NEXT-TIME 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?

a) The preserver upstream.

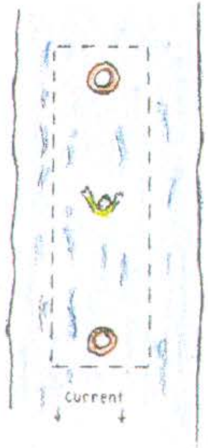
b) The preserver downstream.

c) Both require the same amount of time.

thanx to John Clement and Charlie Camp

Hewitt Drewit!

Next-Time Question



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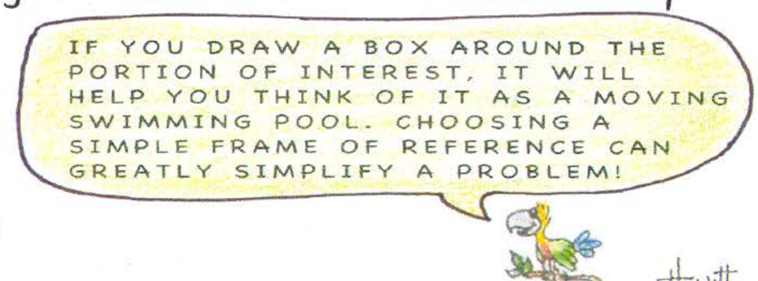
Answer: c

To get a grip on this, pretend that you are in a swimming pool on a fast-moving ocean liner. If both life preservers are the same distance from you in the pool, swimming toward either would take the same time. The speed of the ocean liner through the water makes no difference, just as it makes no difference to people playing shuffleboard or billiards. Can you see that in the flowing river, you're like a person in a pool aboard a moving ocean liner—swimming toward either preserver takes the same time?



Hewitt Drew it!

Physics 100:

- Reminder: All lecture notes and other class material are posted
www.hunter.cuny.edu/physics/courses/physics100/physics-100

- Read the text (it's very readable), work out (some) exercises and problems at the end of the chapters to test your understanding

- **Today:** Chapter 3 Linear Motion

- motion is relative
- instantaneous speed vs. *average* speed
- velocity: constant velocity; changing velocity
- acceleration; special case – free fall

Chapter 3: Linear Motion

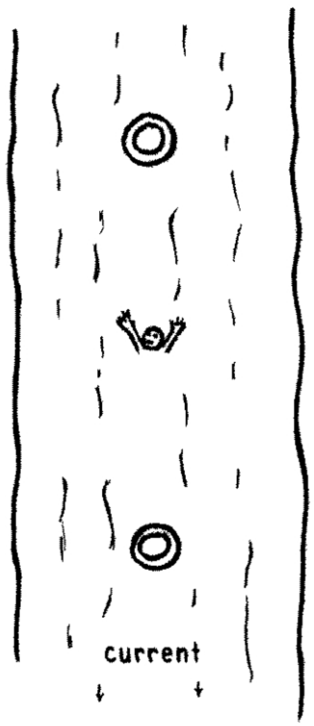
Preliminaries

- Linear motion is motion in a straight line.

- Note that motion is **relative**: eg 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.

Question



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3. Both require the same.

You're lying on the sand on a breezy day when a pesky fly wishes to join you. The breeze is blowing at a steady 2 m/s. In order for the fly to land on you it should hover over you while flying

- against the breeze at 2 m/s.
- with the breeze at 2 m/s.
- a bit faster than 2 m/s.
- about 4 m/s relative to the breeze.

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Sophia runs along the aisle of a train car that moves at 8 m/s. Sophia's speed relative to the floor is 3 m/s. Her speed relative to an observer at rest on the ground is

- 3 m/s.
- 5 m/s.
- 11 m/s.
- either 11 m/s or 5 m/s depending on whether she runs in the same or opposite direction to the train's motion.

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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, eg car starts at 0 km/h, speed up to 50 km/h, stay steady for a while, and then slow down again to stop.

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

A glance at your speedometer will tell you your

- average speed.
- instantaneous speed.
- overall speed.
- acceleration.

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Eg. Usain Bolt once ran 100m in 9.58s.

- What was his average speed during that run?

Average speed = dist/time = 100m/9.58s = 10.4 m/s (= 23.4 mph)

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

10.4 m, by definition of average speed

- How did this relate to his top speed?

Top speed is more (actually about 10% over ! – why?) 27.8 mph

Velocity

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

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

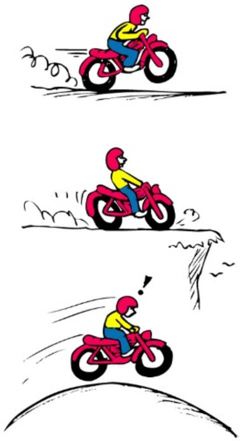
• Note that an object may have constant speed but a changing velocity

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

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

- Measures how quickly **velocity changes**:



Eg. 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** --- from Newton's law, lurches…

Interactive Demo
Const. accel. down inclined plane

Question

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

A) 0

B) 60 mi/h^2

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/h^2

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

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

Zero – its velocity doesn't change

Question

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

Answer: 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

Free-Fall

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

How fast?

