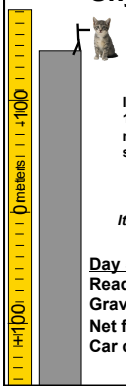
Skydiving and car crashes



If I drop a cat from a 10 story building is it more or less likely to survive than you ??

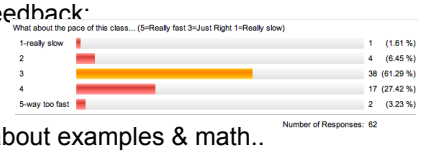
It's not the speed that is a problem it's the stopping

Day 5:
Reading quiz
Gravity (cont)
Net forces: Terminal velocity
Car crashes

Reminders:
Homework 3 online
Midterm next Thursday
Don't forget to 'submit' your HW

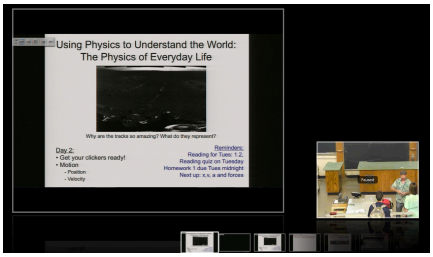
Feedback

- How was help room?
- HW:
  - how many thought difficult?
  - After HR?
- Online feedback:



- A word about examples & math..
  - Graphs / interpretation
  - Negative velocity
- See class website for more :)

Relive the experience!



http://classcapture.colorado.edu/Mediasite/Catalog/Full/49b07ec962f946eaadad598fb352277421/?state=4yGM0OlG8xJLUdq7CvoU

Reading quiz

Which required larger individual forces:
a) Lifting 50 1kg bricks all at once
b) Lifting 50 1kg one at a time
c) They require the same force

Which of the following is **not true** in riding up in an elevator?
a) There is a force of gravity pulling you down
b) There is a force of the floor pushing you up
c) These forces always balance each other out.

How much harder is it to slide a stack of two identical books across a table than it is to just slide one of those books
a) Half as hard
b) Just the same
c) Twice as hard

Reading quiz

Which required larger forces:
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b) Lifting 50 1kg one at a time
c) They require the same force

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b) Just the same
c) Twice as hard

Mid term exams

- **Hour exams in Duane G1B30 on next one, Sept 20**
  - **worth 40 points.**
  - **no make-up exams.**
  - **Exam will be closed book.**
- **Accommodations, please see me. G1b31 11-1p**
- **ONE 3 by 5 inch formula card. You can WRITE anything on it BY HAND.**
- **Calculator.**
  - **Calculator cannot connect to outside world. No calculators on cell phones or laptops allowed.**
  - **No sharing of calculators.**
- **Your lowest midterm score will be dropped.**
- **Exam grades and solutions will be posted after the exam on D2L.**

Midterm preparation

- Prepare by applying the principles we have learned – practice.
- You shouldn't memorize answers to specific questions.
- Make a formula card now with the important equations.
- Go over homeworks, class clicker questions, questions in the book.
  - Not sure how to get the answer – take it to the helproom.
- Tuesday will be a review lecture
  - Lots of clicker questions
  - Do your reviews BEFORE Tuesday and treat Tuesday as a practice exam.

If you wish we can have help room office hours Wed 2:30-4p

Summary

Last time:

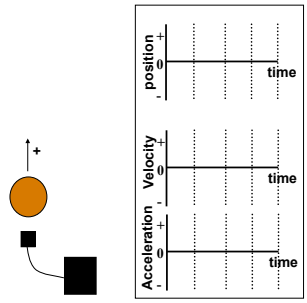
- Introduced forces
- $\underline{F}_{net} = m\underline{a}$
- $F_{gravity} = mg$

