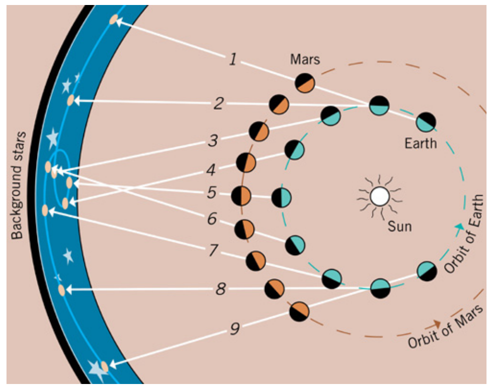
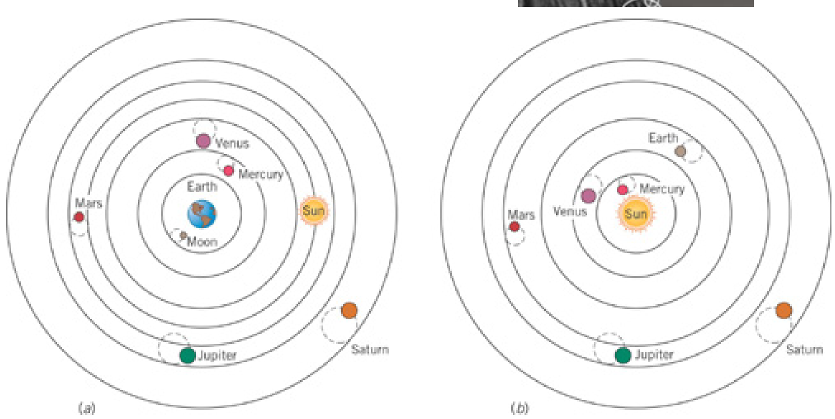
Chap 3 Motion in the Universe

Modern Astronomy



Historical Background

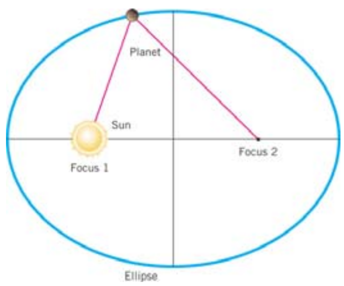
Ptolemy

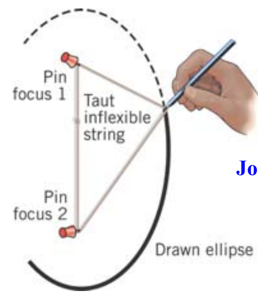


Kepler’s Laws of Planetary Motion

For a Solar System

Law #1: elliptical orbits for all the planets of a solar system, with the sun occupying one of the foci



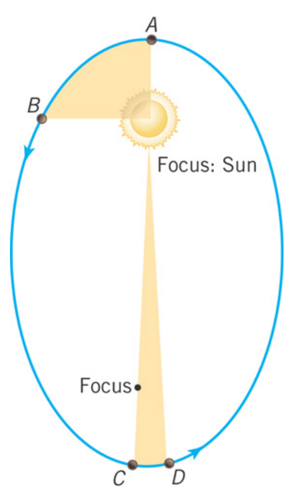


Johannes Kepler (1571-1630)

Elliptical orbit

Kepler’s 2^{nd} Law

Law #2: For a given time interval, a line drawn from the sun the to the planet sweeps out equal area no matter where the planet is in its orbit.

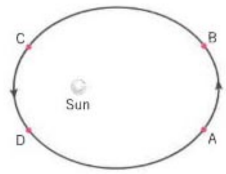


What conservation law leads to Kepler’s Second Law?

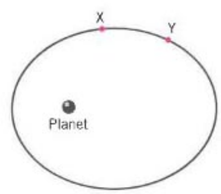
Kepler’s 2^{nd} Law

Kepler's 2nd Law

4. A planet orbits the Sun in an elliptical orbit (see figure). The distance along the orbit from A to B is the same as the distance from C to D. Compare the time it takes the planet to move from A to B to the time it takes the planet to move from C to D. Explain your reasoning.

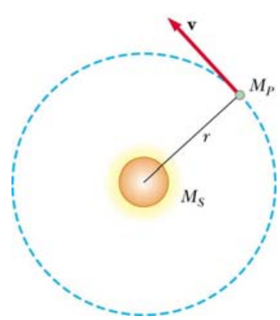


5. Suppose two different moons, X and Y, follow the same elliptical orbit around a planet. Which moon is moving faster according to the figure? Will the faster moon ever catch up to the slower one? Explain.



