Physics 2101
Section 3
March 22rd : Ch.13-14

Announcements:

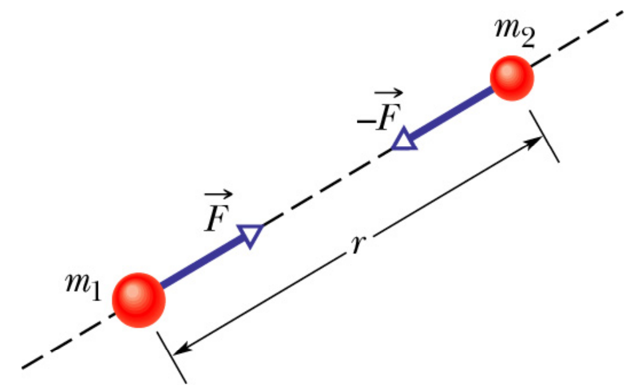
- More on gravity.
- Start Ch. 14
- Exam. 3 on Mar. 24th

Class Website:

http://www.phys.lsu.edu/classes/spring2010/phys2101-3/

http://www.phys.lsu.edu/~jzhang/teaching.html

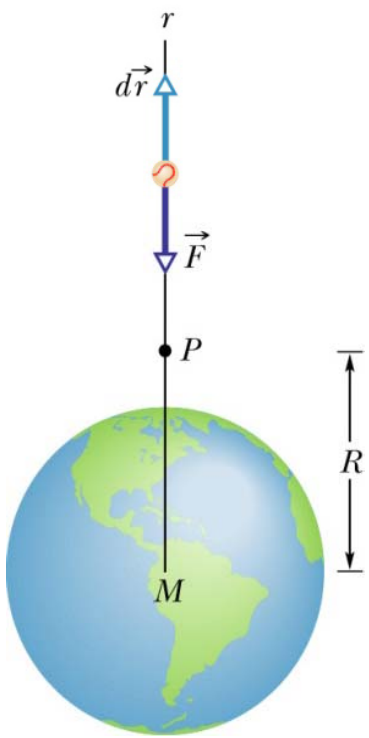
Chapt. 13: review



Force on 1 due to 2: $$\vec{F}_{12} = G\frac{m_1 m_2}{r_{12}^2}\hat{r}_{12}$$

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

Force on 1 due to many: $$\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots + \vec{F}_{1n} = \sum_{i=1}^{n}\vec{F}_{1i}$$ **VECTOR ADDITION!!**



Gravitational potential energy

If we define U = 0 at ∞, then the work done by taking mass m from R to ∞

$$U(r) = -G\frac{m_1 m_2}{|r_{12}|}$$

$$\vec{F}_{12} = G\frac{m_1 m_2}{r_{12}^2}\hat{r}_{12}$$

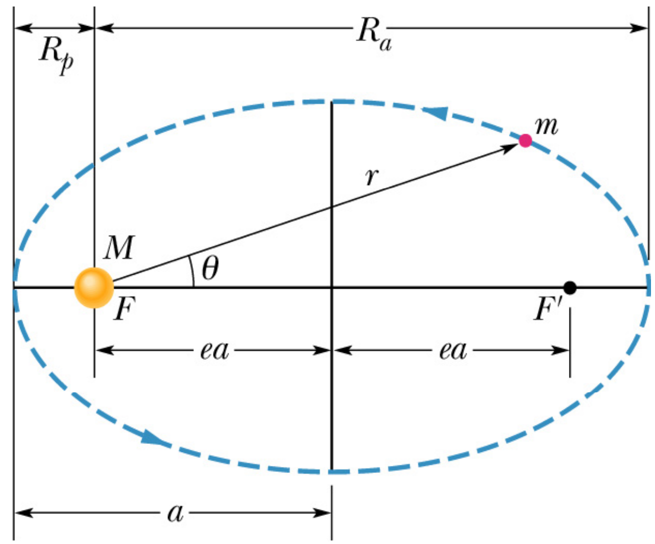
Planets and Satellites: Kepler's Laws

Kepler ⇄ Brahe ⇄ Newton

1571-1630 1546-1601 1642-1727

1) Law of Orbits:

All planets move in elliptical orbits with the Sun at one focus



Ellipse criterion:

Fm + F'm = const

Assumes $M_{Sun} \gg M_E$

a = semimajor axis

e = eccentricity

	sun-earth	earth-moon
farthest point R_a =	aphelion	= apogee
closest point R_p =	perihelion	= perigee

$$R_a = a(1+e)$$

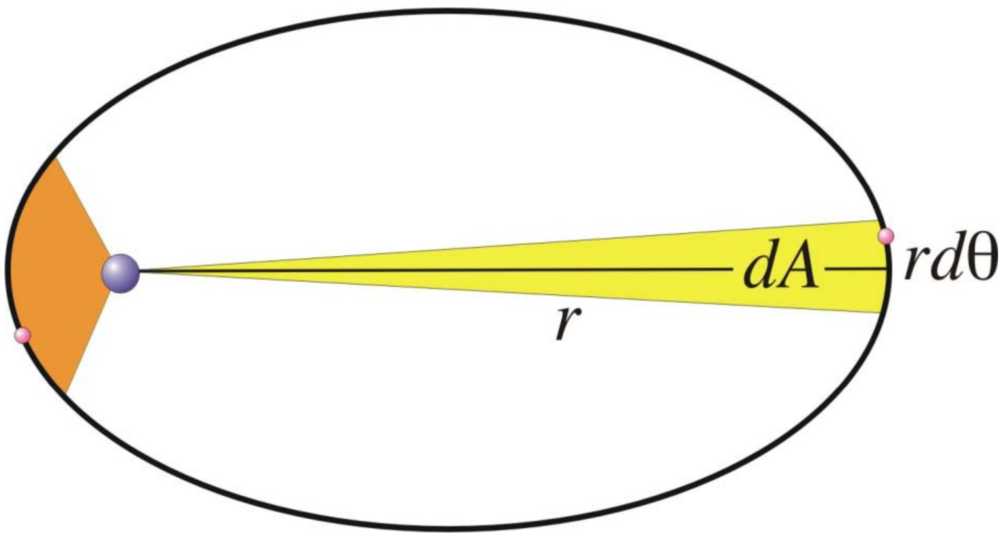
$$R_p = a(1-e)$$

Planets and Satellites: Kepler's 2nd Law

2) Law of equal areas :
A line that connects a planet to the sun sweeps out equal areas in equal time

- Planets move slowest when furthest away from Sun (at R_a)
- Planets move fastest when closest away from Sun (at R_p)

ANGULAR MOMENTUM IS CONSERVED



Angular momentum $\vec{L} = \vec{r} \times \vec{p}$

$$L = rp = r(mv) = r(m(\omega r)) = mr^2\omega$$

$$\frac{L}{m} = r^2\omega$$

Area of "triangle": $dA = \frac{1}{2}(r\,d\theta)r$

$$\frac{dA}{dt} = \frac{1}{2}r^2\frac{d\theta}{dt} = \frac{1}{2}r^2\omega$$

$$\frac{dA}{dt} = \frac{L}{2m} = \text{constant}$$

Planets and Satellites: Kepler's 3rd Law

3) The Law of Periods :

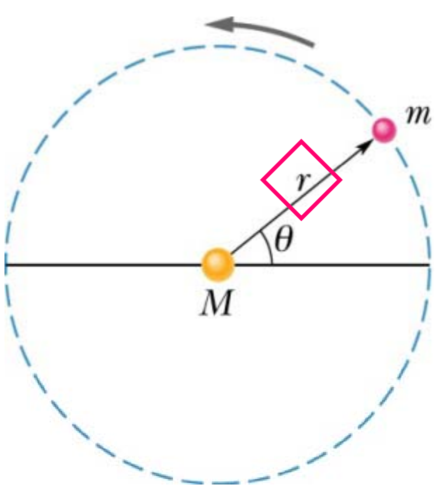
The square of the period of any planet is proportional to the cube of the semimajor axis of its orbit

$$-\frac{Gm_{sat}M_E}{r_{sat}^2} = -m_{sat}\frac{\left(\frac{2\pi r_{sat}}{T}\right)^2}{r_{sat}} \Rightarrow r_{sat}^3 = \left(\frac{GM}{4\pi^2}\right)T^2$$