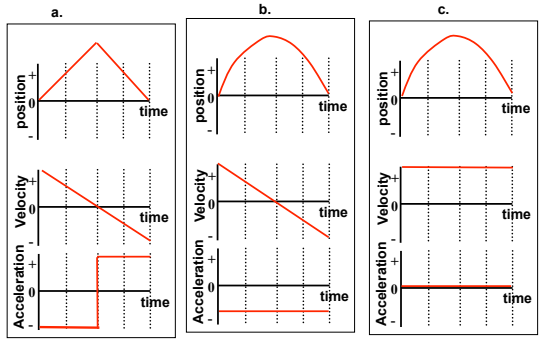
Today: More on forces

- More on gravity
- Net forces : Terminal velocity
- Car crashes

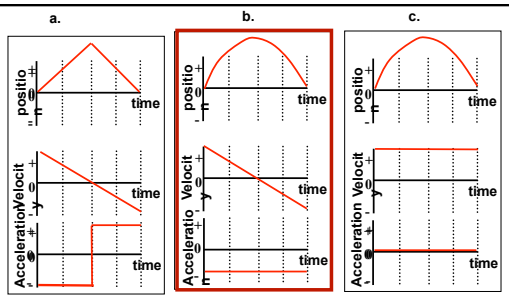
Question: Relating position, velocity and acceleration

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

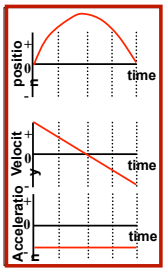




d. none of the above.



- a = -g because the only force acting on the ball is gravity. Therefore a is constant and downwards.
- a is slope of v vs t
- v is slope of x vs t



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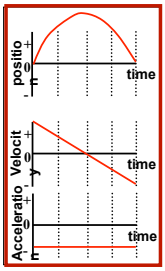
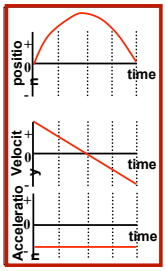
- v is slope of x vs t

b.

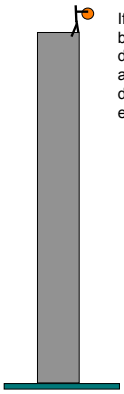


Would these plots for a, v and x change if I used a medicine ball instead of a basketball (same initial velocity)?
a. No
b. Yes

b.

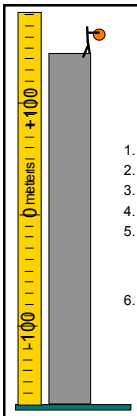


Would these plots for a, v and x change if I used a medicine ball instead of a basketball?
a. No
b. Yes



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

Hint:
$x = x_0 + v_0t + \frac{1}{2} at^2$
And
$v = v_0 + at$ (const a)
And
$x = x_0 + vt$ (const v)



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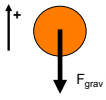
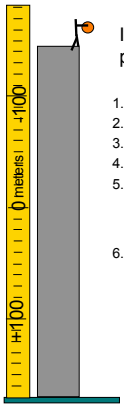
a. 1 m/s b. 9.8 m/s c. -9.8 m/s
d. Not enough information given to determine
e. -4.9 m/s

1. Draw 'free body' (force) diagram of ball
2. Define + direction (up)
3. Recall : $v = v_0 + at$, we want v
4. $v_0 = 0$
5. What is a?
   - First find net force
   - $F_{net} = F_{grav} = -mg$
   - $a = F_{net}/m = -g$
6. $v = 0 + (-9.8 m/s^2)\ (0.5s)$
   $= -4.9 m/s$

Free body diagram



Important note:
g is just a number number ($+9.8 m/s^2$) & positive
Get the sign (±) in front of F_{grav} and g from your diagram



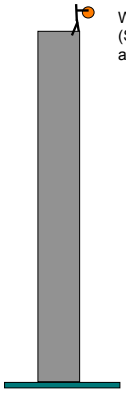
If we chose to define downwards as the positive direction instead……

