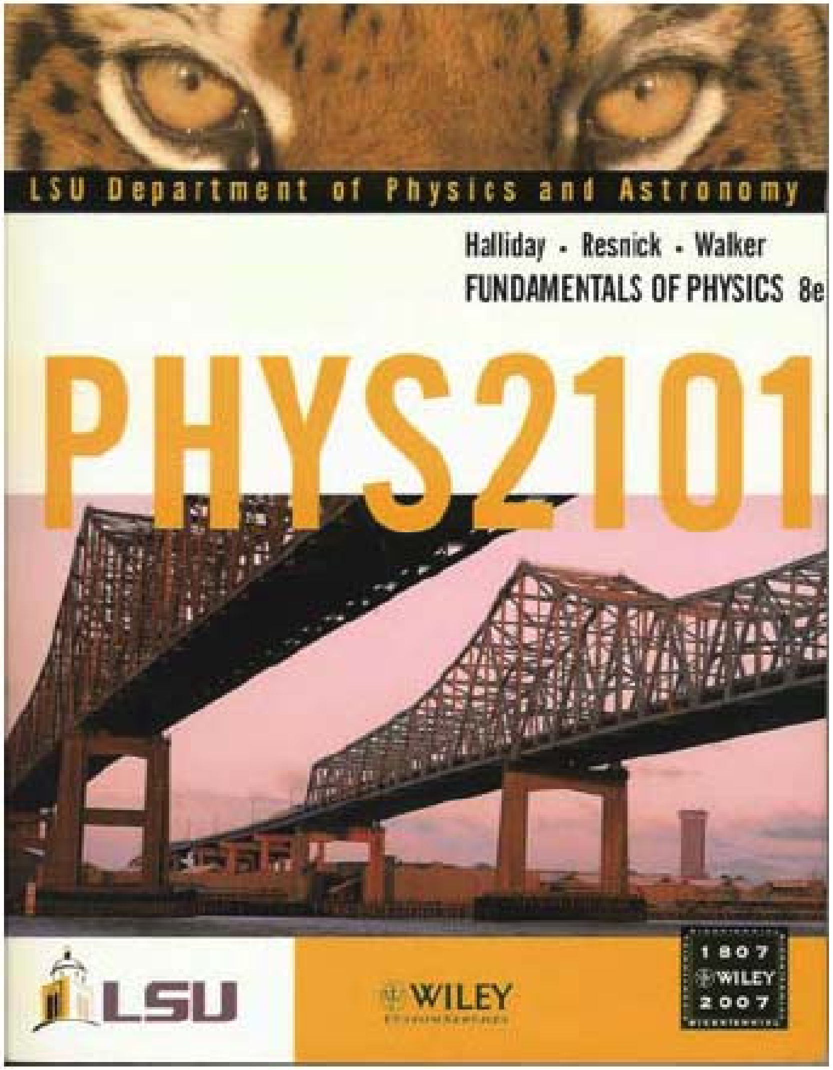


Physics 2101
Section 3
April 28th: REVIEW

Announcements:

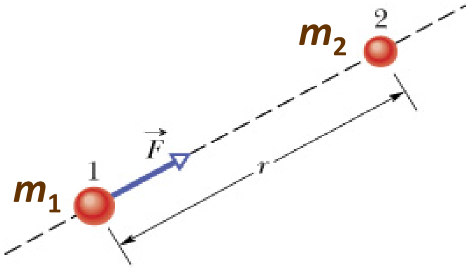
- Exam #4, today at the same place (Ch. 13.6-18.8)
- Final Exam: May 11th (Tuesday), 7:30 AM at Howe-Russell 130
- Make up Final: May 15th (Saturday) 7:30 AM

Class Website:

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

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

Chapter 13 Gravitation



-Newton's law of gravitation, which describes the attractive force between two point masses and its application to extended objects

