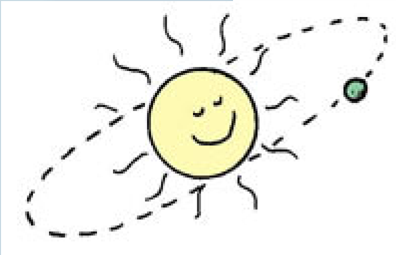
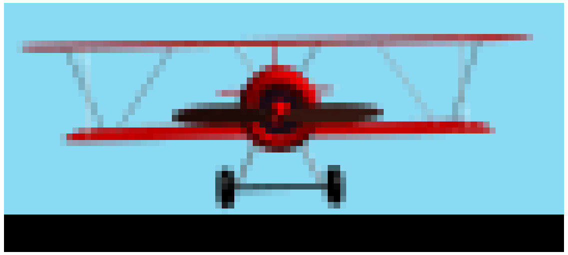
Linear Motion



Motion is Relative

- Everything moves.
- We're moving at about 107,000 relative to the sun.
- We're moving even faster relative to the center of our galaxy.
- Walking down the aisle of an airplane, speed relative to the floor of the plane is likely quite different from your speed relative to the ground



Speed

- **Speed**
  - measure of how fast something moves
  - measured by unit of distance/unit of time.
- **Instantaneous Speed**
  - Speed at an instant….
    - look at speedometer
- **Average Speed**
  - Total distance/total time….
    - set odometer at beginning of trip and divide by total time

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

$$s = \frac{d}{t}$$

Sample speeds

20 km/h = 12 mi/h = 6 m/s

40 km/h = 25 mi/h = 11 m/s

60 km/h = 37 mi/h = 17 m/s

65 km/h = 40 mi/h = 18 m/s

80 km/h = 50 mi/h = 22 m/s

88 km/h = 55 mi/h = 25 m/s

100 km/h = 62 mi/h = 28 m/s

120 km/h = 75 mi/h = 33 m/s

1. What is the average speed of a cheetah that sprints 100 m in 4 s?

25 m/s

   a. How about if it sprints 50 m in 2 s?

25 m/s

2. If a car moves with an average speed of 60 km/h for an hour, it will travel a distance of 60 km.

   a. How far would it travel if it moved at this rate for 4 h?

240 km

   a. For 10 h?

600 km

3. In addition to the speedometer on the dashboard of every car is an odometer, which records the distance traveled.

   a. If the initial reading is set at zero at the beginning of a trip and the reading is 40 km one-half hour later, what has been your average speed?

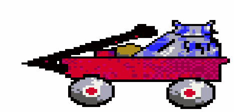
80 km/hr

   b. Would it be possible to attain this average speed and never go faster than 80 km/h?

At times the instantaneous speeds are less than 80 km/h, so the driver must drive at time intervals with speeds greater than 80 km/h to average 80 km/h.

Velocity

- Speed in a given *direction*
  - *When something moves at constant velocity or constant speed, equal distances are covered in equal intervals of time*
  - Constant velocity means constant speed with no change in direction.
  - *A* car that rounds a curve at a constant speed does not have a constant velocity—
  - its velocity changes as its direction changes.



1. The speedometer of a car moving to the east reads 100 km/h. It passes another car that moves to the west at 100 km/h.

   a. Do both cars have the same speed?

   same speed

   b. Do they have the same velocity?

   opposite velocities

2. During a certain period of time, the speedometer of a car reads a constant 60 km/h.

   a. Does this indicate a constant speed?

   yes

   b. A constant velocity?

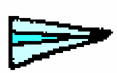
   no, may not be moving in constant direction

Acceleration

$$\text{acceleration} = \frac{\Delta \text{velocity}}{\Delta \text{time}}$$

$$a = \frac{\Delta v}{\Delta t}$$

Acceleration occurs when there is a change (Δ) in motion



1. A particular car can go from rest to 90 km/h in 10 s.
   a. What is its acceleration?

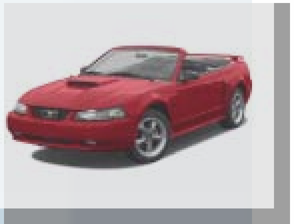
9 km/h•s
(average acceleration)

2. In 2.5 s a car increases its speed from 60 km/h to 65 km/h while a bicycle goes from rest to 5 km/h.
   a. Which undergoes the greater acceleration?

