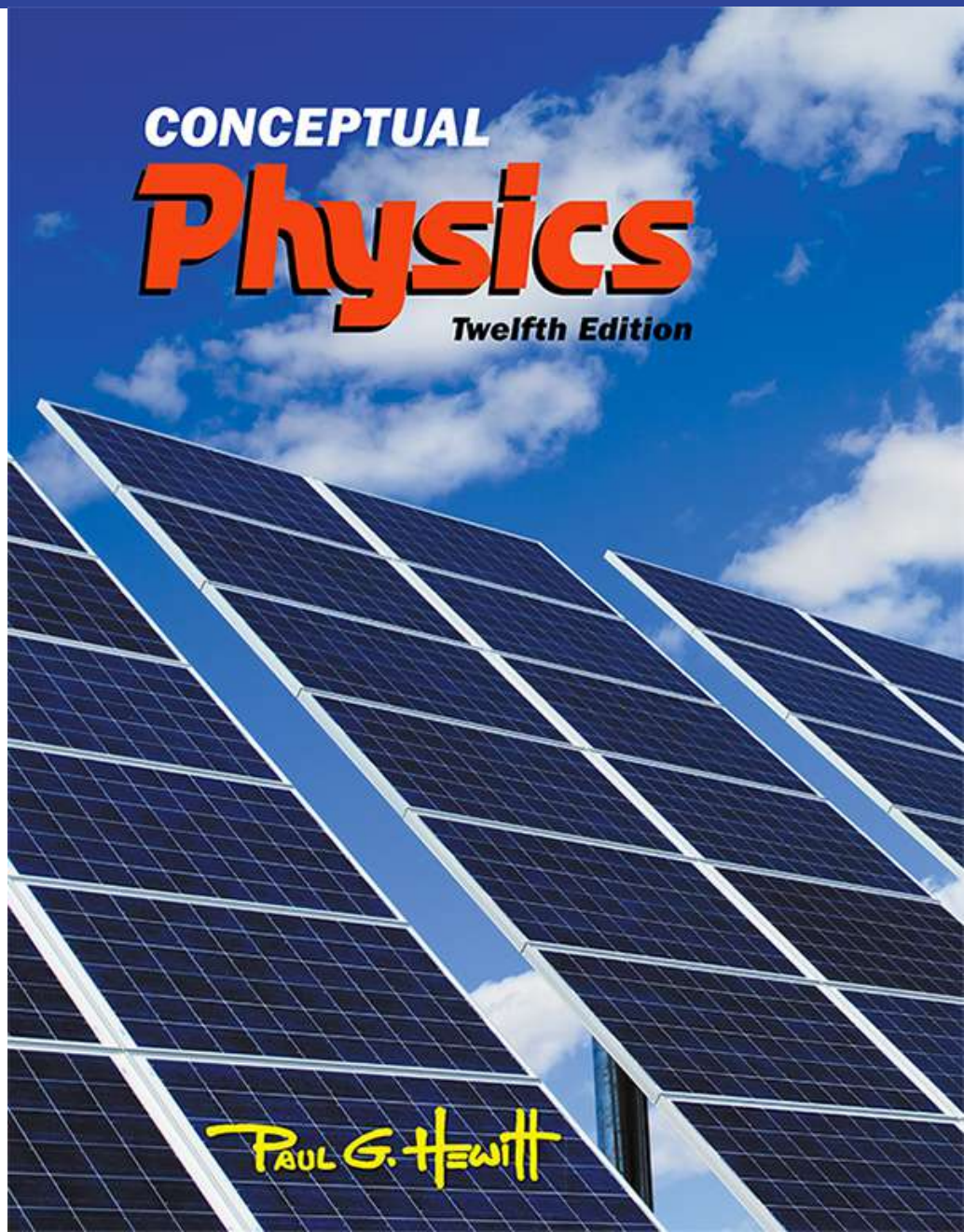
Lecture Outline

Chapter 3: Linear Motion

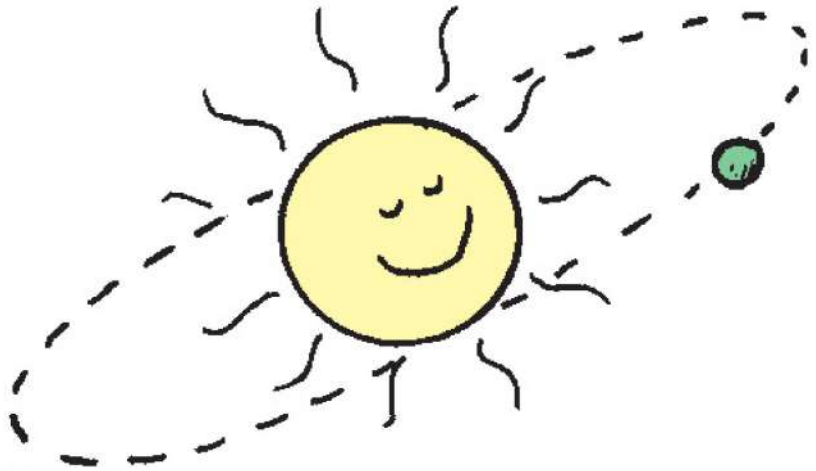


This lecture will help you understand:

- Motion Is Relative
- Speed
- Velocity
- Acceleration
- Free Fall
- Velocity Vectors

Motion Is Relative

- Motion of objects is always described as *relative* to something else. For example:
  - You walk on the road relative to Earth, but Earth is moving relative to the Sun.
  - So your motion relative to the Sun is different from your motion relative to Earth.