Satellites in Circular Orbits

Kepler's Third Law: The square of the orbital period of any planet is proportional to the cube of the average distance from the planet to the Sun.



$$\frac{t^2}{R^3} = const.$$ **indep. of mass**

$$t^2 = const \times R^3$$

Jupiter is 5.2 times farther from the Sun than the Earth is. How long is Jupiter's year?

Galileo Galilei: The Birth of Experimental Science

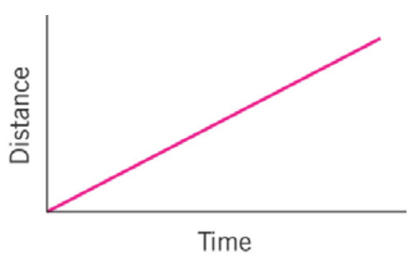
Galileo's heresy trial.

Mechanics: deals with motions of material objects.

Describing Motion: Speed

Speed is the distance an object travels divided by the time it takes to travel that distance.

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



$$d = s \times t$$

Distance traveled = Average speed x Time of travel

Describing Motion: Velocity

Velocity (v) has the same numerical value as speed, but contains information about the direction of travel. It is a vector.

9. As you drive north on the highway at 65 miles per hour, the cars in the opposing lane are traveling south at 65 miles per hour. Do the cars in the opposing lane have the same speed as you do? Do they have the same velocity? Explain.

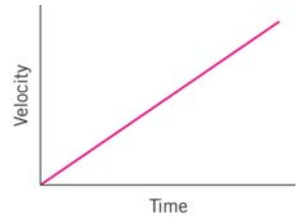
Average Velocity and Instantaneous Velocity

Average velocity is that averaged over a finite time period.

Instantaneous velocity is the velocity at a specific time. (It is the average velocity for a very short time period.)

Acceleration

Acceleration is the rate of change of velocity. It is the change in velocity divided by the time.



$$Acceleration = \frac{Final\ velocity - Initial\ velocity}{Time}$$

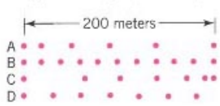
$$a = \frac{\Delta v}{t} \qquad \Delta v = a \times t$$

Unit of acceleration: distance/(time)^2 SI: m/s^2

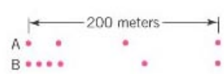
Acceleration

10. Unfortunately, your car has developed an oil leak. One drop of oil falls from your engine every 3 seconds, leaving a trail of oil drops on the road. In the figure are four patterns of oil drops you've left over the same 200-meter stretch of road. For which one(s) is your car accelerating?

For which one(s) is your car moving at a constant speed? For which one is your average speed the greatest?



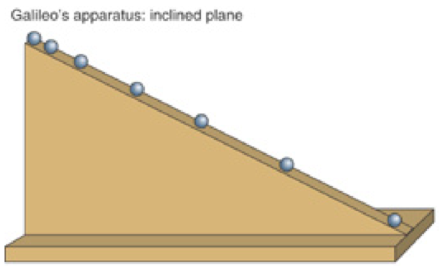
11. Unfortunately, your car has developed an oil leak. One drop of oil falls from your engine every 3 seconds, leaving a trail of oil drops on the road. In the figure are two patterns of oil drops you've left over the same 200-meter stretch of road. In which case do you achieve the highest instantaneous speed? In which case do you have the highest average speed? In which case do you achieve the greatest instantaneous acceleration (acceleration at a specific point)?



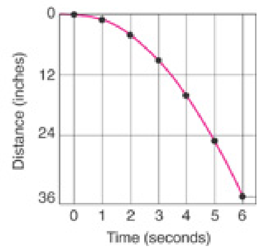
12. Is it possible for your speed to be zero when your acceleration is not zero? Explain.

Distance Traveled for Constant Acceleration

Galileo's measurement of motion with constant acceleration.

