PHYS 1403 Stars and Galaxies

Recap of Important Laws

1. What is Galileo's law of falling body?
   In the absence of friction the acceleration due to gravity is constant.
   For Earth g is 9.8 m/s^2

Recap of Important Laws

1. What are Newton's Laws of Motion?
   Law of Inertia:
   A body stays at rest or in uniform motion until and unless an external force acts on it.
   Law of Force:
   Acceleration of a body is proportional to the force it experiences and inversely proportional to the mass it has.
   Law of Action and Reaction:
   For every action there is equal and opposite reaction.

Recap of Important Laws

1. What are Kepler's laws of planetary motion?
   Law of Ellipses:
   A planet revolves around the Sun in an ellipse, a circle is a special type of ellipse.
   Law of Equal Areas:
   A planet moves faster when it is closer to the Sun and slower when it is farthest from the Sun.
   Law of Periods:
   The period squared is equal to the cube of semi-major axis of the ellipse.

Questions for Today's Class

1. Why do we need to study circular motion?
2. What is Centripetal force?
3. What is Newton's law of gravitation?
4. How do we describe Orbital Motion using Newton's Laws.

Why do we need to study circular motion?

Natural motion is not always straight line, many objects exhibit circular motion and stars and galaxies are no exception.

To describe motion of rotating bodies we use the terminology Angular analogue for linear motion are

Topics

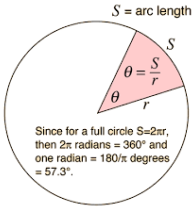
Radian
Angular speed
Angular Velocity
Angular Acceleration
Torque
Angular Momentum.

Radian

Radian: An angle at the center of a circle whose arc is equal in length to the radius

Units of Measure: Radian, Degrees and Revolutions

1 radian = 57.3 degrees



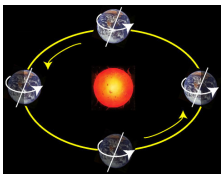
Source: wikipedia

Angular Speed and Velocity

Angular speed (ω): How fast something is rotating

Angular Velocity (ω): How fast something is rotating, clockwise or counter clockwise

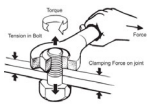
ω = change in angle / change in time
SI units rad/s or rev/s, or deg/s



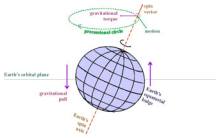
Angular Acceleration (α): How fast angular velocity is changing
α = change in ω / change in time
SI units rad/s^2 or rev/s^2, or deg/s^2

Torque and Angular Momentum

Torque (τ): How much force it takes to rotate something

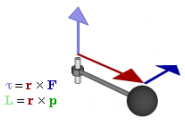


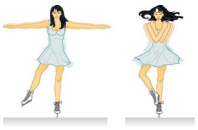
Physics Stack Exchange



UNLV Physics

Angular Momentum (L): How much momentum does a rotating body posses.





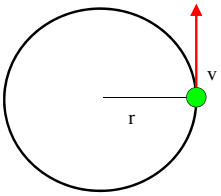
https://en.wikipedia.org/wiki/Angular_momentum

What is Centripetal Force?

1. Centripetal and Centrifugal Force
2. Visual Demo
3. Consequences of Centripetal Force in Astronomy

What is Centripetal Force?

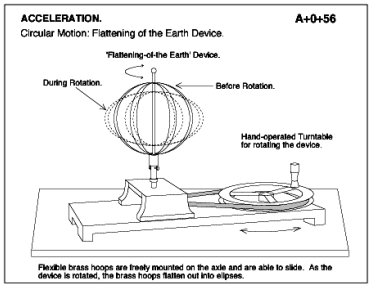
- Any object that moves in a circle or an arc has centripetal force
- Centripetal force (F_c) measured in Newton's $F_c = ma = m\ v^2 / r$
- Centripetal (radial) acceleration $a_c = v^2 / r$