Speed

- Defined as the distance covered per amount of travel time.
- Units are meters per second.
- In equation form:

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

- Example: A girl runs 6 meters in 2 s.
- What is her speed?

Average Speed

- The total distance covered divided by the total travel time.
  - Doesn't indicate various instantaneous speeds along the way.
- In equation form:

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

- Example: Drive a distance of 200 km in 2 h.
- What is your average speed?

Average Speed
CHECK YOUR NEIGHBOR

The average speed of driving 30 km in 1 hour is the same as the average speed of driving

A. 30 km in 1/2 hour.

B. 30 km in 2 hours.

C. 60 km in 1/2 hour.

D. 60 km in 2 hours.

Average Speed
CHECK YOUR ANSWER

The average speed of driving 30 km in 1 hour is the same as the average speed of driving

D. 60 km in 2 hours.

Explanation:

Average speed = total distance / time
So, average speed = 30 km / 1 h = 30 km/h.

Now, if we drive 60 km in 2 hours:
Average speed = 60 km / 2 h = 30 km/h

Same

1. What is the average speed of a cheetah that sprints 100 meters in 4 seconds? If it sprints 50 m in 2 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?
   b. For 10 h?

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

$$\text{Total distance covered} = \text{average speed} \times \text{time interval}$$

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

Instantaneous Speed

- *Instantaneous* speed is the speed at any instant.
- Example:
  - When you ride in your car, you may speed up and slow down with speed at any instant that is normally quite different than your average speed.
  - Your instantaneous speed is given by your speedometer:

- *Can you tell how many km/h equals 60 mph?*

Velocity

- A description of both
  - the instantaneous speed of the object.
  - the direction of travel.

- Velocity is a *vector* quantity. It has
  - Magnitude (speed) and Direction.
  - Velocity is "directed" speed.

Ex: 60 mph, east is a velocity

What is its magnitude? Its direction?

Speed and Velocity

- *Constant* speed is steady speed, neither speeding up nor slowing down.
- Constant velocity is
  - constant speed and
  - constant direction (straight-line path with no acceleration).
- Motion is relative to Earth, unless otherwise stated.
- What is the net force acting on you if you are moving at constant velocity?

1. "She moves at a constant speed in a constant direction." Rephrase the same sentence in fewer words.

2. The speedometer of a car moving to the east reads 100 km/h. The car passes another car that is moving to the west at 100 km/h. Do both cars have the same speed? Do they have the same velocity?

3. During a certain period of time, the speedometer of a car reads a constant 60 km/h. Does this indicate a constant speed? A constant velocity?

You change velocity in a car by changing your speed or your direction.

What are the 3 controls in your car that allow you to change your *velocity*?

1. Gas pedal (increase speed)
2. brakes (decrease speed)
3. Steering wheel (change direction)

Homework:

1. **Due today by 4:00 pm:**
   Chapter 3 Reading

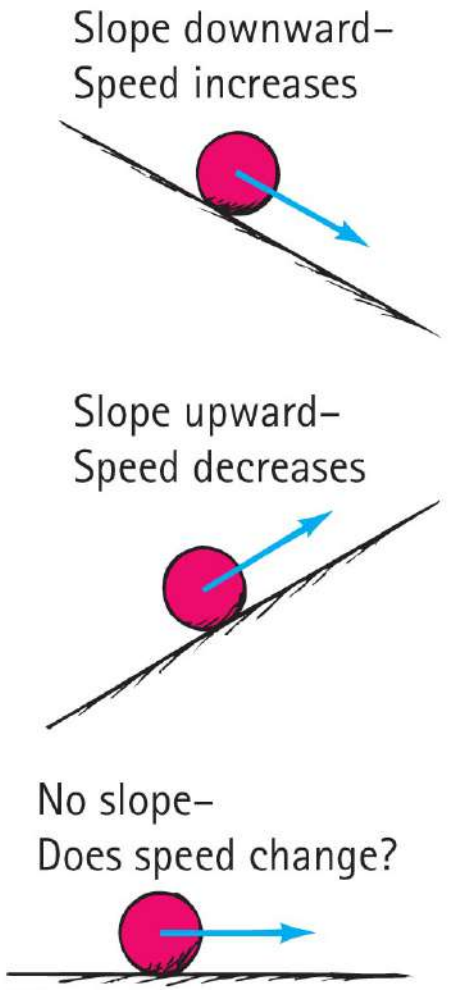
***Submit to *Physics* Team

2. **New homework due Sunday 11:59 pm:**

On page 52, in the Reading Check Comprehension section, do questions 1 to 8.
Hand write neatly on separate sheet. Name at top of each page. Skip lines between answers.
Scan or take photo and upload to Assignment in …..
***either *5th hour Physics* or *6th hour Physics* team.