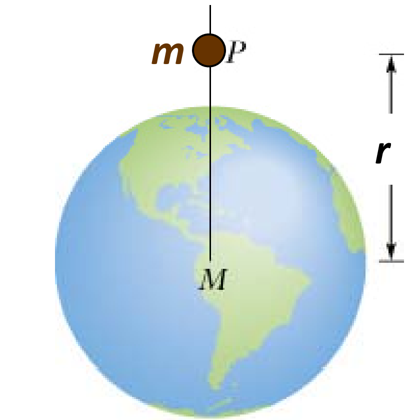
$$F = G\frac{m_1 m_2}{r^2}$$

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

-The acceleration of gravity on the surface of the Earth, above it as well as below it.

Vector addition of forces !

Gravitational Potential Energy

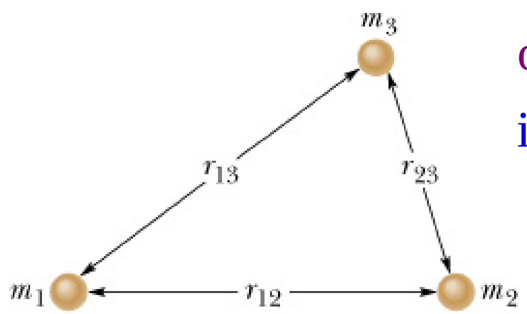


The gravitational potential energy is $U = -\dfrac{GmM}{r}$.

$$U = -\frac{GmM}{r}$$

The negative sign of U expresses the fact that the force is attractive.

Assume : $U(r = \infty) = 0$



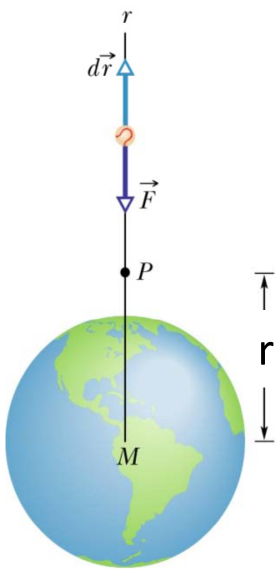
ote: The gravitational potential energy is not only associated ith the mass m but with M as well, i.e., with both objects .

If we have three masses m_1, m_2, and m_3 positioned as shown in the figure, the potential energy U due to the gravitational forces among the objects is

$$U = -\left(\frac{Gm_1m_2}{r_{12}} + \frac{Gm_1m_3}{r_{13}} + \frac{Gm_2m_3}{r_{23}}\right).$$ We take into account each pair once.

Gravitational potential energy

$$-\Delta U = W_{\text{done by force}}$$ **-- Conservative force-path independent**



$$\Delta U_g = -W_{\text{done}} = -\int_{x_i}^{x_f} \vec{F}_g \bullet d\vec{x}$$

At Earth's surface, F_g~const.

$$W = \int_{r_i}^{r_f} \left(-G\frac{mM}{r^2}\right)dr = -GmM\int_{r_i}^{r_f}\left(\frac{1}{r^2}\right)dr \qquad \Delta U_g = -W_{\text{done}} = -m(-g)\int_{y_i}^{y_f} dy = mg\Delta y$$

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

$$U_\infty - U(r) = -W = -GmM\left[0 - \left(-\frac{1}{r}\right)\right]$$

$$U(r) = -\frac{GmM}{r}$$

$$F(r) = -\frac{dU(r)}{dr}$$

$$-\frac{d}{dr}\left(-\frac{GmM}{r}\right) = -\frac{GmM}{r^2}$$

Note:

1) As before, *U* decreases as separation decreases (more negative)
2) Path independent
3) MUST HAVE AT LEAST TWO PARTICLES TO POTENTIAL ENERGY (& force)
4) Knowing potential, you can get force….