1. Draw 'free body' (force) diagram of ball
2. Define positive direction (up)
3. Recall : $v = v_0 + at$, we want v
4. $v_0 = 0$
5. What is a?
   - First find net force
   - $F_{net} = F_{grav} = +mg$
   - $a = F_{net}/m = +g$
6. $v = 0 + (+9.8 m/s^2)\ (0.5s)$
   $= +4.9 m/s$

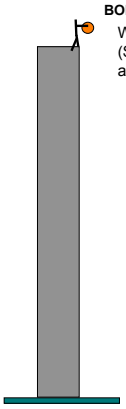
Free body diagram

Important note:
In equations g is always a positive number ($+9.8 m/s^2$)
Get the sign (±) infront of F_{grav} and g from your diagram

BONUS QUESTION:



What will the position of the ball be after 0.5s?
(Set the position of my hands to be the origin and set up as the positive direction)
a) 2.5m
b) - 2.5m
c) 4.9 m
d) - 4.9 m
e) None of these



BONUS QUESTION:

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(Set the position of my hands to be the origin and set up as the positive direction)

a) 2.5m
b) - 2.5m
c) 4.9 m
d) - 4.9 m
e) None of these

We want x. We know x_0, v_0, t and a (from previous question).
- What equation includes these things but doesn't include anything else we don't know about?
- $x = x_0 + v_0t + \frac{1}{2} at^2$ looks useful

$x = 0 + 0*t + \frac{1}{2} (-9.8)(0.5)^2$
$= -1.2m$

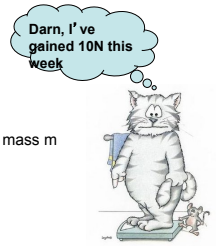
Sanity check:
a)Expect a negative answer. Ball is BELOW hand after 0.5s
b)Expect a fall of less than 2.5m based on previous question.
0.5s * -4.9m/s = -2.5m …
….but ball wasn't travelling that fast at first

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
kg is unit 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

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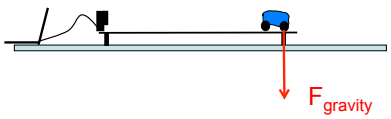
b) $m_E = m_M$, $w_E > w_M$
c) $m_E = m_M$, $w_E = w_M$
d) $m_E > m_M$, $w_E = w_M$
e) None of these

Net force

The little car is at rest on a horizontal track. Which way does the force on the car due to *gravity* point?



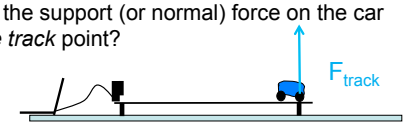
A) Left
B) Right
C) Up
D) Down
E) None of these

Answer: D

But **F = ma**
So why is it not accelerating down into the track?

Net force

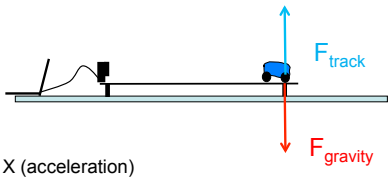
The little car is at rest on a horizontal track. Which way does the support (or normal) force on the car due to *the track* point?



A) Left
B) Right
C) Up
D) Down
E) None of these

Answer: C

Net force

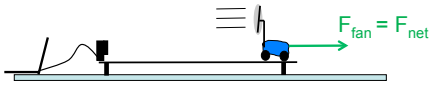


F_{net} = (mass) X (acceleration)

No acceleration ⇔ Net force is zero.

F_{grav} and F_{track} are equal in magnitude, opposite in direction.

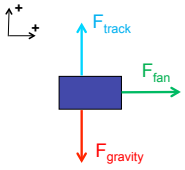
The little car is on a horizontal track, and blown by a fan. Which way does the net force point?



