Acceleration and forces

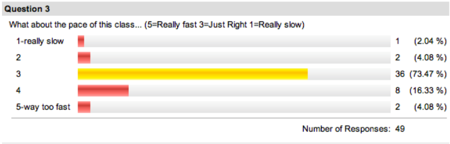
Which hits the ground first?

Day 4:
What causes acceleration?
Gravity

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

Feedback . .

- HW 1
  - - make sure to submit
- Help Room: will you attend Thursdays:
  a) Yes b) No



Question 3

What about the pace of this class... (5=Really fast 3=Just Right 1=Really slow)

1-really slow	1	(2.04 %)
2	2	(4.08 %)
3	36	(73.47 %)
4	8	(16.33 %)
5-way too fast	2	(4.08 %)

Number of Responses: 49

Tuesday:

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

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

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

Today:

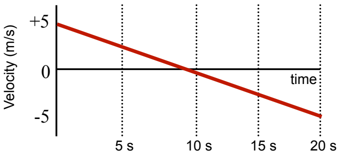
Motion at constant acceleration (cont):
- $x = x_0 + v_0 t + ½ at^2$

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



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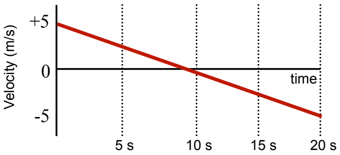
$$a = \frac{v_f - v_i}{t_f - t_i} = \frac{-5m/s - 5m/s}{20s - 0s} = \frac{-10m/s}{20s} = -0.\ 5m/s^2$$



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

$$\boxed{v = v_0 + a\,t}$$

Motion at constant acceleration

$$\boxed{v(t) = v_0 + at}$$

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)

$v = v_0 + at$ $(a = \text{constant})$ (2)

From (1) : $x = x_0 + v_{average}t$ $(\text{if } a \neq 0)$ (3)

$v_{average} = v_0 + ½\,(\text{change in velocity})$

(change in velocity) = $v - v_0 = (a\,t)$ (from (2))

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

Substitute (4) into (3)

$x = x_0 + (v_0 + ½\,at)t$

$$\boxed{x = x_0 + v_0t + ½\,at^2}$$

Position at constant acceleration

$$\boxed{x(t) = x_0 + v_0\,t + ½\,at^2}$$

your position at time t depends on

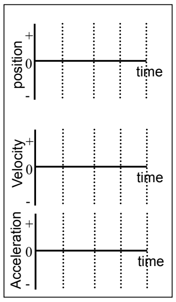
Where you started, and

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

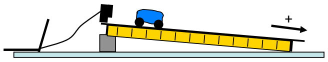
A car accelerates at a steady rate from stationary along a straight road. Sketch position, velocity and acceleration as a function of time



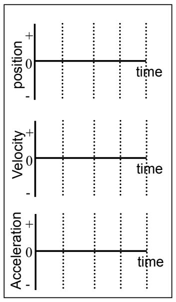
Hint:
a is slope of v vs t
v is slope of x vs t

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.

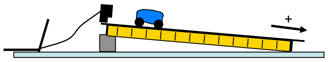


Hints:
- The origin is always at the motion detector
- Start with acceleration
- a is slope of v vs t
- v is slope of x vs t



Motion down a ramp 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.



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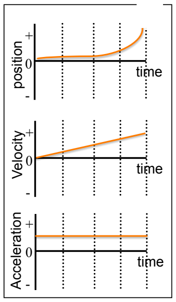
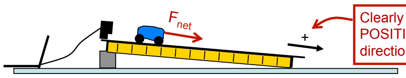


Motion down a ramp (with forces!)



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)

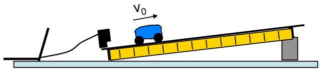
- Force and Acceleration are vectors, mass is a scalar
- Acceleration is always in same direction as net force
- Force is pointing in **positive** direction. So acceleration is also **positive**

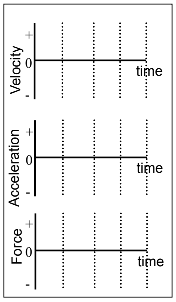
Force

- 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$\underline{a}$

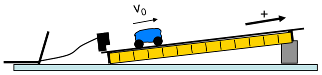
Motion down a ramp 2 (with forces!)

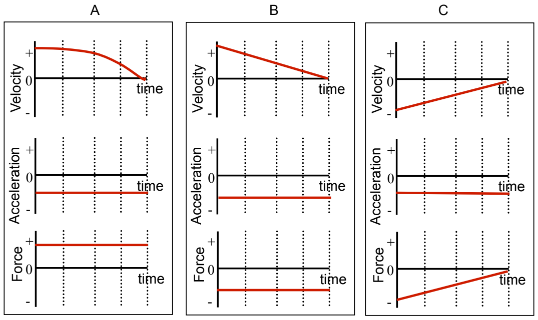
Sketch **Velocity, acceleration and net force vs. time** graphs for the car **moving away** from the motion detector and **slowing down** at a steady rate.



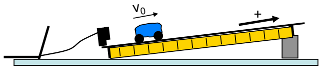


Motion down a ramp 2

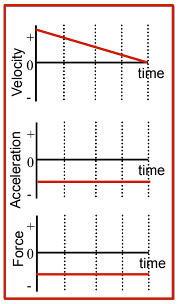




Motion down a ramp 2



B

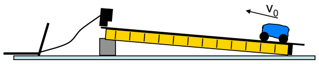


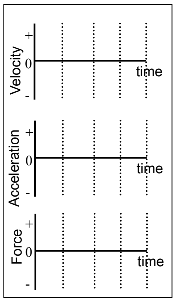
Why B??

