Physics 101

- Please pick up a clicker!

- Reminder: All lecture notes posted, after lecture, at:

http://www.hunter.cuny.edu/physics/courses/physics101/spring-2012

(or google hunter college physics 101 and follow links)

- Note: Before the actual lecture, a "PreLec" will be available on line, which is the lecture **without** the clicker questions

These will be removed after the lecture and replaced by the actual lecture.

- **Today:** Chapter 3

Chapter 3: Linear Motion

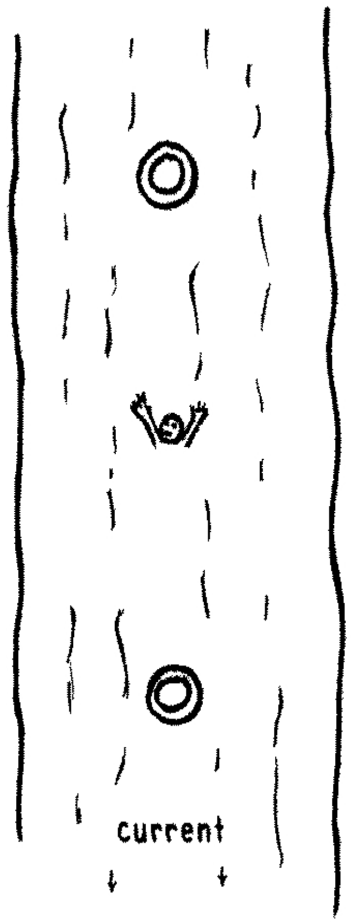
Preliminaries

- Linear motion is motion in a straight line.

- Note that motion is **relative**: e.g. your paper is moving at 107 000 km/hr relative to the sun. But it is at rest relative to you.

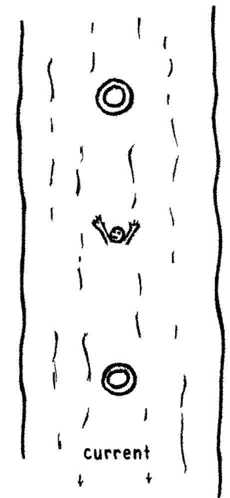
Unless otherwise stated, when we talk about speed of things in the environment, we will mean relative to the Earth's surface.

Clicker Question



Suppose you and a pair of life preservers are floating down a swift river, as shown. You wish to get to either of the life preservers for safety. One is 3 meters downstream from you and the other is 3 meters upstream from you. Which can you swim to in the shortest time?

1. The preserver upstream.
2. The preserver downstream
3. Both require the same.



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1. The preserver upstream.
2. The preserver downstream
3. **Both require the same.** ✔

Answer: 3, same time.

You, and both life preservers are moving with the current – relative to you before you start swimming, neither of the life preservers are moving.

An analogy: We can think of things on earth as being in a "current" traveling at 107 000 km/h relative to sun.

Speed

- Speed measures "how fast" :

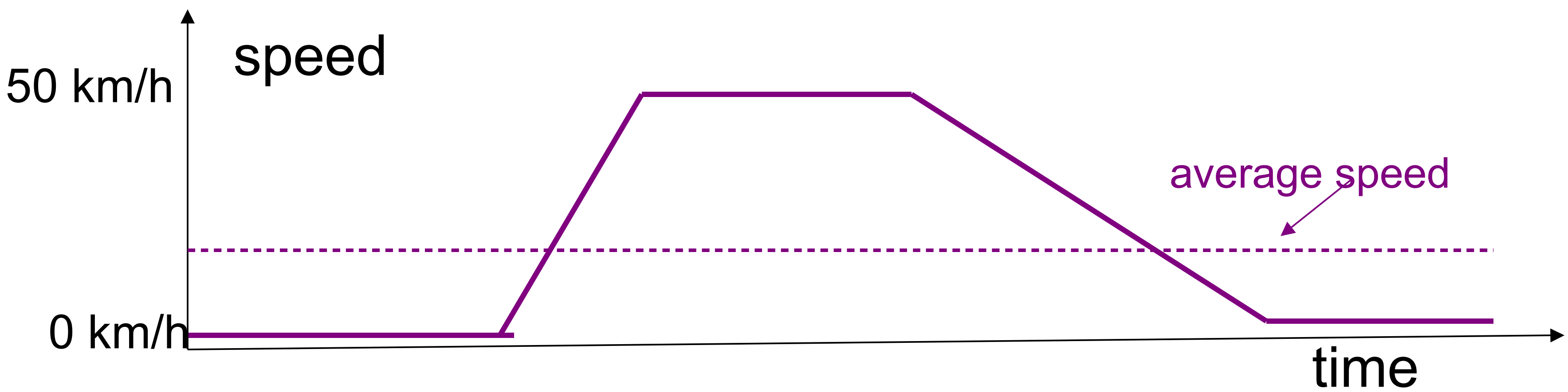
$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

