- Newton's second law: $F_{net} = ma$
- Force and acceleration due to gravity

Graph shows the velocity of a car as a function of time.
What is its acceleration?

a. $- 0.25 m/s^2$
b. $+0.25 m/s^2$
c. $- 0.5 m/s^2$
d. $+ 0.5 m/s^2$
e. $0 m/s^2$

$$a = \frac{v_f - v_i}{t_f - t_i} = \frac{-5m/s - 5m/s}{20s - 0s} = \frac{-10m/s}{20s} = -0.5 m/s^2$$



Equations when velocity is changing

What if velocity is changing? … Accelerating

Acceleration (a) = $\frac{v_f - v_i}{t_f - t_i}$

Rearrange:

$v_f - v_i = a(t_f - t_i)$
$v_f = v_i + a(t_f - t_i)$

Now let t_i = 0s and so $v_i = v_0$ and drop the f subscript

$$v = v_0 + a t$$

Motion at constant acceleration

$$v(t) = v_0 + at$$

your velocity at time t depends on

Your velocity when you started,

How fast and in what direction you are accelerating,

How long you've been going

What about position at constant acceleration?

So far: $x = x_0 + vt$ (a = 0) (1)
$v = v_0 + at$ (a = constant) (2)

From (1) : $x = x_0 + v_{average}t$ (if $a \neq 0$) (3)
$v_{average} = v_0 + ½$ (change in velocity)
(change in velocity) =
$v - v_0 = (a t)$ (from (2))

$\Rightarrow v_{average} = v_0 + ½ at$ (4)

Substitute (4) into (3)

$x = x_0 + (v_0 + ½ at)t$

$$x = x_0 + v_0 t + ½ at^2$$

Position at constant acceleration

$x(t) = x_0 + v_0\, t + \frac{1}{2} at^2$

your position at time t depends on

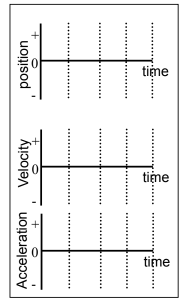
Where you started, and

How fast and in what direction you started going, and

How fast and in what direction you're accelerating, and

How long you have been going

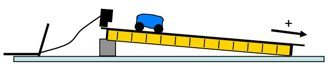
A car accelerates at a steady rate from stationary along a straight road. Sketch position, velocity and acceleration as a function of time

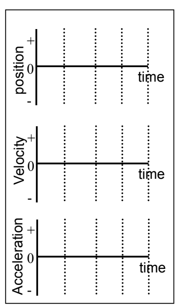


Hint:
a is slope of v vs t
v is slope of x vs t

Motion down a ramp 1 (with forces!)

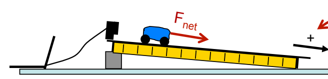
Sketch position, velocity and acceleration vs time graphs for the car **moving away** from the motion detector and **speeding up** at a steady rate.





Hints:
- The origin is always at the motion detector
- Start with acceleration
- a is slope of v vs t
- v is slope of x vs t

Motion down a ramp (with forces!)



Clearly identify the POSITIVE direction of motion

What causes the acceleration down the track?

The net force on the car

$\underline{F}_{net} = m\, \underline{a}$
(Newton's second Law of motion)

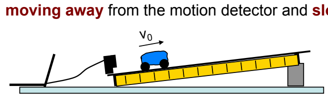
- Force and Acceleration are vectors, mass is a scalar
- Acceleration is always in same direction as net force
- Force is pointing in **positive** direction. So acceleration is also **positive**

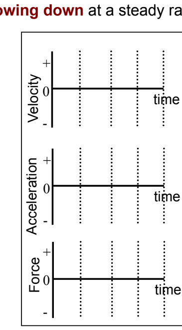
Force

- Force is a VECTOR
- Units: Newton (N)
- $1N = 1kg * 1m/s^2$
- Net force on object = Vector sum of all forces acting on object
- N2: $\underline{F}_{net} = m\underline{a}$

Motion down a ramp 2 (with forces!)

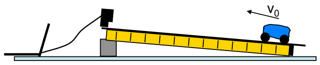
Sketch **Velocity, acceleration and net force vs. time** graphs for the car **moving away** from the motion detector and **slowing down** at a steady rate.

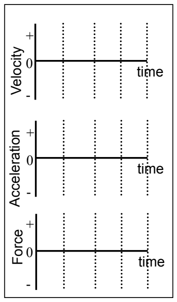




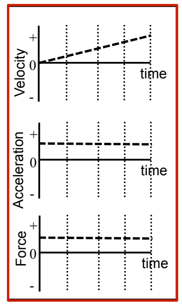
Motion down a ramp 3 (with forces!)

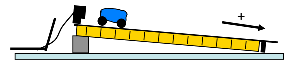
Start car up ramp with velocity v_0 (give it a push). Sketch **velocity, acceleration and net force vs. time** graphs for the motion that follows.