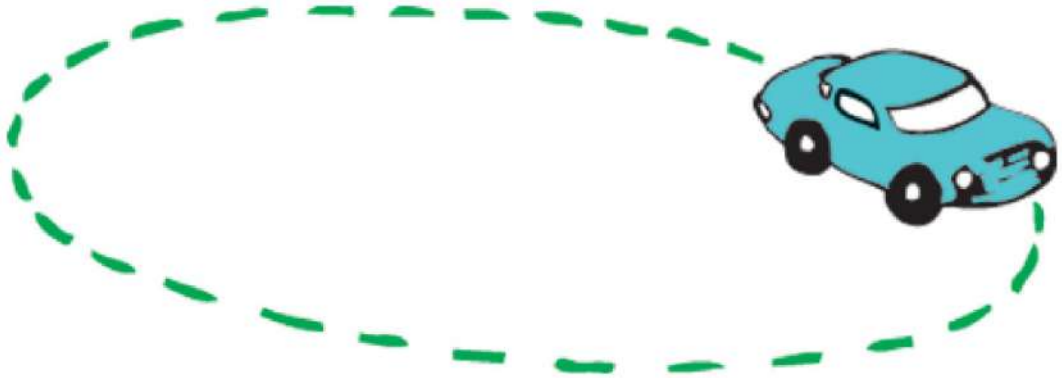
Acceleration

- Formulated by Galileo based on his experiments with inclined planes.
- Rate at which velocity changes over time.



Acceleration, Continued

- Involves a
  - change in speed, or
  - change in direction, or
  - both.
- Example: Car making a turn.



Acceleration, Continued-1

- In equation form:

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

- Unit of acceleration is unit of velocity / unit of time.
- Example:
  - Your car's speed may presently be 40 km/h.
  - Your car's speed 5 s later is 45 km/h.
  - Your car's change in speed is 45 - 40 = 5 km/h.
  - Your car's acceleration is 5 km/h·5 s = 1 km/h·s.

Acceleration
CHECK YOUR NEIGHBOR

An automobile is accelerating when it is

A. slowing down to a stop.
B. rounding a curve at a steady speed.
C. Both of the above.
D. Neither of the above.

Acceleration
CHECK YOUR ANSWER

An automobile is accelerating when it is

C. Both of the above.

Explanation:

Change in speed (increase or decrease) per time is acceleration, so slowing is acceleration.

Change in direction is acceleration (even if speed stays the same), so rounding a curve is acceleration.

Checkpoint page 44:

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

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

Checkpoint page 44

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. Which undergoes the greater acceleration? What is the acceleration of each?

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

Checkpoint page 45

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

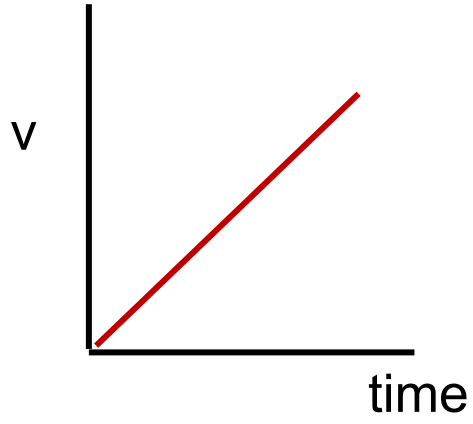
$$\text{Acceleration} = \frac{\text{change of velocity}}{\text{time interval}}$$

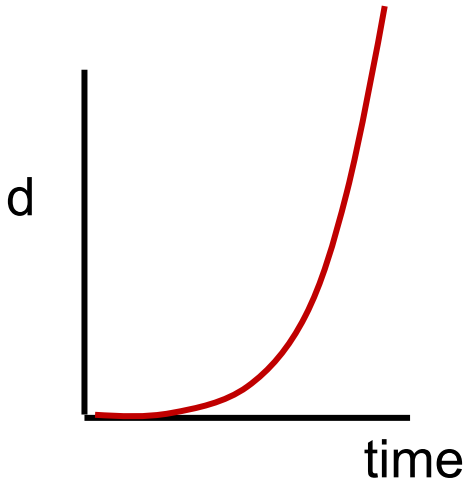
Checkpoint page 45

2. **Which undergoes 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?**

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

Speed v vs distance d in accelerated motion:





speed = acceleration x time

$v = a \times t$

$v \sim t$ (linear)

distance = (1/2) acceleration x time x time

$d = (1/2)\, a \times t^2$

$d \sim t^2$ (quadratic)

Acceleration
CHECK YOUR NEIGHBOR, Continued

Acceleration and velocity are actually

A. the same.
B. rates but for different quantities.
C. the same when direction is not a factor.
D. the same when an object is freely falling.