Units: eg. km/h, mi/h (or mph), m/s

meters per second, standard units for physics

Instantaneous vs Average Speed

Things don't always move at the same speed, e.g. car starts at 0 km/h, speed up to 50 km/h, stay steady for a while, and then slow down again to stop.



Average speed = $\frac{\text{total distance covered}}{\text{time interval}}$

Eg. Carl Lewis once ran 100m in 9.92s.

- What was his average speed during that run?

Average speed = dist/time = 100m/9.92s = 10.1 m/s

- How much distance did he cover per second, on average?

10.1 m, by definition of average speed

- How did this relate to his top speed?

Top speed is more (actually about 10% over !)

Velocity

- Velocity is **speed** in a given **direction** *(velocity is a vector, speed is a scalar)*

- When there's just one direction of interest (up or down), often indicate direction by + or -.

- Note that an object may have constant speed but a changing velocity

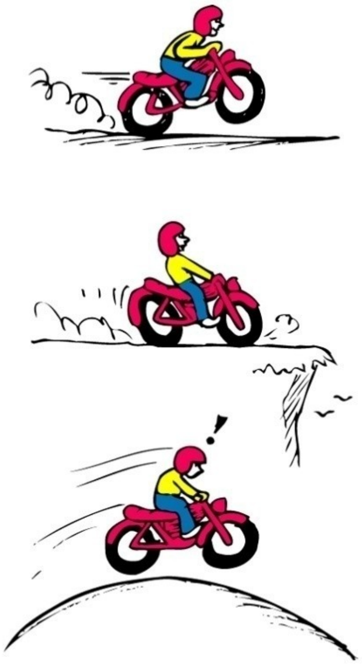
Eg. Whirling a ball at the end of a string, in a horizontal circle – same speed at all times, but changing directions. Or, think of a car rounding a bend, speedometer may not change but velocity is changing, since direction is.

Acceleration

- Measures how quickly **velocity changes**:

$$\text{Acceleration} = \frac{\text{change of velocity}}{\text{time interval}}$$

E.g. We feel acceleration when we lurch backward in the subway (or car, bike etc) when it starts, or when it stops (lurch forward).



- Note acceleration refers to : decreases in speed, increases in speed, and/or changes in direction i.e. to **changes in the state of motion.** Newton's law says then there must be a force acting (more next lecture)

Clicker Question

What is the acceleration of a cheetah that zips past you at a constant velocity of 60 mph?

A) 0
B) 60 mi/h2
C) Not enough information given to answer problem
D) None of the above

Answer

What is the acceleration of a cheetah that zips past you going at a constant velocity of 60 mph?

A) 0
B) 60 mi/h2
C) Not enough information given to answer problem
D) None of the above

Constant velocity means no change in velocity i.e. no acceleration

Questions

a) A certain car goes from rest to 100 km/h in 10 s. What is its acceleration?

10 km/h.s *(note units!)*

b) In 2 s, a car increases its speed from 60 km/h to 65 km/h while a bicycle goes from rest to 5 km/h. Which undergoes the greater acceleration?

The accelerations are the same, since they both gain 5 km/h in 2s, so acceleration = (change in v)/(time interval) = (5 km/h)/(2 s) = 2.5 km/h.s

c) What is the average speed of each vehicle in that 2 s interval, if we assume the acceleration is constant ?

For car: 62.5 km/h

For bike: 2.5 km/h

Clicker Question

Can an object have zero velocity but non-zero acceleration?

A) Yes

B) No

Answer: A) Yes!