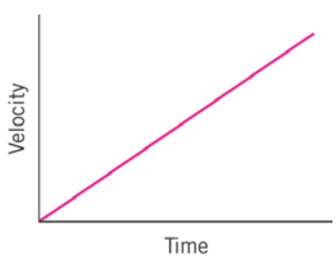


Time	Distance
0	0
1	1
2	4
3	9
4	16
5	25
6	36



$$d = k\,t^2$$

Distance, Velocity, Acceleration



$$v = at$$

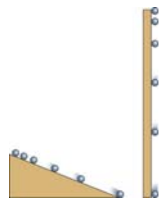
$$d = \tfrac{1}{2} a t^2$$

Acceleration due to Gravity

g = 32feet/s^2 = 9.8 m/s^2

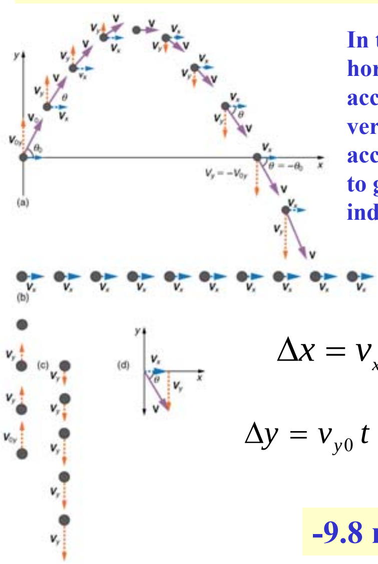
$$v = gt$$

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

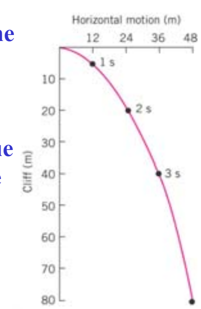


rock and feathers`

Projectile Motion



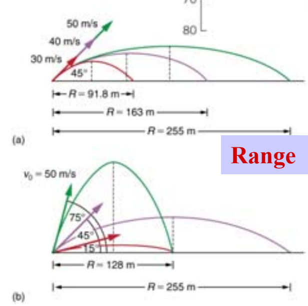
In the absence of air resistance, the horizontal or x component of the acceleration is zero, and the vertical or y component of the acceleration is the acceleration due to gravity. These two motions are independent of each other.



$$\Delta x = v_{x0}\, t$$

$$\Delta y = v_{y0}\, t + \frac{1}{2} g\, t^2$$

-9.8 m/s^2



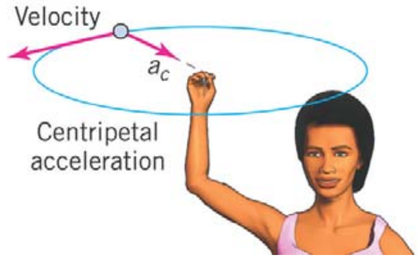
Range

Motion in a Circle

Uniform circular motion is the motion of an object traveling at a constant speed on a circular path.

The speed, v, is related to the radius of the circle, r, and the period, T, of the circular motion

$$v = \frac{2\pi r}{T}$$



The acceleration of an object in uniform circular motion is called "centripetal acceleration".

$$a = \frac{v^2}{r}$$

Examples

10. Imagine that a new asteroid is discovered in the solar system with a circular orbit and an orbital period of 8 years.

a. What is the average distance of this object from the Sun in Earth units?

b. Between which planets would this new asteroid be located?

11. The four Galilean moons of Jupiter are Io, Europa, Ganymede, and Callisto. Their average distances from Jupiter and orbital periods are listed below in terms of Io's values.

Moon	Relative average distance	Relative orbital period
Io	1.00	1.00
Europa	1.59	2.00
Ganymede	2.54	4.05
Callisto	4.46	9.42

a. Plot the square of the relative orbital period versus the cube of the relative average distance for each moon. In words, state the pattern you find in your graph.

b. From this information, do you agree or disagree that Kepler's third law (as applied to the moons of Jupiter) holds for Jupiter's four Galilean moons? Explain.

Examples

16. It takes light (speed = 3.0×10^8 m/s) 8.33 minutes to travel from the Sun to the Earth and 1.3 seconds from the Moon to the Earth. What is the Sun's average distance from the Earth? The Moon's?

17. While traveling out in the country at 50 miles per hour, your car's engine (and brakes) stops working and you coast to a stop in 25 seconds. What was your average acceleration during the time after the motor shut off?

18. Starting from rest, a train reaches a final, constant speed in 35 seconds while accelerating at a constant rate of 3 km/hour/s.

a. What is the final speed of the train?
b. What is the total distance traveled by the train during this period of constant acceleration? (Be careful here with your units.)

Examples

23. Two balls are released simultaneously from the same height, 10 meters above the ground. The first ball is released at rest and the second ball is released with a horizontal velocity of 15 m/s. Which ball reaches the ground first? Why?

24. A girl grabs a bucket of water and swings it around her in a horizontal circle, at a constant speed of 2 m/s at an arm's length of 0.7 meters. What is the centripetal acceleration of the bucket of water?

25. The space shuttle orbits the Earth in a near-circular orbit at a constant speed approximately 100 miles above the Earth's surface. If we assume that the centripetal acceleration is equal to the acceleration due to gravity at sea level (9.8 m/s^2) and the orbital radius is equal to the radius of the Earth (6380 km):

a. What is the average speed of the space shuttle?
b. How long does the space shuttle take to make one orbit around the Earth?