Same: Rates of Δ are the same
5 km/h/2.5 s

   b. What is the acceleration of each vehicle?

2 km/h•s
Velocities are very different, but acceleration is the same!



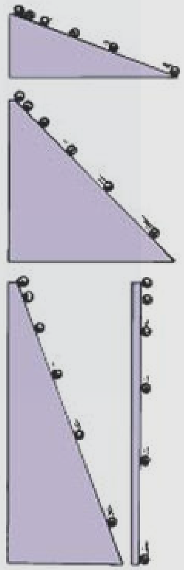
1. What is the acceleration of a race car that whizzes past you at a constant velocity of 400 km/h?

(0: Velocity is Constant!)

2. Which has the greater acceleration, an airplane that goes from 1000 km/h to 1005 km/h in 10 seconds or a skateboard that goes from zero to 5 km/h in 1 second?

Airplane a = 0.5 km/ km/h•s

Skateboard a = 5 km/h•s



Inclined planes

Galileo :

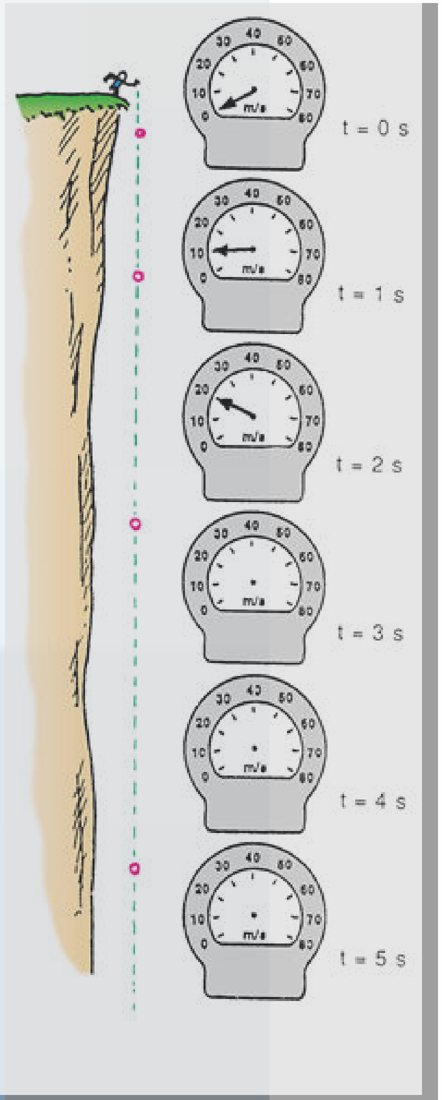
- Ball rolling down an inclined plane picks up same amount of speed in successive seconds
- Ball rolls with unchanging acceleration.
- Greater the slope the greater the acceleration
- Vertical acceleration = ?

10 m/s

$$\text{velocity} = \text{acceleration x time}$$

$$v = at$$

Free Fall



Object falling under influence of gravity alone

During each second of fall, the object gains a speed of 10 meters per second.

Acceleration = gain per second = 10 m/s^2

Rock's speed increasing by the same amount: 10 m/s.