Escape Velocity

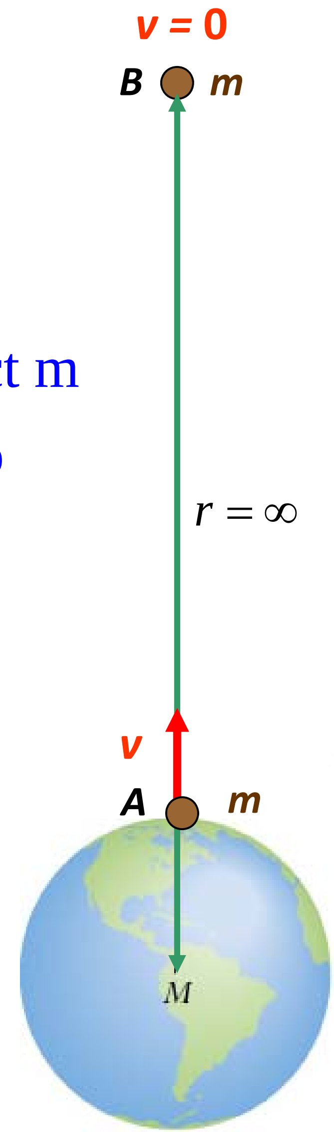
$$v = \sqrt{\frac{2GM}{R}}$$

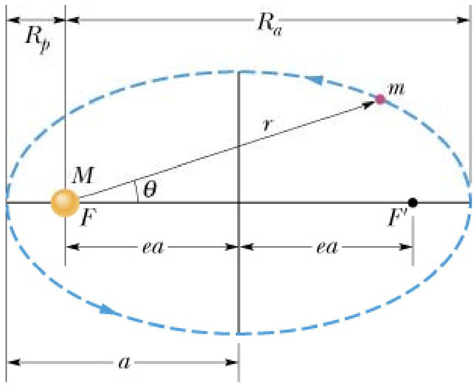
The minimum initial speed for which the projectile object m will escape from the gravitational pull of M and will stop at infinity (point *B* in the figure).

$$E_A = K + U = \frac{mv^2}{2} - \frac{GMm}{R} \qquad E_B = K + U = 0$$

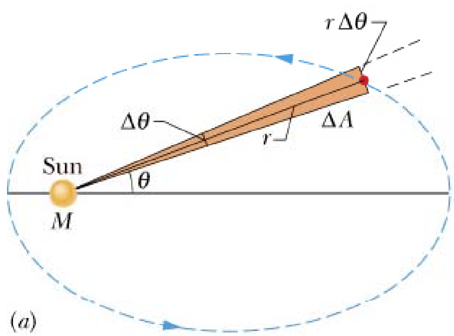
$$E_A = E_B \rightarrow \frac{mv^2}{2} - \frac{GMm}{R} = 0 \rightarrow v = \sqrt{\frac{2GM}{R}}$$

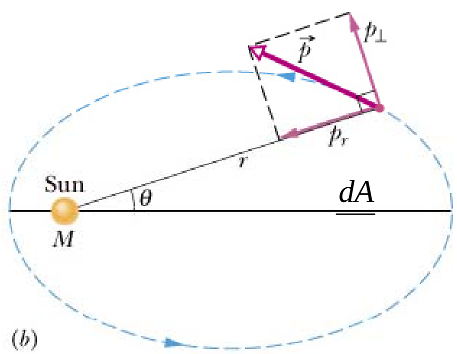
Note: The escape speed does not depend on *m*.





Kepler's First Law. All planets move on elliptical orbits with the Sun at one focus.





Kepler's Second Law.

The line that connects a planet to the Sun sweeps out equal areas ΔA in the plane of the orbit in equal time intervals Δt : $\dfrac{dA}{dt} =$ constant.