Acceleration
CHECK YOUR ANSWER, Continued

Acceleration and velocity are actually

B. rates but for different quantities.

Explanation:

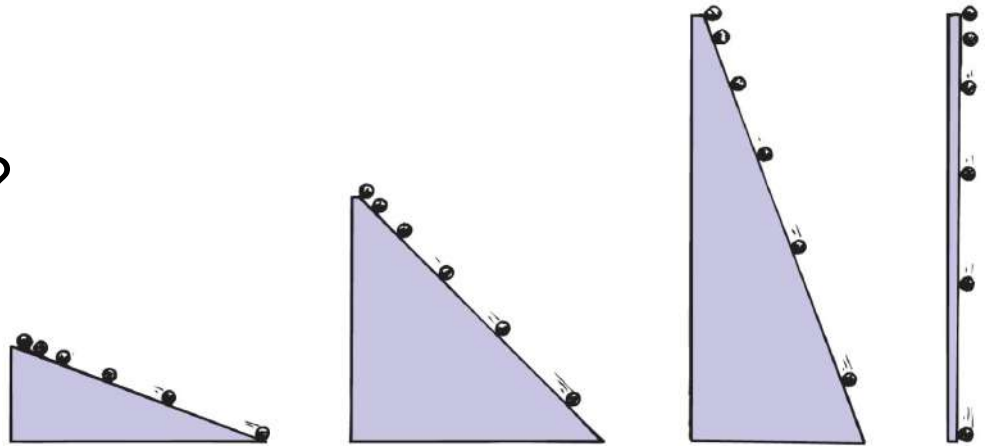
Velocity is the rate at which distance traveled changes over time,

Acceleration is the rate at which velocity changes over time.

Acceleration, Continued-2

- Galileo increased the inclination of inclined planes.
  - Steeper inclines result in greater accelerations.
  - When the incline is vertical, acceleration is at maximum, the same as that of a falling object.
  - When air resistance is negligible, all objects fall with the same unchanging acceleration.

- What is the acceleration if the incline is horizontal?
- **0.**



Homework:

1. Chapter 3 reading….due the 18th.
Submit to the *Physics* Team.

→ From now on, submit assignment to either *5th hour or 6th hour Physics* team.

2. Finish Problem Set 4…
Page 52: RCQ #1-8 …due yesterday.

3. New Problem Set:
Page 52: RCQ #9-14
page 53: TS (Think and Solve) #38
→ *Show your work* on #38.

Free Fall

- Falling under the influence of gravity only-with no air resistance

TABLE 3.2 FREE FALL FROM REST

Time of Fall (seconds)	Velocity Acquired (meters/second)
0	0
1	10
2	20
3	30
4	40
5	50
.	.
.	.
.	.
t	$10t$

- Freely falling objects on Earth accelerate at the rate of 10 m/s·s, that is, 10 m/s^2 (more precisely, 9.8 m/s^2).

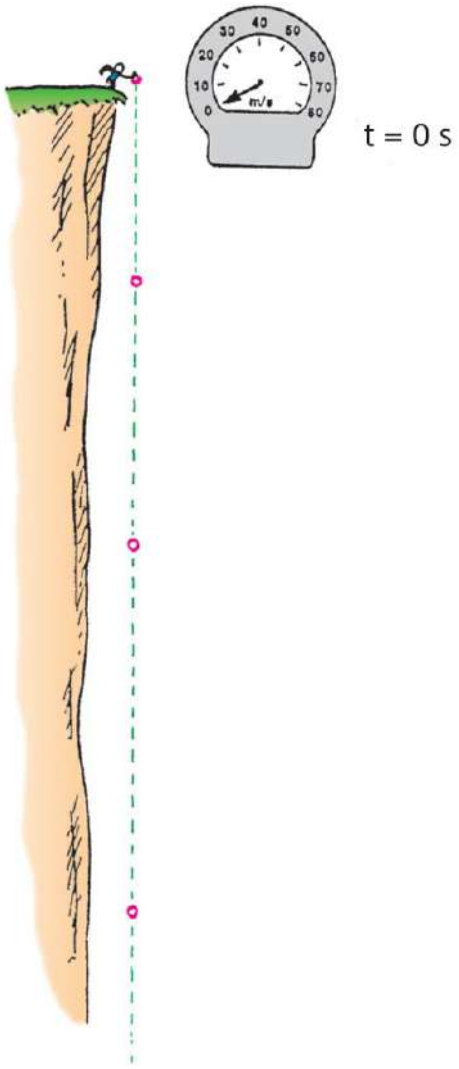
Free Fall—How Fast?

- The velocity acquired by an object starting from rest is

  $$\text{Velocity} = \text{acceleration} \times \text{time}$$

- So, under free fall, when acceleration is $10\ m/s^2$, the speed is
  - 10 m/s after 1 s.
  - 20 m/s after 2 s.
  - 30 m/s after 3 s.

  And so on.



Free Fall—How Fast?
CHECK YOUR NEIGHBOR

At a particular instant a free-falling object has a speed of 30 m/s. Exactly 1 s later its speed will be

A. the same.
B. 35 m/s.
C. more than 35 m/s.
D. 60 m/s.

Free Fall—How Fast?
CHECK YOUR ANSWER

At a particular instant a free-falling object has a speed of 30 m/s. Exactly 1 s later its speed will be

C. more than 35 m/s.

Explanation:

One second later its speed will be 40 m/s, which is more than 35 m/s.