A) Left
B) Right
C) Up
D) Down
E) None of these

Answer: B

Free body (force) diagram



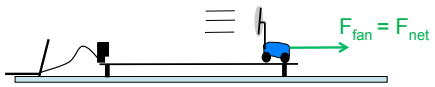
Free body (force) diagrams

Draw ALL forces acting on object as vectors
- Include magnitude of force,
- Arrow gives direction

Define a positive direction

Why?: To calculate NET force with a picture
Use net force in F = ma

The little car is on a horizontal track, and blown by a fan. In which direction does it accelerate?



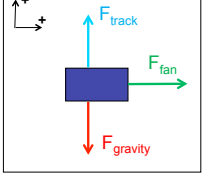
A) Left
B) Right
C) Up
D) Down
E) a = 0

Answer: B

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

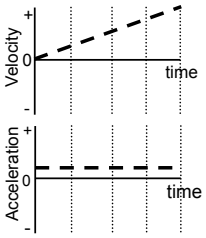
Acceleration in direction of net force

Free body (force) diagram



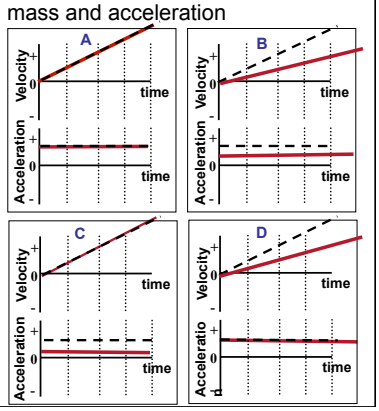
Force, mass and acceleration

The car is pushed by the fan with a constant force. Its velocity and acceleration are as shown below. Now double the mass of the car. Sketch what the new velocity and acceleration curves look like.



Force, mass and acceleration

Dashed curves are the velocity and acceleration for a single car. Which red curves represent car plus weight?



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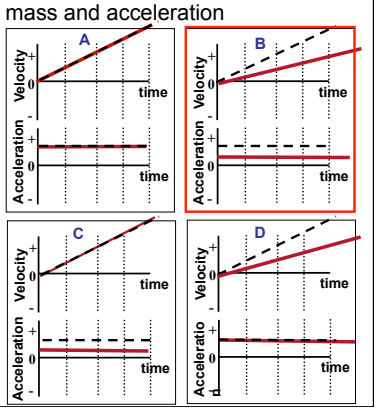
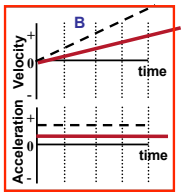


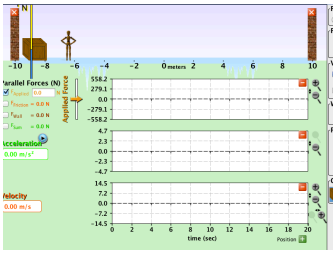
Force, mass and acceleration

Car plus weight (red line) versus one car (dashed line)



- Both cases: Same net force on car.
- Second (red) case: Mass bigger
- F_{net} = mass x acceleration
- Acceleration = $\frac{F_{net}}{mass}$ (same; smaller; larger)
- Acceleration is slope of v vs t

Play with this on your own



Forces and Motion Sim

http://phet.colorado.edu/en/simulation/forces-and-motion

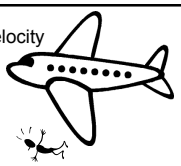
Confusing language

Regular people: Velocity: how fast you are going = speed.
Physicists: Velocity: the speed and direction of motion.

Regular people: acceleration: speeding up.
Physicists: acceleration: the rate of speeding up or slowing down or changing direction of motion.

Regular people: kg: a weight= 2.2 pounds,
Physicists: kg: a mass. On earth this mass has a weight of 1kg x 9.8 m/s² = 9.8 N

Terminal velocity

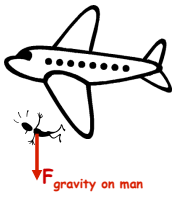


A 100 kg man steps out of a plane. Immediately after he leaves the plane:

a. The force of gravity on the man is 100 kg downwards, the net force on him is 100kg downwards, and his acceleration is 9.8 m/s² downwards.
b. The force of gravity on the man is 100 kg downwards, his net force is 0, and his acceleration is 0 m/s².
c. The force of gravity on the man is 980 N downwards, the net force on him is 980 N downwards, and his acceleration is 9.8 m/s² downwards.
d. The force of gravity on the man is 980 N, the net force on the man is 0 N, and his velocity increases until it is 9.8 m/s downwards and then stops increasing.
e. The force of gravity on the man is 980 N, the net force on the man is 0 N, and his acceleration is 9.8 m/s² downwards.