v at t = 3s = 30 m

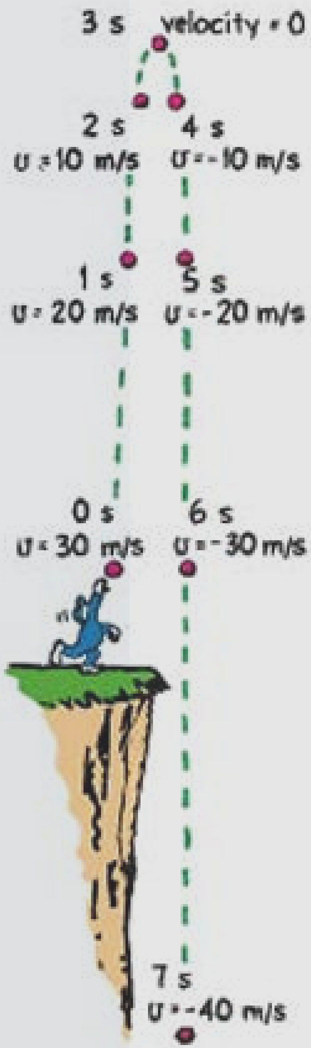
v at t = 4s = 40 m

v at t = 5s = 50 m

velocity acquired in free fall

$$v = gt$$

Up and Down



- Highest point: instantaneous speed is 0
- Then behaves as if dropped from rest
- Deceleration = -10 m/s^2
- Will be at *rest* at t = 30 s
- At t = 4 s v = 10 m/s

At t = 5 s v = ? 20 m/s
At t = 6 s v = ? 30 m/s
At t = 7 s v = ? 40 m/s

How Far?

- How *far* an object falls is altogether different from how *fast* it falls
- An object falls a distance of only 5 meters during the 1st second of fall, although its speed is then 10 m/s.
- Starts from rest…is at 10 m/s at 1 s

$$v_{average} = \frac{10-0}{2} = 5\text{ m/s}$$

$$\text{distance traveled} = \frac{1}{2}(\text{acceleration x time x time}$$

distance fallen free fall

$$d = \frac{1}{2}gt^2$$

A cat steps off a ledge and drops to the ground in 1/2 second.

1. What is its speed on striking the ground?

$v = gt = 10\ m/s^2 \times ½\ s = 5\ m/s.$

2. What is its average speed during the 1/2 second?

$$\bar{V} = \frac{v_i + v_f}{2} = \frac{0\ m/s + 5\ m/s}{2} = 2.5\ m/s$$

3. How high is the ledge from the ground?

$d = vt = 2.5\ m/s \times 1/2\ s = 1.25\ m$

$d = 1/2\ gt^2 = 1/2 \times 10\ m/s^2 = (1/2\ s)^2 = 1/2 \times 10\ m/s^2 \times 1/4\ s2 = 1.25\ m.$