Circumference = $2\ \pi\ r$

$v = 2\ \pi\ r\ /\ t$

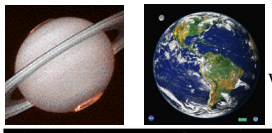
Visual Demo of Centripetal Force



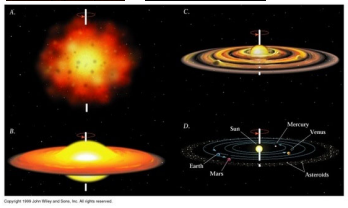
https://www.youtube.com/watch?v=Tctr8CIMOZA

Image source: NASA, STSI

Consequences of Centripetal Force



Why planets are not perfect spheres?



Solar System

Source: Wikipedia

Galaxy

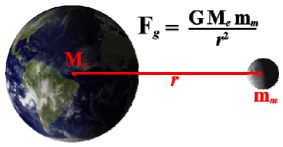
What is Newtons Law of Gravity?

1. Newton's Law of Gravity
2. Inverse Square Law
3. Gravitational Constant
4. Important Consequence of Newtons Laws

What is Newton's Law of Gravitation?

Any two bodies are attracting each other through gravitation, with a force (F_g) proportional to the product of their masses (M,m) and inversely proportional to the square of their distance (r). G is called gravitational constant.

$$F_g = \frac{GMm}{r^2}$$

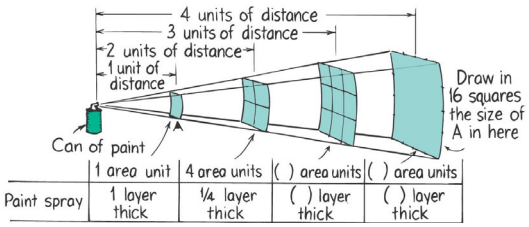


Gravity and Distance: The Inverse-Square Law

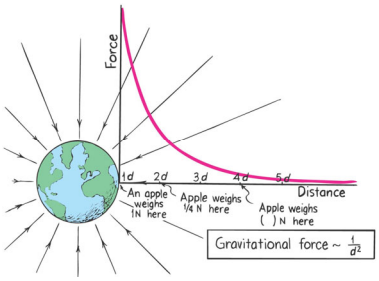
Inverse-square law -- $\frac{1}{r^2}$

- relates the intensity of an effect to the inverse-square of the distance from the cause
- in equation form: *intensity* = 1/*distance*^{2}
- for increases in distance, there is decreases in force
- even at great distances, force approaches but never reaches zero

Inverse-Square Law



Force of Gravity and Inverse-Square Law

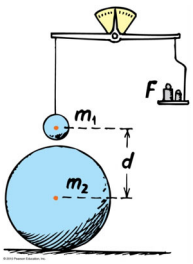


Gravitational Constant

How to find the value of G?

$G=6.67\times10^{-11}\ N.m^2/kg^2$

$$F_g = \frac{Gm_1m_2}{d^2}$$



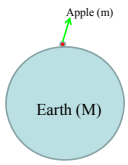
Gravitational force is significant only for very large masses and small separation distance

How to find the mass of Earth?

Weight = Gravitational Force

$$mg = \frac{GMm}{r^2}$$

$$M = \frac{g\ r^2}{G}$$



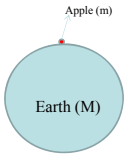
Since g, r and G are known we can calculate the mass of Earth = 6×10^{24} kg

Acceleration due to Gravity *g* depends on Mass and Size of a Planet

Weight = Gravitational Force

$$mg = \frac{GMm}{r^2}$$

$$g = \frac{GM}{r^2}$$



If we know G, M and r then we can find g

Important Consequence of Newtons Laws

- Why Earth has to Move around Sun?
  - $a_{sun} = F/M_{sun}$
  - $a_{earth} = F / M_{earth}$
  - M_{sun} is 300,000 times larger than M_{earth}
  - Therefore a_{sun} is much small than a_{earth}
- The sun also moves slowly just as you would move if you swing a child in a circle.
- The center of mass is inside the Sun, therefore we see only a wobble motion.