NOTE: $r^3 \propto T^2$

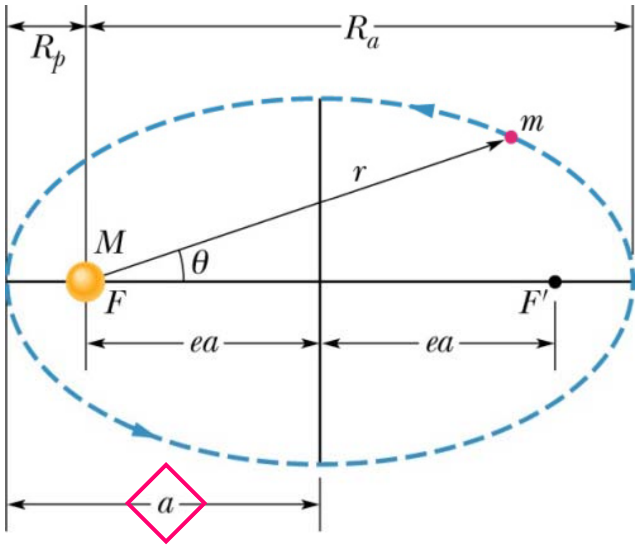
$$\Rightarrow T^2 = \left(\frac{4\pi^2}{GM}\right)r_{sat}^3$$

Circular Orbit



When used in the equations, r (radius) and a (semimajor axis) are synonymous

Elliptical Orbit



Example: Hot Jupiter

In 2004 astronomers reported the discovery of a large Jupiter-sized planet orbiting very close the star HD 179949. The orbit was about 1/9 the distance of Mercury from our sun, and it takes the planet only 1.09 days to make one orbit (assumed to be circular). (a) What is the mass of the star? (b) How fast is this planet moving?

a) $$T = \frac{2\pi r^{3/2}}{\sqrt{GM_{star}}} = 2.67\times10^{5}\text{s} \quad \text{and} \quad r = \frac{1}{9} r_{Mercury} = 6.43\times10^{9}\ \text{m}$$

$$M_{star} = \frac{4\pi^2 r^3}{T^2 G} = 2.21\times10^{30}\ \text{kg} = 1.11 M_{Sun}$$

b) $$v = \frac{2\pi r}{T} = 1.51\times10^{5}\ \text{m/s}$$

Conservation of Mechanical Energy

Escape speed: **Minimum speed (v_{escape}) required to send a mass m, from mass M and position R, to infinity, while coming to rest at infinity.**

At infinity: E_{mech}= 0 because U = 0 and KE = 0
Thus any other place we have:

$$E_{mech} = (KE + U_g) = 0 \;\Rightarrow\; E_{mech} = \left(\frac{1}{2}mv^2 - \frac{GmM}{R}\right) = 0 \;\Rightarrow\; v_{escape} = \sqrt{\frac{2GM}{R}}$$

Escape speed:
Earth = 11.2 km/s (25,000 mi/hr)
Moon = 2.38 km/s
Sun = 618 km/s

Problem 13-37

a) What is the escape speed on a spherical asteroid whose radius is 500 km and whose gravitational acceleration at the surface is is 3 m/s^2 ?
b) How far from the surface will the particle go if it leaves the asteroid's surface with a radial speed of 1000 m/s?
c) With what speed will an object hit the asteroid if it is dropped from 1000 km above the surface?