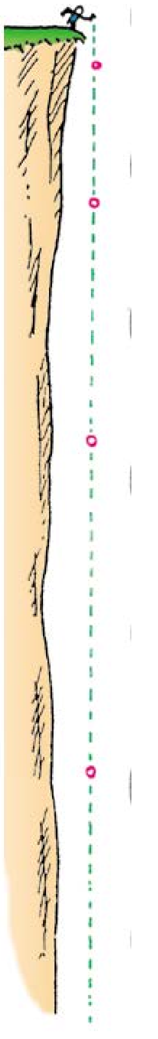
During each second of fall, the object speeds up by 10 m/s *(independent of its weight)*

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/s^2

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



G. Hewitt, printed courte

Since this acceleration is due to gravity, call it *g*. Near surface of Earth, $\boldsymbol{g = 9.8\ m/s^2}$

So we can write $\boldsymbol{v = g\,t}$ (*Note! We rounded g to 10 m/s^2 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.*

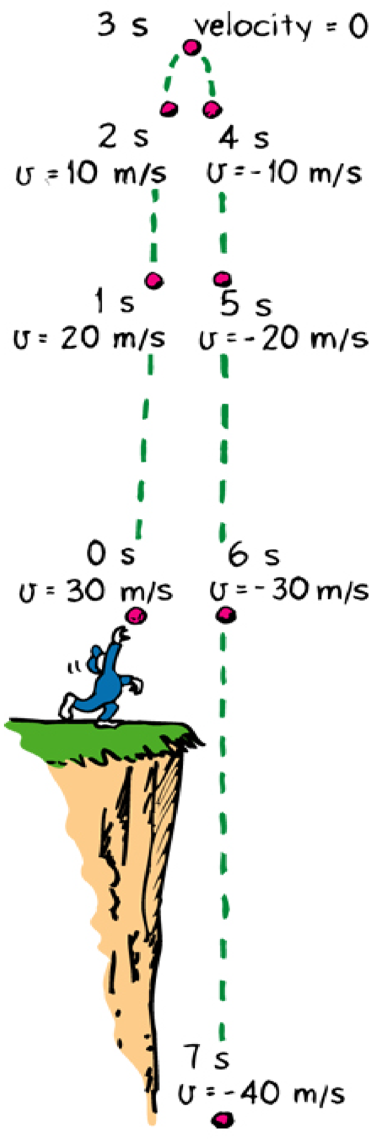
-- At the top, it has zero velocity as it changes its direction from up to down.

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

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

Interactive Demo

Const. accel. from free fall



Paul G. Hewitt, printed courtesy of Pearson Education Inc., publishing as A

Question

A ball is thrown up in the air. What is acceleration as it rises and falls?

A) $g = 9.8\ m/s^2$ downwards
B) $g = 9.8\ m/s^2$ upwards as it rises and $g = 9.8\ m/s^2$ downwards as it falls
C) It starts out with a small acceleration that decreases as it rises, then increases as it falls
D) None of the above

Answer: A

The acceleration due to gravity is *always* g = 9.8m/s^2 (near the surface of the earth) and points towards earth. When ball is thrown up, its speed decreases because acceleration (= rate of change of velocity) is in a direction opposite to its velocity. As it falls, it speeds up since acceleration is in the same direction as velocity.

Don't confuse velocity and acceleration!

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 : $\boldsymbol{d = \frac{1}{2} g t^2}$

Free-fall:

Time(s)	Distance fallen(m)
0	0
1	5
2	20
3	45
..	..
t	$\frac{1}{2}\, 10\, t^2$

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 the average speed is the average of the initial and final speeds.