Motion down a ramp 4 (with forces!)



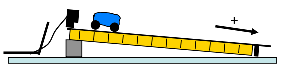


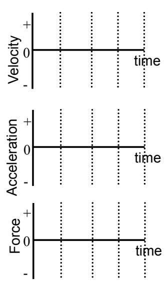
The car is released from rest and exhibits the velocity, acceleration and net force graphs given by the dashed lines.
Now, add weights to the car and redo experiment.
Sketch the new velocity, acceleration and net force graphs on the same axes.

Motion down a ramp 4

Just car

Car with extra weights





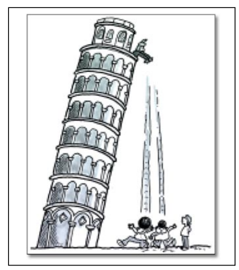
When weights added:
- Greater net force on car.
- More mass.
- These 2 changes cancel

F_{net} = mass x acceleration

Acceleration $= \frac{F_{net}}{\text{mass}}$

Gravity

Force and acceleration due to gravity

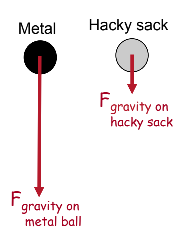


Dropping stuff

I drop heavy metal ball and a hacky sack from lecture hall ceiling

a. the light ball will fall fastest and hit the ground first
b. they will fall at the same speed and hit the ground together
c. the heavy ball will fall fastest and hit the ground first.
d. neither will fall, they will stay suspended in mid air
e. they will both fall up and hit the ceiling.

Dropping stuff



- **$F_{gravity}$ = mass_{object} × g**
  Where g = 9.8 m/s² (on earth)

- $F_{net} = ma \Rightarrow a = \frac{F_{net}}{m}$
- In this case, $F_{net} = F_{gravity} = mg$
  $\Rightarrow a = \frac{mg}{m} = g$
- a = 9.8 m/s² for both hacky sack and metal ball!

Acceleration due to gravity is independent of mass!

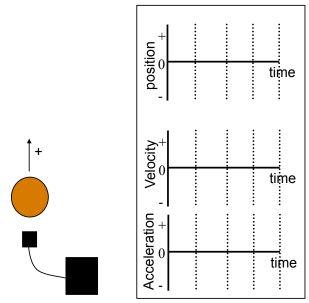
- $v = v_0 + at$
- $x = x_0 + v_0t + \frac{1}{2}at^2$

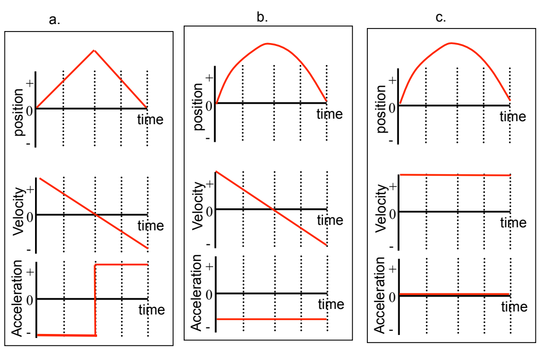
a, x_0 and v_0 the same $\Rightarrow$ v and x the same

The leaning tower

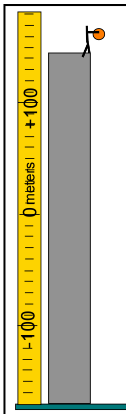
Question: Relating position, velocity and acceleration

Toss a basketball straight up in air with initial velocity v_0
Plot position, velocity and acceleration vs time.





d. none of the above.



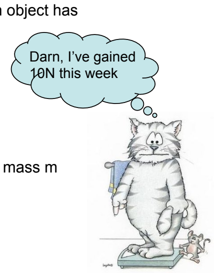
If I drop the basketball off a tall building, what will the ball's the velocity be after 0.5 s (define up as positive direction):
a. 1 m/s b. 9.8 m/s c. -9.8 m/s
d. Not enough information given to determine
e. -4.9 m/s

Common confusion: Weight and Mass…….

Mass is a measure of how much stuff an object has
Units: kg (old fashioned units = lb)

$Force_{net}$ = mass X acceleration
Units: Newton (N).
1 kg X 1 m/s^2 = 1N

Weight = force of gravity on an object of mass m
Measured in N NOT kg or lb
kg and lb are units of mass



The acceleration due to gravity on the Moon is less than it is on Earth.
Suppose
m_E = your mass on Earth
m_M = your mass on the Moon
w_E = your weight on Earth
w_M = your weight on the Moon.

Which statement is correct?

a) $m_E > m_M$, $w_E > w_M$
b) $m_E = m_M$, $w_E > w_M$
c) $m_E = m_M$, $w_E = w_M$
d) $m_E > m_M$, $w_E = w_M$
e) None of these