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a) $\mathrm{a_g} = \dfrac{GM}{R^2} = 3\ \mathrm{m/s^2}; \quad M = \dfrac{a_g R^2}{G}$

$$v = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2GM}{R}} = \sqrt{2a_g R} = 1.732\times10^3\ \mathrm{m/s}$$

b) Mechanical energy consevation: $\dfrac{1}{2}mv_i^2 \text{-G}\dfrac{\mathrm{mM}}{\mathrm{R_i}} = \text{-G}\dfrac{\mathrm{mM}}{\mathrm{R_f}}$

$$R_f = \frac{2GM}{\dfrac{2GM}{R_i} - v_i^2} = 2.5\times10^5\ \mathrm{m/s}$$

c) Mechanical energy consevation: $-G\dfrac{mM}{R_i} = -G\dfrac{mM}{R_f} + \dfrac{1}{2}mv_f^2$

$$\frac{1}{2}v_f^2 = GM\left(\frac{1}{R_i} - \frac{1}{R_f}\right) \Rightarrow v_f = \sqrt{2GM\left(\frac{1}{R_i} - \frac{1}{R_f}\right)} = 1.4\ \mathrm{km/s}$$

Why $v_f \neq \sqrt{2a_g h} = \sqrt{2a_g (R_i - R_f)}$?

Chapter 14: Fluids

What is a fluid??

Solids <u>**vs**</u> **liquids** <u>**vs**</u> **gasses**

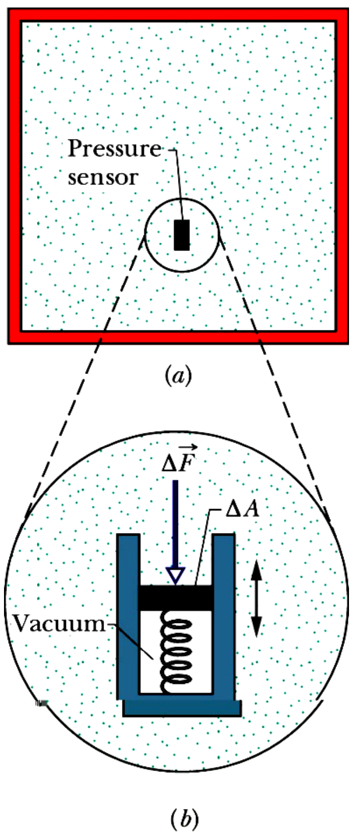
Today : Fluids at "rest"

Pressure

$$P \equiv \frac{F}{A}$$

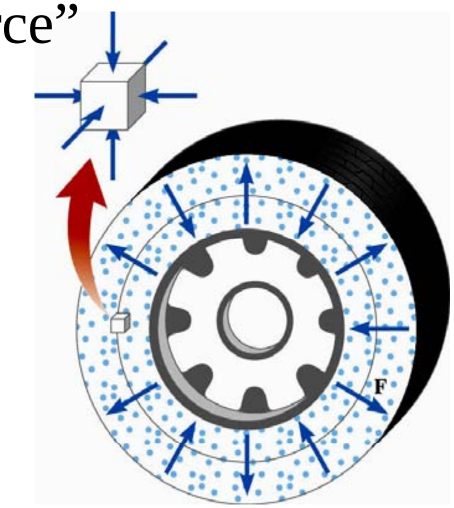
Units: pascal = Pa = N/m^2

1 atmosphere = 1 atm
= 1.01×10^5 Pa
= 760 torr
= 14.7 lb/in^2

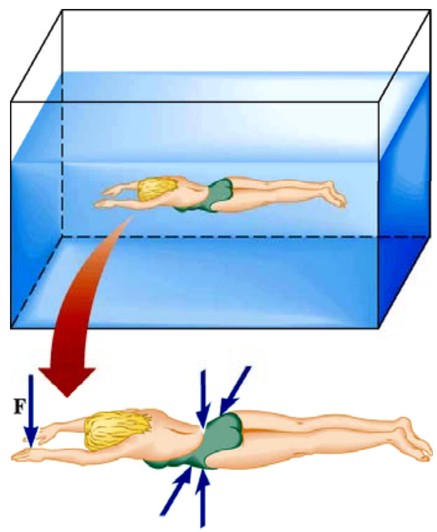


Uniform ⊥ force on flat area

“collisional force”