Eg. Throw a ball up in the air – at the top of its flight, as it turns around it has momentarily zero speed but is changing its direction of motion, so has non-zero acceleration

I'd like to take attendance now.

Please enter the last 4 digits of your SSN into your clicker, and click send..

Free-Fall

- Free-fall: is when falling object falls under influence of gravity alone (no air resistance, or any other restraint).

How fast?

During each second of fall, the object speeds up by about 10 m/s *(independent of its weight)*

Eg. Free-fall from rest

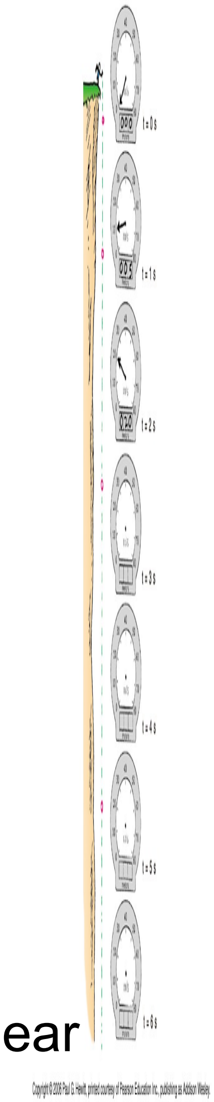
Time(s)	Velocity(m/s)
0	0
1	10
2	20
3	30
..	..
t	10 t

Hence, free-fall **acceleration** = 10 m/s2

i.e. velocity gain of 10 meters per second, per second

Since this acc. is due to gravity, call it *g*. Near surface of Earth, ***g* = 9.8 m/s2**

So we can write ***v* = *g t*** if dropped from rest



Note! We rounded g to 10 m/s2 in the table…

- What happens if object is thrown upwards, instead of being dropped?

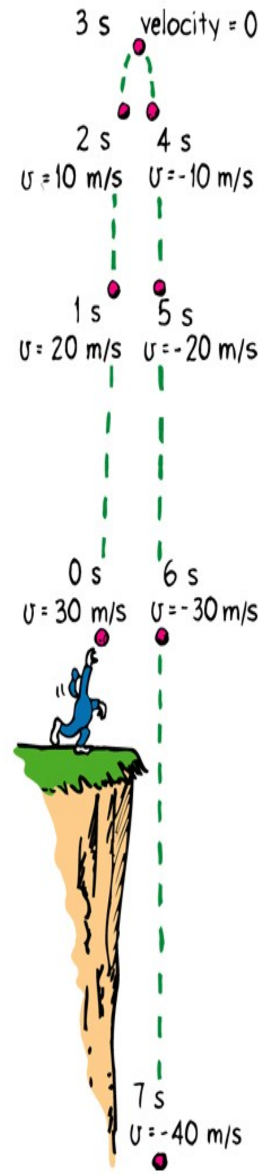
Once released, it continues to move upwards for a while, then comes back down. At the top, its instantaneous speed is zero (changing direction); then it starts downward just as if it had been dropped from rest at that height.

-- As it rises, it slows down at a rate of *g.*

-- At the top, it has zero velocity as it changes its direction from up to down.

-- As it falls, it speeds up at a rate of *g.*

-- Equal elevations have equal speed (but opposite velocity)



Free-fall continued:

How far?

i.e. what distance is travelled?

From the sketch before, we see distance fallen in equal time intervals, increases as time goes on.

Actually, one can show (appendix in book), for any uniformly accelerating object,

distance travelled, ***d* = ½ (acceleration x time x time)**

So in free-fall : $d = \frac{1}{2} g t^2$

Free-fall continued:

…in free-fall : ***d = ½ g t 2***

Free-fall:

Time(s)	Distance fallen(m)
0	0
1	5
2	20
3	45
..	..
t	½ 10 *t2*

Notice that in the 1st second, the distance is 5m, so the average speed is 5 m/s.

On the other hand, the instantaneous speed at the beginning of the 1st sec (ie t=0) is 0 and at the end of 1st sec is v = 10 m/s (earlier table).

So, in this case, the average speed is the average of the initial and final speeds.

Application: “Hang-time” of jumpers

- Michael Jordan’s best hang-time was 0.9 s – this is the time the feet are off the ground. Let’s round this to 1 s. How high can he jump?