What would the speedometer reading on the falling rock shown in Figure 3.7 be 5 s after it drops from rest? How about 6 s after it is dropped? 6.5 s after it is dropped?

t= 5 s:

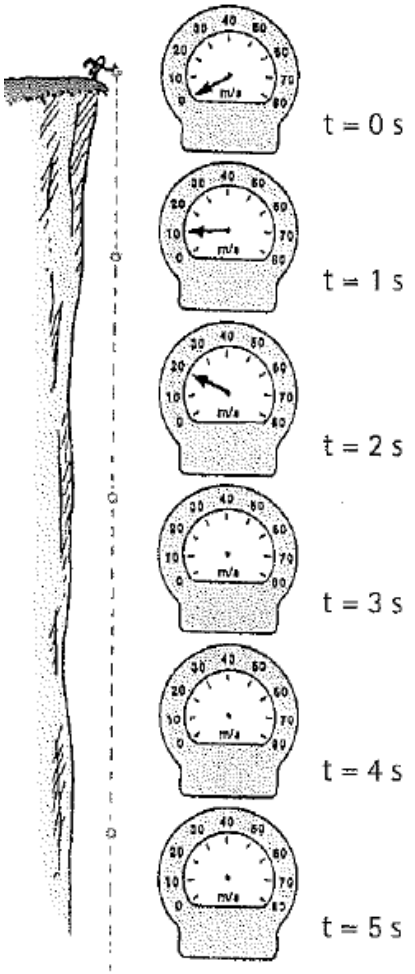
V = 50 m/s

t= 6 s:

v = 60 m/s

t= 6.5 s:

v = 65 m/s



Speed V = 0 when dropped

V = 10 m/s

V = 20 m/s

V = 30 m/s

V = 40 m/s

V = 50 m/s

What was the initial speed of the ball? 30 m/s

On the way up:

How much speed did it lose each second? 10 m/s

How many seconds did it take to rise to its maximum height (top)? 3 s

At the top:

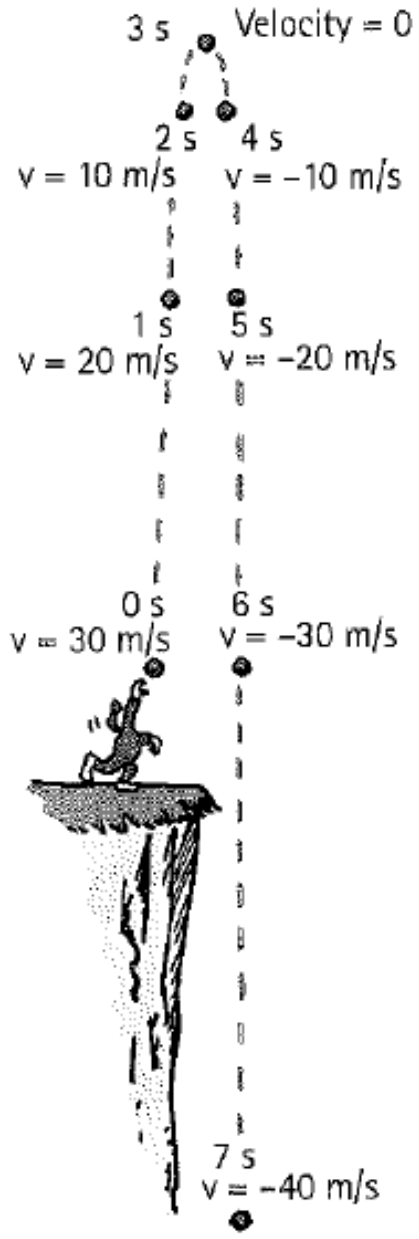
What is its *speed* at the top? 0 m/s

What is its *acceleration* at the top? **-10 m/s^2!**

On the way down:

How much speed does it gain each second? 10 m/s

How much total time does it take to return to the same height as it had originally? 6 s



Checkpoint:

A ball is thrown straight upward and leaves your hand at 20 m/s. What predictions can you make about the ball? (Please think about this *before* reading the suggested predictions!)

Free Fall—How Far?

- The distance covered by an accelerating object starting from rest is

$$\text{Distance} = (1/2) \times \text{acceleration} \times \text{time} \times \text{time}$$

- Under free fall, when acceleration is 10 m/s^2:
  - Distance $d = (1/2)\,(10\ m/s^2) \times t^2$
  - $d = 5 \times t^2$

    $d = 5$ m after 1 s.
    - $d = 20$ m after 2 s.
    - $d = 45$ m after 3 s.

    And so on.

Free Fall—How Far?
CHECK YOUR NEIGHBOR

What is the distance fallen after 4 s for a freely falling object starting from rest?

A. 4 m
B. 16 m
C. 40 m
D. 80 m

Free Fall—How Far?
CHECK YOUR ANSWER

What is the distance fallen after 4 s for a freely falling object starting from rest?