The collisions of gas molecules on the wall of the tire keep it inflated



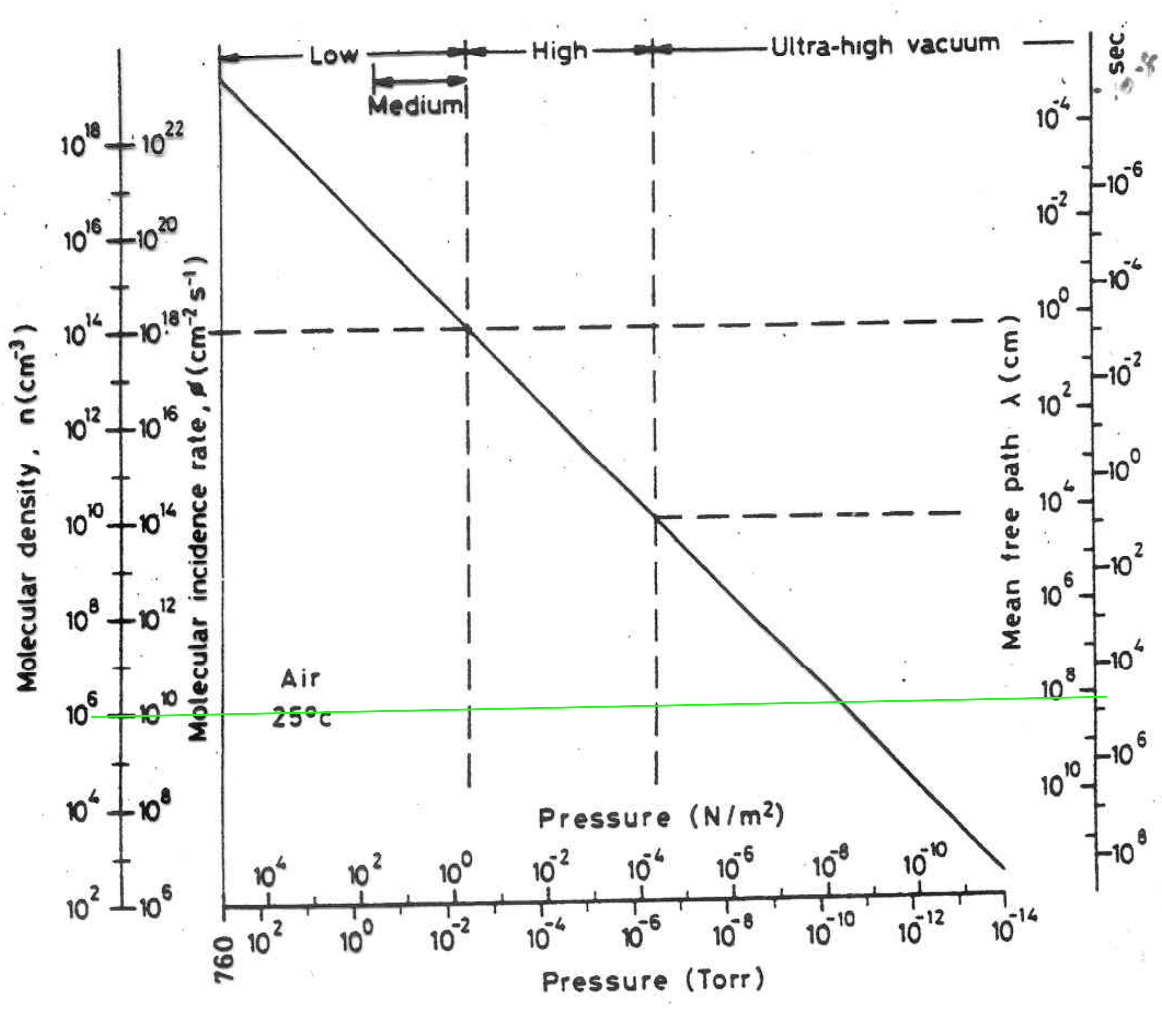
Hydrostatic Pressure: Water applies a force perpendicular to all of the surfaces in the pool, including the swimmer, the walls of the pool etc.

Density

$$\rho \equiv \frac{m}{V}$$

air = 1.21 kg/m^3
wood = 550 kg/m^3
water = 1000 kg/m^3
Al = 2700 kg/m^3 = 2.7 g/cm^3
Cu = 8960 kg/m^3 = 8.9 g/cm^3
Pb = 11340kg/m^3 = 11.34 g/cm^3

Note: density solid > liquid > gas



"Vacuum"