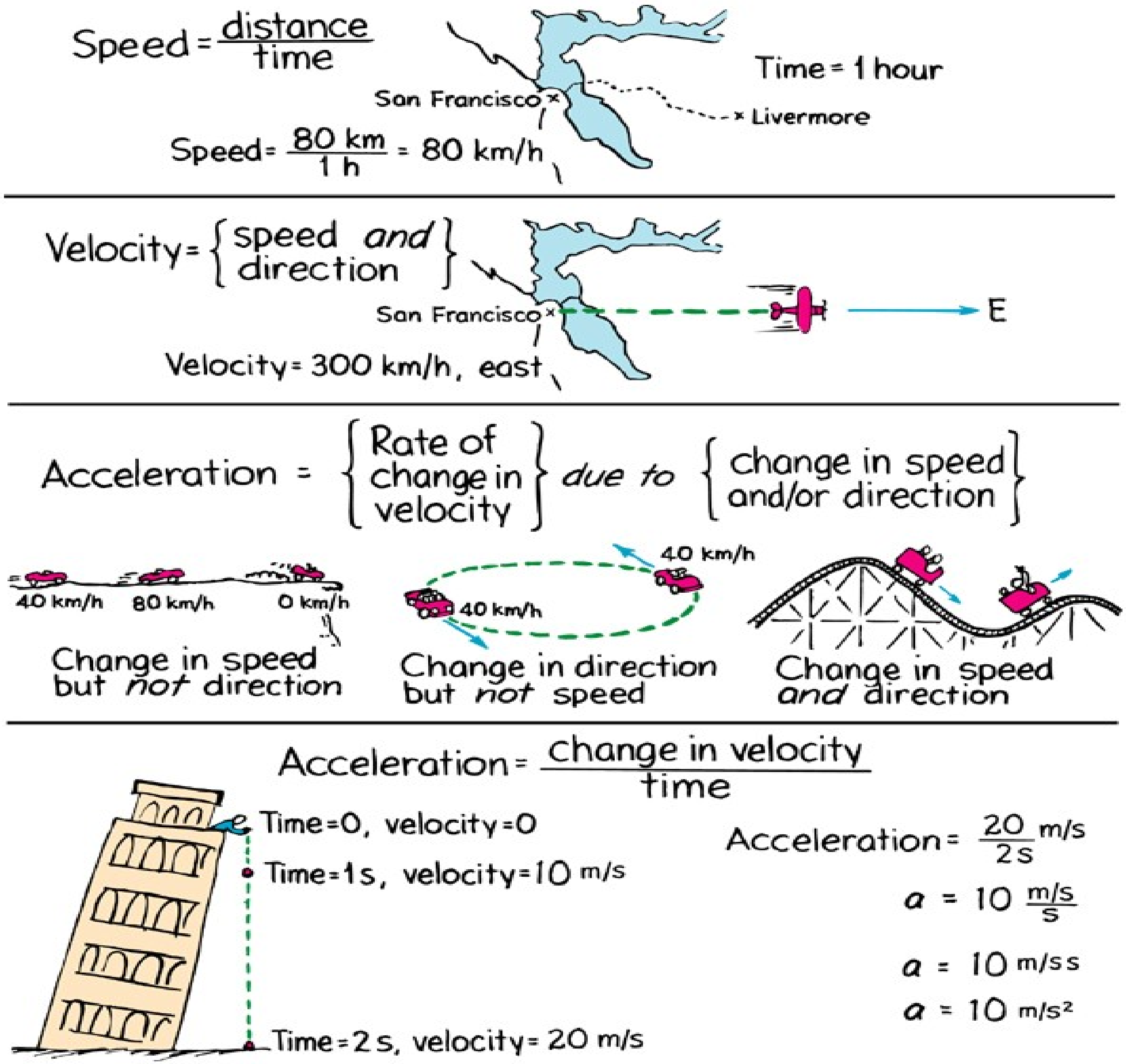
Use $d = ½\, g\, t2$. For 1 s hang-time, that’s ½ s up and ½ s down. So, substituting