D. 80 m

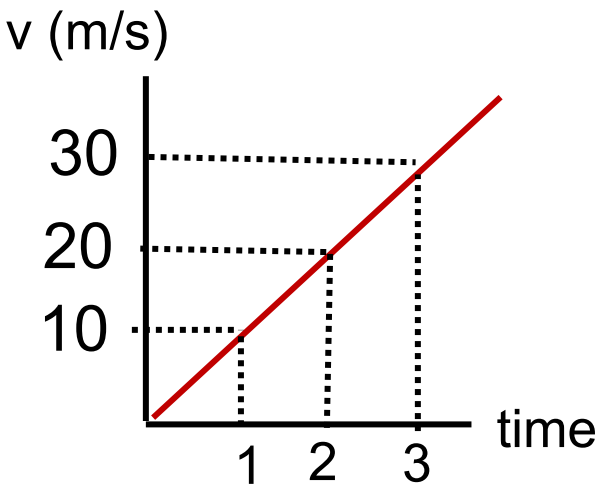
Explanation:

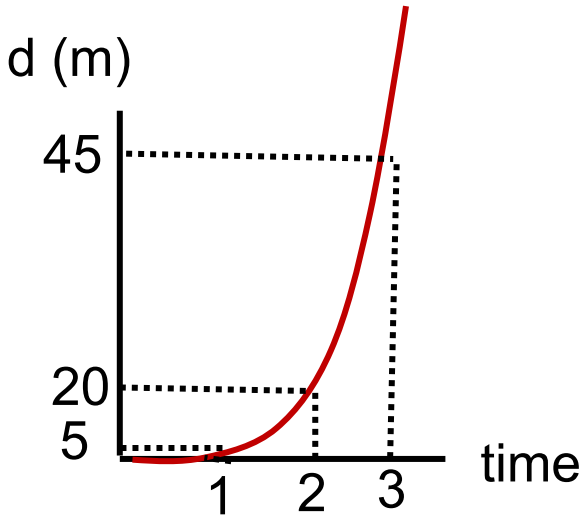
$$\text{Distance} = (1/2) \times \text{acceleration} \times \text{time} \times \text{time}$$

So: $\text{Distance} = (1/2) \times 10\ \text{m/s}^2 \times 4\ \text{s} \times 4\ \text{s}$

So: $\text{Distance} = 80\ \text{m}$

Summary: Speed v vs distance d in free fall:





speed = acceleration x time

$v = g \times t$

$= 10\ t$

= 0, 10 m/s, 20 m/s, 30 m/s,etc

distance = (1/2) acceleration x time x time

$d = (1/2)\ g \times t^2$

$d = 5\ t^2$

= 0, 5 m, 20 m, 45 m, etc

Why does it fall further and further?

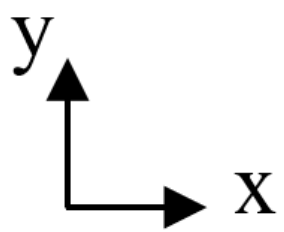
Work on:

- Many of you have unfinished old assignments

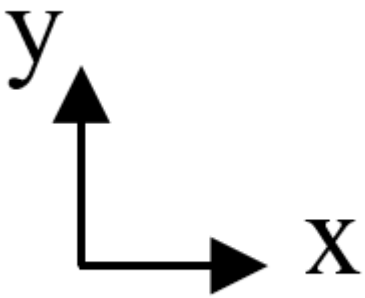
  - On page 52:
  - Do #15-23 of the Reading Comprehension Questions
  - Due Wednesday at midnight.

Reference Frames

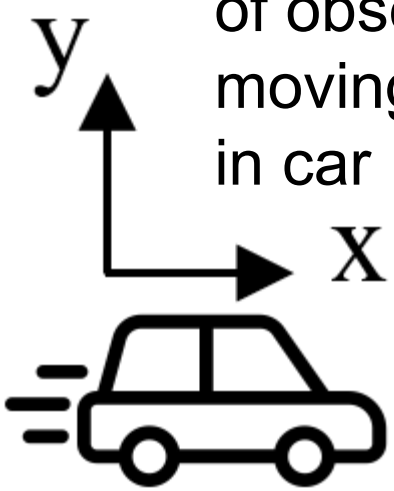
Anybody in relative motion has their own *reference frame*—a set of axes: This reference frame allows you to measure things *from your point of view.*



Reference frame of Observer at rest Along side road:



Reference frame of observer moving in car

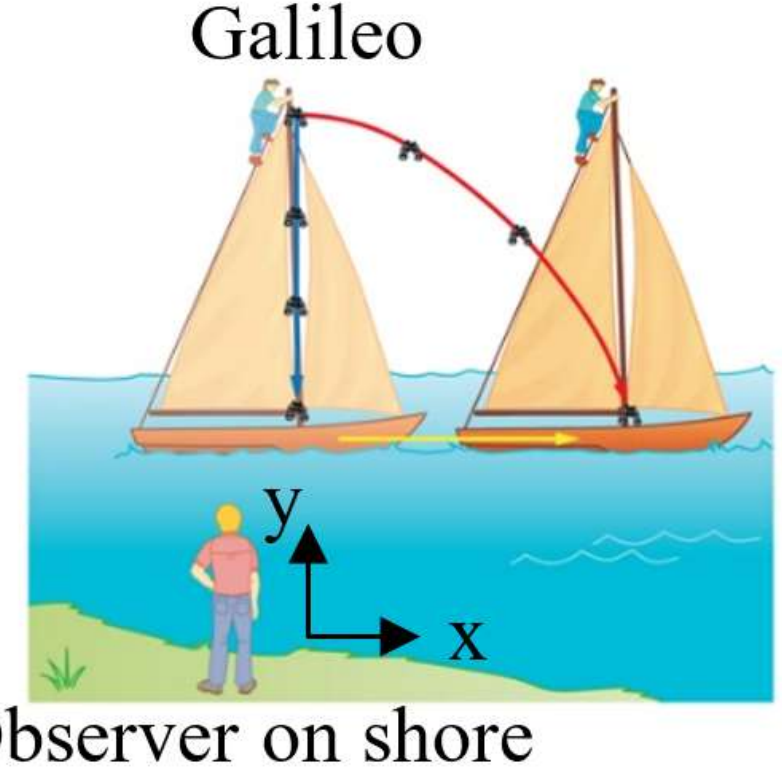


Relative motion occurs when observers move with respect to (or relative to) each other.