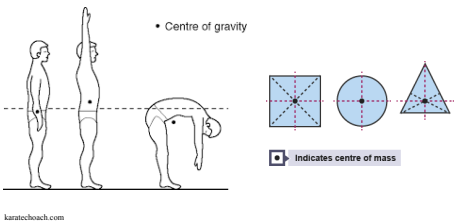
How do we describe orbital motion using Newton's Laws?

1. Center of mass and Gravity
2. Center of mass in Sun-Earth system
3. Types of Orbits
4. Geosynchronous Orbits
5. Escape Velocity
6. Artificial Gravity
7. Gravity Assist

Center of Gravity and Mass

Atvconnection.com

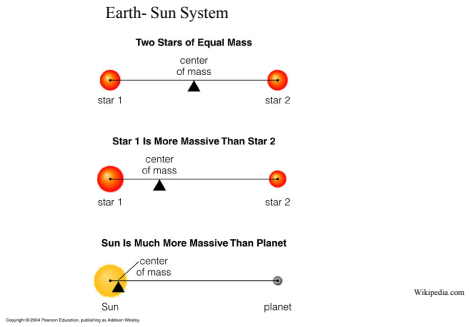
Balance point of any System



karatechoach.com

Wikipedia.com

Sun – Earth System



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Types of Orbits

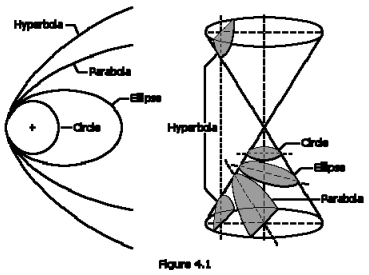
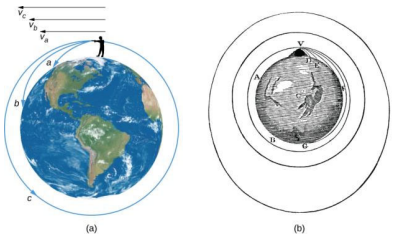


Figure 4.1

What is the Velocity of Escape?

Rocket and Space Technology

Types of Orbits



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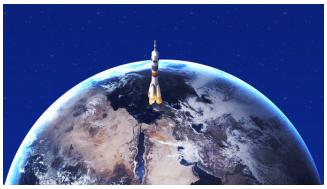
Escape Velocity

Escape velocity is the velocity required to escape the gravitational force of attraction of an astronomical body

$$v = \sqrt{\frac{2GM}{r}}$$



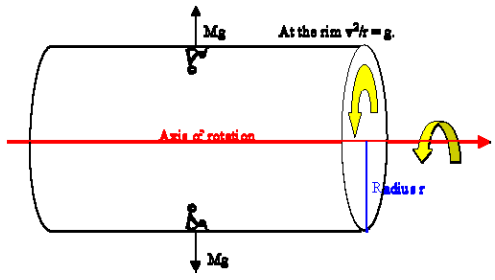
M = mass of the central body in kg
G = gravitational constant (6.67×10-11 m3/s2/kg)
r = radius of the central body

For Earth it is 11.2 km/s or 24,600 miles/hour

Can We Create Artificial Gravity?

cv.nrao.edu

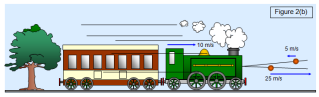
Yes, But Technology is Challenging



https://www.youtube.com/watch?v=jkgrYL69mmA

Image source: NASA, STSI

What is Gravity Assist?



Source: schoolphysics.co.uk

HyperPhysics Concepts

Wednesday class this week

- Complete Class Assignment 4

Acknowledgment

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- Images and text material have been borrowed from various sources with appropriate citations in the slides, including PowerPoint slides from adopted text book.