How quickly how fast changes

- how fast ====== speed or velocity

  $v = gt$

  rate of change of position

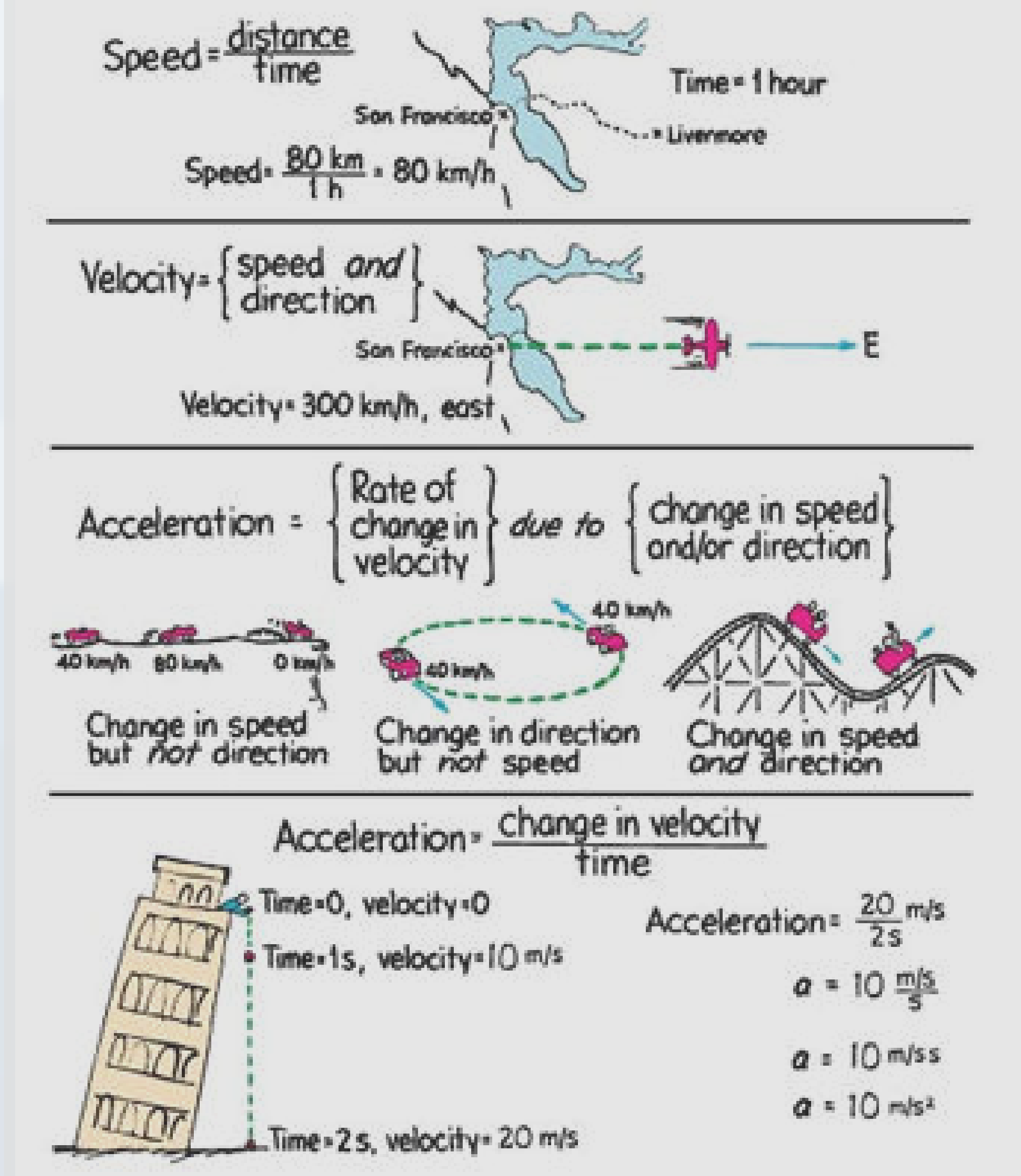
- how far ====== distance

  $d = \frac{1}{2} gt^2$ *or* $d = vt$

- How quickly how fast changes ==== acceleration

  rate of a rate

  rate at which velocity changes



Speed = distance / time
Time = 1 hour
San Francisco
Livermore
Speed = 80 km / 1 h = 80 km/h
Velocity = {speed and direction}
San Francisco
E
Velocity = 300 km/h, east
Acceleration = {Rate of change in velocity} due to {change in speed and/or direction}
40 km/h
80 km/h
0 km/h
Change in speed but not direction
40 km/h
40 km/h
Change in direction but not speed
Change in speed and direction
Acceleration = change in velocity / time
Time = 0, velocity = 0
Time = 1 s, velocity = 10 m/s
Time = 2 s, velocity = 20 m/s
Acceleration = 20 m/s / 2 s
a = 10 m/s / s
a = 10 m/s s
a = 10 m/s²

Summary of Terms

- **Speed**
  How fast something moves.
  The distance traveled per unit of time.

- **Velocity**
  The speed of an object and specification of its direction of motion.

- **Acceleration**
  The rate at which velocity changes with time
  the change in velocity may be in magnitude or direction or both.

- **Free fall**
  Motion under the influence of gravity only.

Summary of Formulas

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

$$s = \frac{d}{t}$$

$$\text{velocity} = \text{acceleration x time}$$

$$v = at$$

$$v_{\text{average}} = \frac{10-0}{2} = 5 \text{ m/s}$$

$$\text{velocity} = \frac{\Delta\text{position}}{\Delta\text{time}}$$

$$v = \frac{\Delta d}{\Delta t}$$

$$\text{velocity acquired in free fall}$$

$$v = gt$$

$$\text{acceleration} = \frac{\Delta\text{velocity}}{\Delta\text{time}}$$

$$a = \frac{\Delta v}{\Delta t}$$

$$\text{distance fallen free fall}$$

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