Where do the binoculars hit?

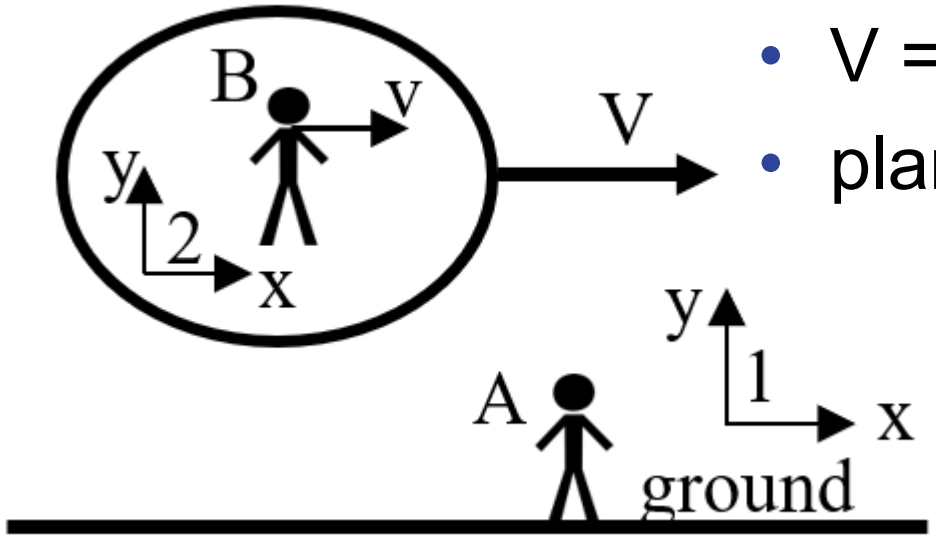
According to *Galileo*, What shape is the path of the falling binoculars?

According to the *observer*, What shape is the path of the falling binoculars?



They see different paths and velocities, but both see the binoculars hitting the same place!

Simple cases: Parallel motion

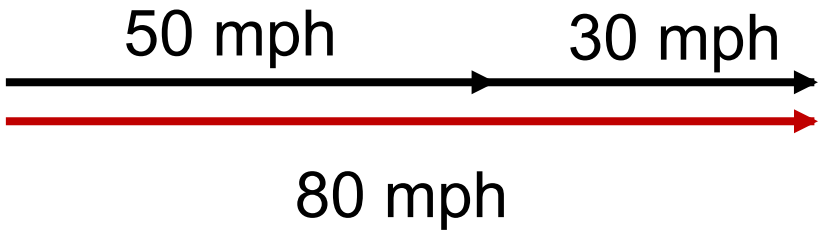


- V = velocity of air,
- plane, car, etc

- What velocity does the ground observer see?
- Rules:
- If v and V are in *same* direction, *add* speeds.
- If v and V are in *opposite* directions, subtract.

Examples

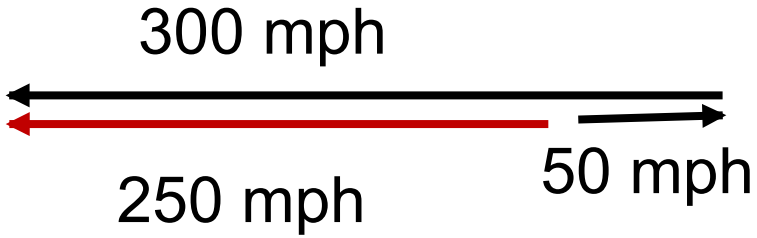
- Ex. A train moves *east* at 50 mph. A baseball player on the train throws a ball 30 mph *east*. What speed does an observer on the ground measure for the speed of the ball relative to the ground?



Both velocities are in the same direction, so you add the speeds.

Examples

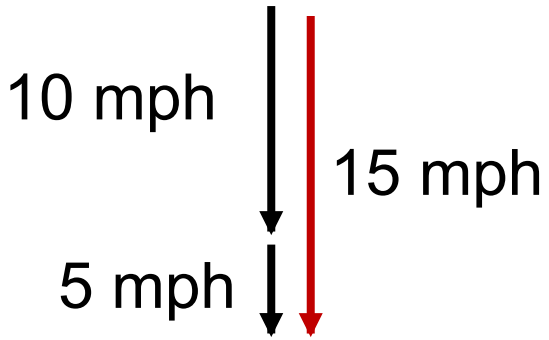
- Ex. The air is moving *east* at 50 mph. A plane is flies west at 300 mph relative to the air. What speed does an observer on the ground measure for the speed of the plane relative to the ground?