Kepler's second law is equivalent to the law of conservation of angular momentum:

$$L = rp_\perp = rmv_\perp = rm\omega r = mr^2\omega \rightarrow \frac{dA}{dt} = \frac{L}{2m} = \text{constant}$$

Kepler's 3rd Law

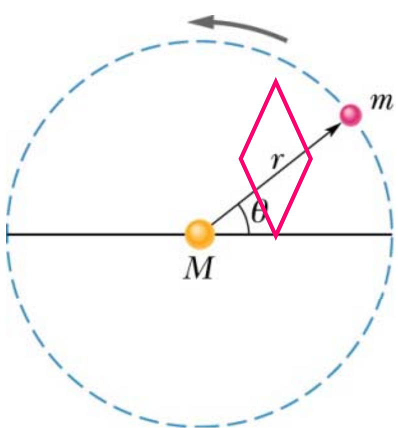
The square of the period of any planet is proportional to the cube of the semimajor axis of its orbit.

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

NOTE: r^3 proportional T^2

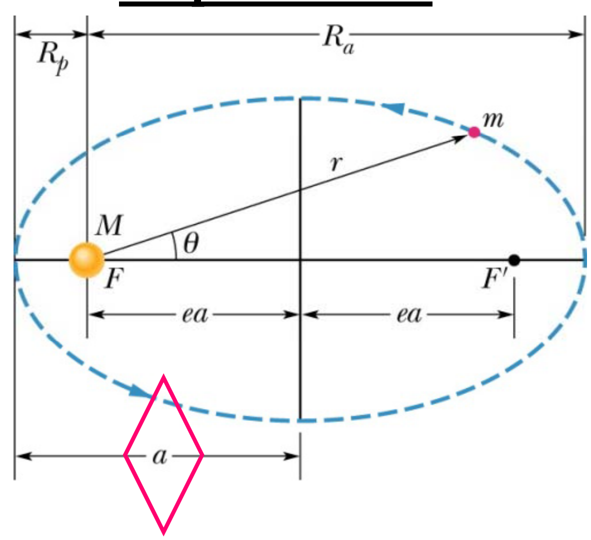
$$\Rightarrow T^2 = \left(\frac{4\pi^2}{GM}\right)r_{sat}^3$$

Circular Orbit



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

Elliptical Orbit



SHW#9 problem 3: Assume the orbital of a lunched satellite around the earth is circular.

•Show that there is only one speed that a satellite can have if the satellite is to remain in an orbit with a fixed radius and it does not depend on the mass of the satellite.

• What is the speed and height *H* above the earth's surface at which all synchronous satellite (regardless of mass) must be placed in orbit, assuming the earth is spherical?

•If a synchronous satellite has a mass *m*. How much additional kinetic energy is needed for it to escape from the earth?

(a) Since $G\frac{M_E m}{r^2} = m\frac{v^2}{r}$ is the centripetal force for a satellite with mass m, $v = \sqrt{\frac{GM_E}{r}}$, which is dependent only on radius r but independent on mass m.

(b) For a synchronous satellite,

$$24\text{h} = T = \frac{2\pi r}{v} = 2\pi r\sqrt{\frac{r}{GM_E}} = \frac{2\pi r^{3/2}}{\sqrt{GM_E}}; \qquad r = R_E + H = \left(\frac{\sqrt{GM_E}T}{2\pi}\right)^{2/3}$$

$$H = \left(\frac{\sqrt{GM_E}T}{2\pi}\right)^{2/3} - R_E$$

(c) Based upon the condition that $\left(\frac{1}{2}mv_{escape}^2 - \frac{GmM_E}{r}\right) = 0$

$v_{escape} = \sqrt{\frac{2GM_E}{r}}$ with $r = \left(\frac{\sqrt{GM_E}T}{2\pi}\right)^{2/3}$ for asynchronous satellite, so that

$$v_{escape} = \sqrt{2}\left(\frac{2\pi GM_E}{T}\right)^{1/3}$$

Chapter 14: Fluids

In this chapter we will explore the behavior of fluids. In particular we will study the following:

Static fluids:

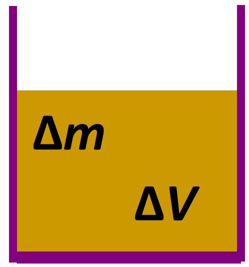
Pressure exerted by a static fluid

Methods of measuring pressure

Pascal's principle

Archimedes' principle, buoyancy

Fluid:



$$\rho = \frac{\Delta m}{\Delta V}$$

Density of mass

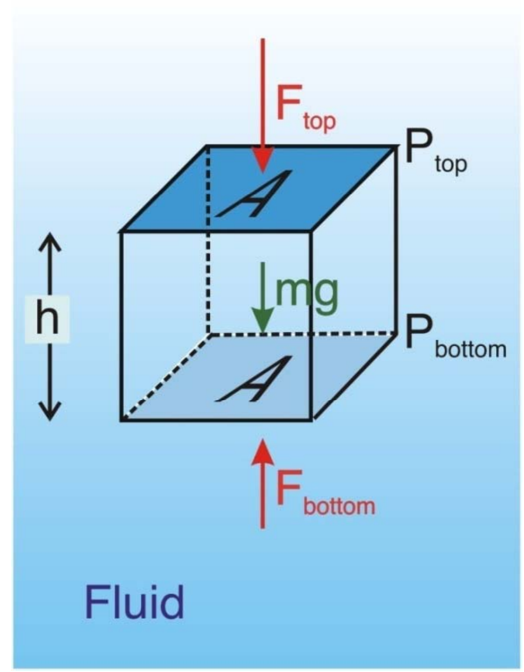
Pressure:

$$p = \frac{F}{A}$$

Fluid at rest:

$$p_{bottom} = p_{top} + \rho g h$$

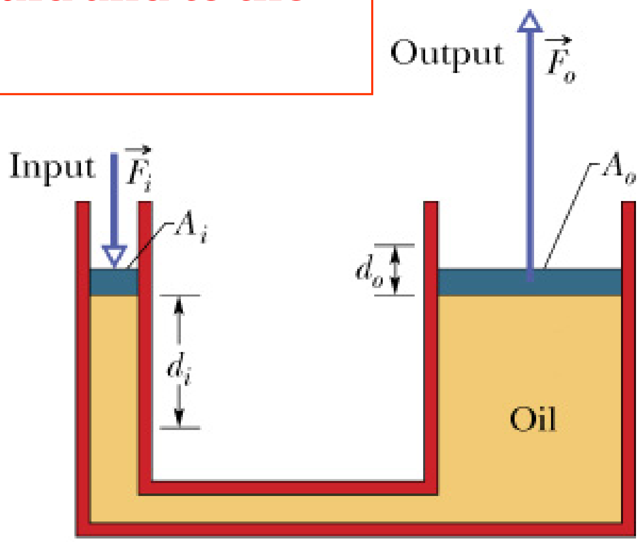
Can you calculate the pressure at any depth?



Pascal's Principle and the Hydraulic Lever:

A change in the pressure applied to an enclosed incompressible liquid is transmitted undiminished to every portion of the fluid and to the walls of the container.

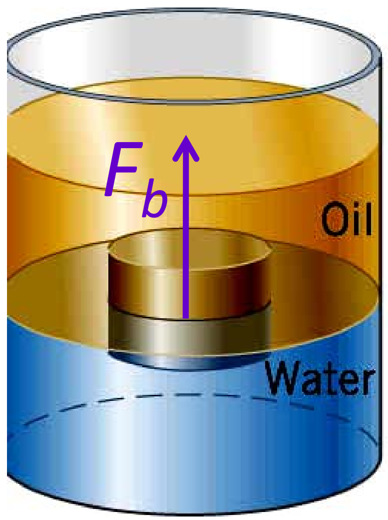
$$F_o = F_i \frac{A_o}{A_i}$$



Buoyant Force and Archimedes' Principle

When a body is fully or partially submerged in a fluid a buoyant force $\vec{F}_b$ is exerted on the body by the surrounding fluid.
This force is directed upward and its magnitude is equal to the weight $m_f g$ of the fluid that has been displaced by the body.