- Constant net force down the slope in negative (-) direction
- $\underline{F}$ = m$\underline{a}$
  - ⇒ Constant acceleration down the slope in negative (-) direction.
- Initial velocity positive (+) and > 0.
- Acceleration is slope of v vs t

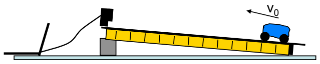
Motion down a ramp 3 (with forces!)

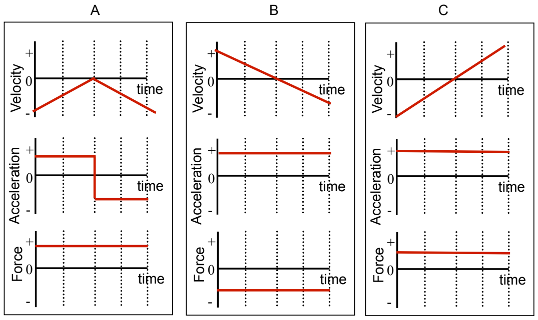
Start car up ramp with velocity v_0 (give it a push). Sketch **velocity, acceleration and net force vs. time** graphs for the motion that follows.



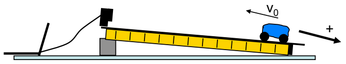


Motion down a ramp 3



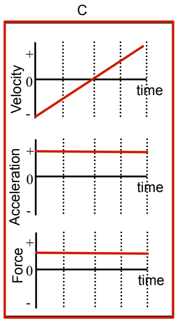


Motion down a ramp 3

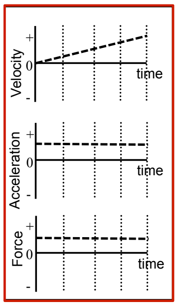


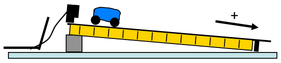
Why C??

- Constant net force down the slope in positive (+) direction
- F = ma
  ⇒ constant a in positive (+) direction
- Velocity
  - starts negative (going up ramp)
  - instantaneously zero at top
  - then positive (going down ramp)



Motion down a ramp 4 (with forces!)



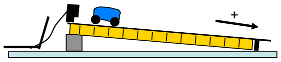


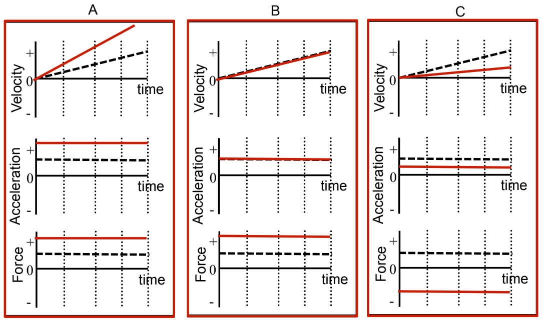
The car is released from rest and exhibits the velocity, acceleration and net force graphs given by the dashed lines.
Now, add weights to the car and redo experiment.
Sketch the new velocity, acceleration and net force graphs on the same axes.

Motion down a ramp 4

┄ Just car

— Car with extra weights

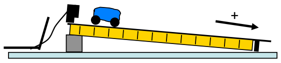


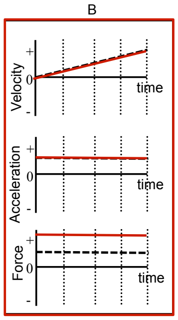


Motion down a ramp 4

┄ 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

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

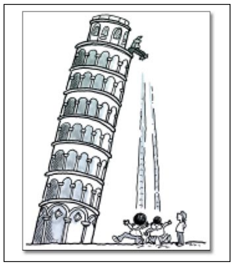
larger

unchanged

larger

Gravity

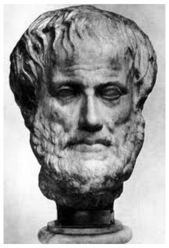
Force and acceleration due to gravity



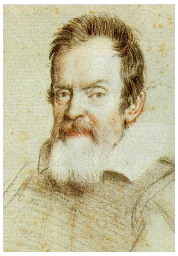
Dropping stuff

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.



Aristotle (500 BC):
Heavier ball hits first



Galileo (1600 AD):
Let's go check!

Dropping stuff

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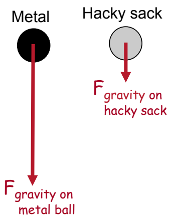

- **$F_{gravity}$ = $mass_{object}$ × g**
  Where g = 9.8 m/s^2 (on earth)

- **$F_{net} = ma$** $\Rightarrow a = \frac{F_{net}}{m}$
- In this case, $F_{net} = F_{gravity} = mg$

$$\Rightarrow a = \frac{mg}{m} = g$$

- a = 9.8 m/s^2 for both hacky sack and metal ball!

Acceleration due to gravity is independent of mass!

$$\left.\begin{array}{l} \bullet\ v = v_0 + at \\ \bullet\ x= x_0 + v_0t + \frac{1}{2} at^2 \end{array}\right] \begin{array}{l} a,\ x_0 \text{ and } v_0 \text{ the same} \\ \Rightarrow v \text{ and } x \text{ the same} \end{array}$$

Dropping stuff

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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.