Application: "Hang-time" of jumpers

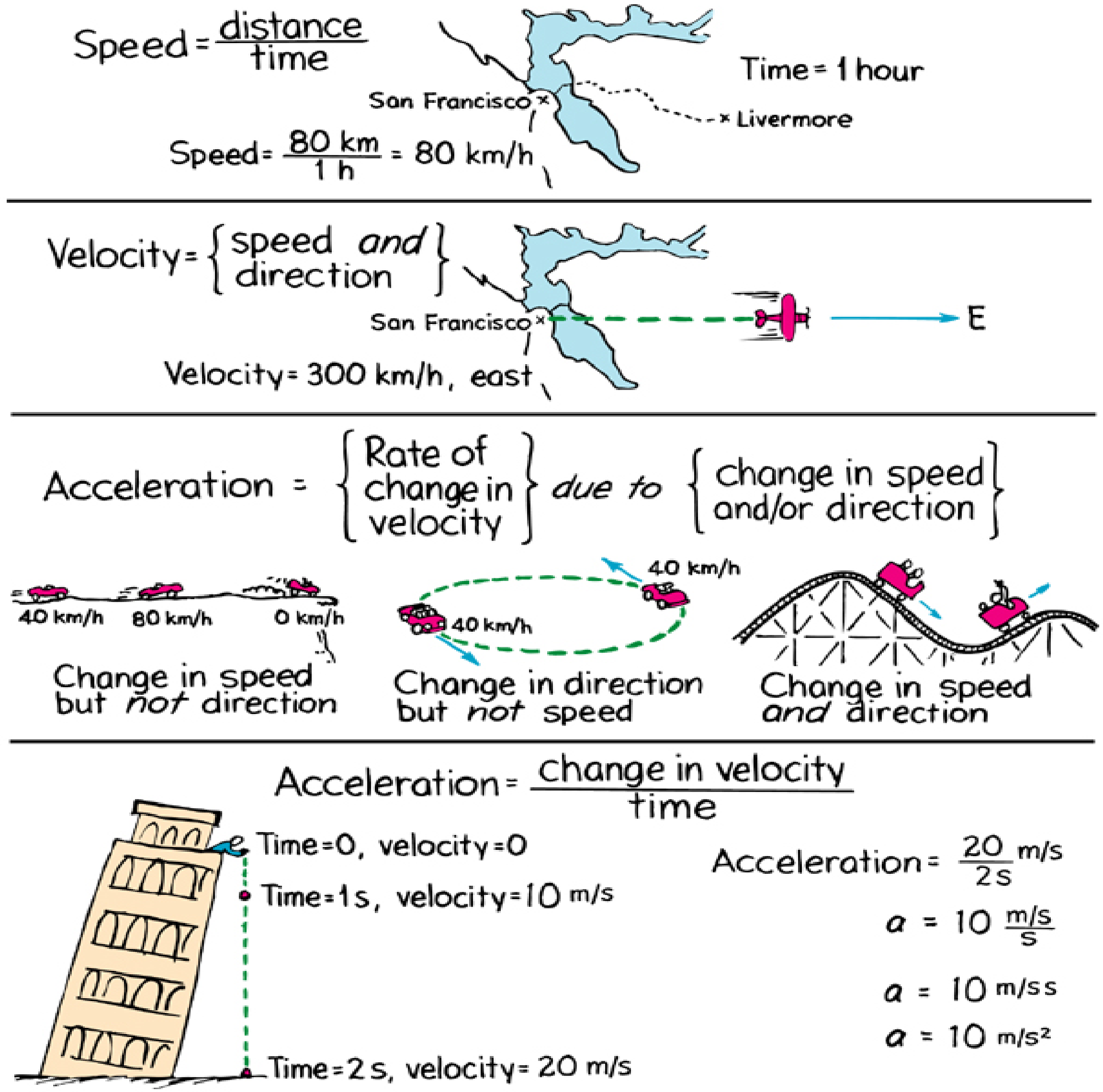
- Michael Jordan's best hang-time was 0.9 s – this is the time the feet are off the ground. Let's round this to 1 s. How high can he jump?

Use $d = ½\, g\, t^2$. 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

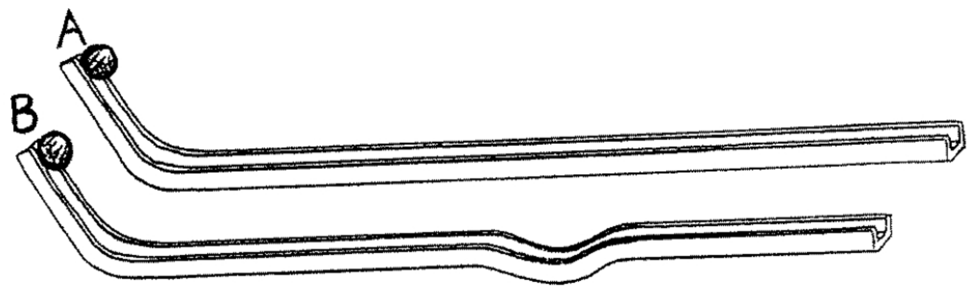


Two-Dimensional Projectile Motion:

horizonal velocity + vertical acceleration

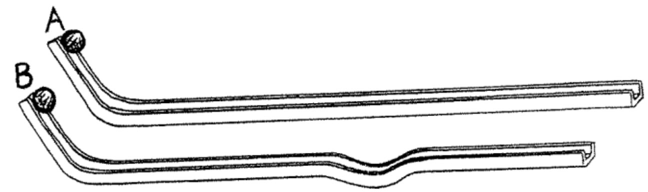
DEMO

Question (to think about…)



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.



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

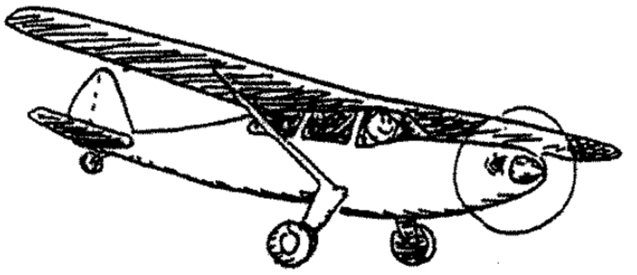
Answer: 2

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.

Next Time Question



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?

Sorry next time!