Terminal velocity

A 100 kg man steps from a plane.
Immediately after he leaves plane,
c. The force of gravity on the man is 980 N downwards, the net force on him is 980 N downwards, and his acceleration is 9.8 m/s² downwards.



Forces always measured in Newtons (N)! 100 kg is a mass.

Force of gravity on an object = m g *straight* downwards.
= 100 kg x 9.8 m/s² = 980 N downwards

F_{net} = sum of all forces → In this case, $F_{net} = F_{gravity\ on\ man} = mg$

Acceleration = $\frac{F_{net}}{m} = \frac{mg}{m} = g$ (downwards)

Acceleration is always in the same direction as the net force!

Terminal velocity

After the man falls for some time, he finds that he is falling at a constant velocity. At this time…

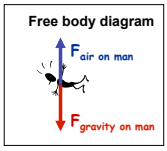
a. The force of gravity on the man is 100 kg downwards, the net force on him is 100kg downwards, and his acceleration is 9.8 m/s² downwards.
b. The force of gravity on the man is 100 kg downwards, his net force is 0, and his acceleration is 0 m/s².
c. The force of gravity on the man is 980 N downwards, the net force on him is 980 N downwards, and his acceleration is 9.8 m/s² downwards.

d. The force of gravity on the man is 0 N, the net force on the man is 0 N, and his acceleration is 0 m/s².
e. The force of gravity on the man is 980 N, the net force on the man is 0 N, and his acceleration is 0 m/s².

Terminal velocity

After the man falls for some time, he finds that he is falling at a constant velocity. At this time…

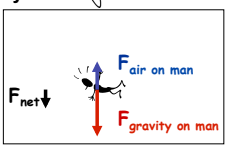
e. The force of gravity on the man is 980 N, the net force on the man is 0 N, and his acceleration is 0 m/s^2.



- $F_{gravity}$ (near earth) = mg
  = 100 kg x 9.8 m/s^2 = 980 N downward
- 'falling at constant velocity' ⇒ acceleration = 0
- F_{net} = ma ⇒ F_{net} = 0
- F_{net} = sum of all forces
  ⇒ $F_{net} = F_{gravity\ on\ man} + F_{air\ on\ man} = 0$!!!!
- When falling at terminal velocity, force of air resistance exactly equal and opposite to force of gravity.

Terminal velocity

F_{air} increases with velocity:
⇒ Before reaching terminal velocity, forces don't quite cancel.



- F_{net} = sum of all forces
  → In this case, $F_{net} = F_{gravity\ on\ man} + F_{air\ on\ man} \neq 0$
- F_{net} = mass x acceleration

- Since F_{net} is not zero, tells us man will accelerate!
- Acceleration will be smaller than 9.8 m/s^2 because net force is smaller than force of gravity on man.
- Velocity will be changing ! Speeding up in downwards direction

Terminal velocity numbers

Humans: 120mph.
Reached after falling 50 stories
Falls are fatal from 15 to 38 mph

Cats: 60mph.
Reached after falling about 5 stories
Can survive a terminal velocity fall

Why Terminal Velocity lower for cats than humans?
- **Smaller mass ➡ force of gravity smaller**
- **More hair ➡ Air resistance increases rapidly with increasing velocity**

Smaller animals: Mice, spiders etc
Even smaller terminal velocity
Very likely to survive a terminal velocity fall

Large raindrops ~ 20 mph