Both velocities are in the opposite direction, so you subtract the speeds.

Examples

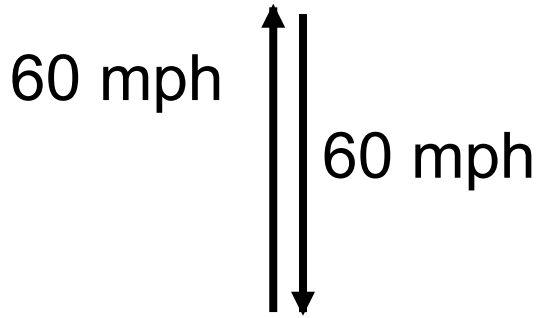
- Ex. Water in a river is flowing south at 10 mph. A boat is moving at 5 mph south relative to the water. What speed does an observer on the ground measure for the speed of the boat relative to the ground?



Both velocities are in the same direction, so you add the speeds.

Examples

- Ex. A train is moving at 60 mph north. A baseball pitcher on the train throws a pitch at 60 mph south relative to the train. What speed does an observer on the ground measure for the pitch?

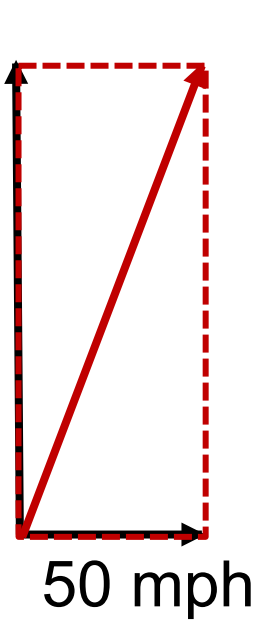


Both velocities are in the opposite direction, so you subtract the speeds.

0 mph! The ball appears to move neigther forward nor backward…it falls straight down.

Velocities at right angles:

- If the 2 velocities are at right angles, you have to add them using the parallelogram rule to find the velocity relative to the ground.
- Ex: A plane flies at 200 mph north in a wind that blows at 50 mph east.



The plane is blown off course unless it corrects by heading into the wind..

What is its speed relative to the ground?

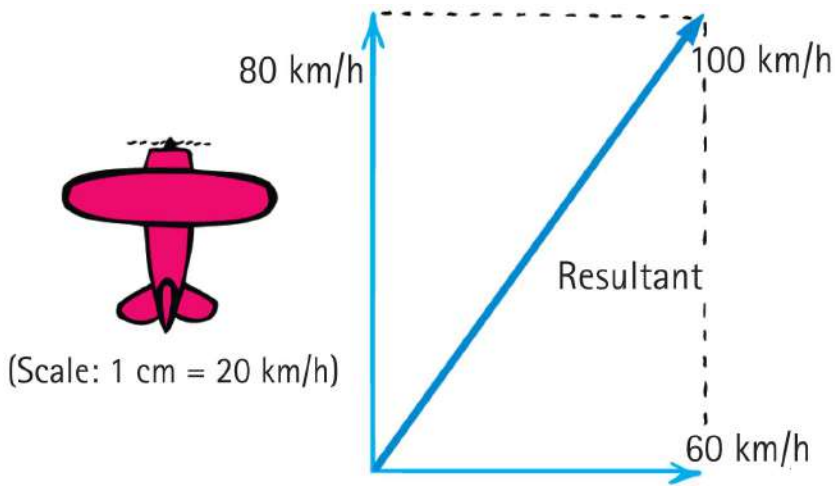
Use the Pythagorean theorem:

$$X^2 = \sqrt{200^2 + 50^2}$$

Vectors
CHECK YOUR NEIGHBOR

The 60-km/h crosswind blows the 80-km/h airplane off course at 100 km/h. If the crosswind were 80 km/h, the airplane would travel at 113 km/h at an angle of

A. less than 45 degrees.
B. 45 degrees.
C. more than 45 degrees.
D. None of the above are correct.



Vectors
CHECK YOUR ANSWER

The 60-km/h crosswind blows the 80-km/h airplane off course at 100 km/h. If the crosswind were 80 km/h, the airplane would travel at 113 km/h at an angle of

B. 45 degrees.

Comment:

The parallelogram would then be a square with a 45-degree diagona

Vectors
CHECK YOUR NEIGHBOR, Continued

You run horizontally at 4 m/s in a vertically falling rain that falls at 4 m/s. Relative to you, the raindrops are falling at an angle of

A. 0°.
B. 45°.
C. 53°.
D. 90°.

Vectors
CHECK YOUR ANSWER, Continued

You run horizontally at 4 m/s in a vertically falling rain that falls at 4 m/s. Relative to you, the raindrops are falling at an angle of

B. 45°.

Explanation:
The horizontal 4 m/s and vertical 4 m/s combine by the parallelogram rule to produce a resultant of 5.6 m/s at 45°. Again, the parallelogram is a square.

New Homework: page 54: #41-46

Test Monday for Everybody:

Still have to show up in Meeting.

Test is mostly on Unit 3, but 2-3 questions from Unit 2.

Z and DL will have a form.

The form must be submitted by the end of the hour.