$d = ½ (10) (1/2)2 =$ <u>1.25 m</u>

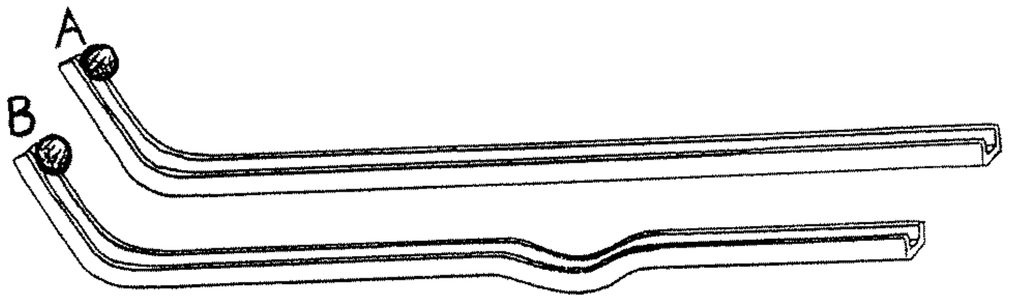
This is about 4 feet!

Note that good athletes, dancers etc may appear to jump higher, but very few can raise their *center of gravity* more than 4 feet.

Summary of definitions



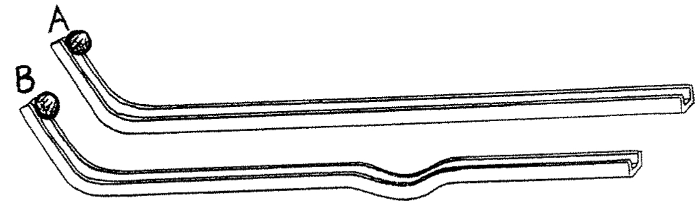
Clicker Question



Tracks A and B are made from pieces of channel iron of the same length. They are bent identically except for a small dip near the middle of Track B. When the balls are simultaneously released on both tracks as indicated, the ball that races to the end of the track first is on

1. Track A.
2. Track B.
3. Both reach the end at the same time.

Answer: 2



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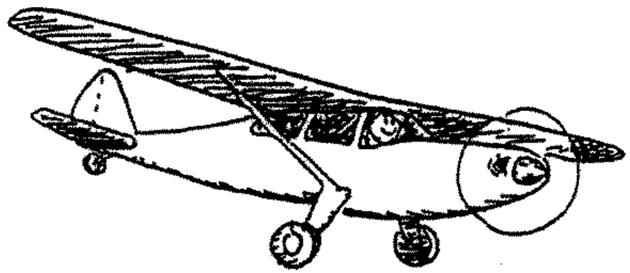
1. Track A.
2. **Track B.** ✔
3. Both reach the end at the same time.

The ball to win the race is the ball having the greatest *average speed.* Along each track both balls have identical speeds—except at the dip in Track B. Instantaneous speeds everywhere in the dip are greater than the flat part of the track. Greater speed in the dip means greater overall average speed and shorter time for a ball on Track B.

Note that both balls finish at the *same speed*, but not in the *same time*. Although the speed gained when going down the dip is the same as the speed lost coming out of the dip, average speed while in the dip is greater than along the flat part of the track.
If this seems tricky, it's the classic confusion between speed and time.

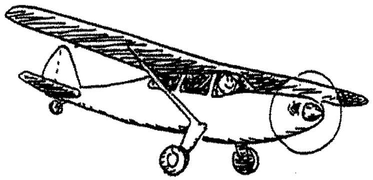
Question (to think about…)



An airplane makes a straight back-and-forth round trip, always at the same airspeed, between two cities. If it encounters a mild steady tailwind going, and the same steady headwind returning, will the round trip take:

1. more
2. less
3. the same time as with no wind?

Answer: 1: The windy trip will take more time.



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✔ **1. more**

2. less

3. the same time as with no wind?

E.g. Suppose the cities are 600 km apart, and the airspeed of the plane is 300 km/h (relative to still air). Then time each way with no wind is 2 hours. Roundtrip time is 4 hours.

Now consider a 100 km/h tailwind going, so groundspeed is (300 + 100) km/h. Then the time is (600 km)/(400km/h) = 1 hour and 30 minutes.
Returning groundspeed is (300 – 100) km/h, and the time is (600 km)/(200km/h) = 3 hours.
So the windy round trip takes 4.5 hours—longer than with no wind at all.