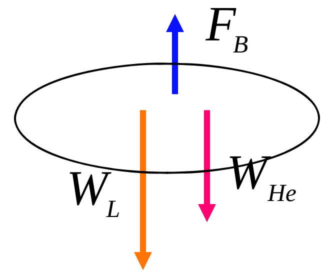
$$F_b = \rho_f g V$$



Helium Blimps

Length 192 feet Width 50 feet Height 59.5 feet
Volume 202,700 cubic feet **(5740 m³)**
Maximum Speed 50 mph Cruise Speed 30 mph
Powerplant: Two 210 hp fuel-injected, air-cooled piston engines

What is the maximum load weight of blimp (W_L) in order to fly?



The "fluid" blimp is in is: air

$$\rho_{He} = 0.179 \cdot kg/m^3 \quad \& \quad \rho_{air} = 1.21 \cdot kg/m^3$$

At static equilibrium $\sum F = 0: \quad W_{He} + W_L = F_B$

$$W_L = F_B - W_{He}$$

$$\begin{aligned} W_L &= m_{air} g - m_{He} g \\ &= \rho_{air} V_{ship} g - \rho_{He} V_{ship} g \\ &= V_{ship} g(\rho_{air} - \rho_{He}) \\ &= (5740 \cdot m^3)(9.8 \cdot m/s^2)(1.21 - 0.179 \cdot kg/m^3) \\ &= \underline{58 \cdot kN = 13{,}000 \cdot lbs} \end{aligned}$$

"Maximum Gross Weight 12,840 pounds"

Chapter 15: Oscillations

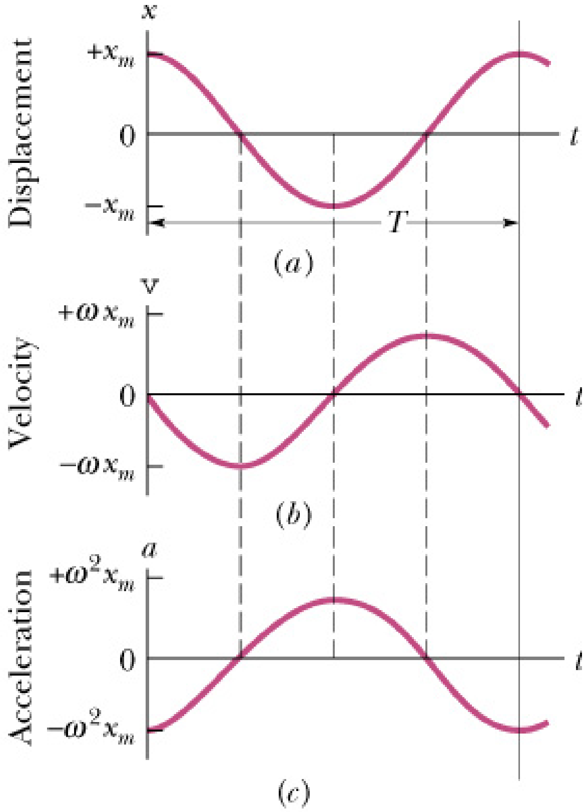
Displacement, velocity, and acceleration of a simple harmonic oscillator

Energy of a simple harmonic oscillator

Examples of simple harmonic oscillators: spring-mass system, simple pendulum, physical pendulum, torsion pendulum

Forced oscillations/resonance

Simple harmonic Motion: Kinematics



Displacement:

$$x(t) = x_m \cos(\omega t + \phi)$$

Velocity of SHM

$$v(t) = \frac{dx(t)}{dt} = \frac{d}{dt}\left[x_m \cos(\omega t + \phi)\right] = -\omega x_m \sin(\omega t + \phi)$$

Acceleration of SHM:

$$a(t) = \frac{dv(t)}{dt} = \frac{d}{dt}\left[-\omega x_m \sin(\omega t + \phi)\right] = -\omega^2 x_m \cos \omega t$$

$$a(t) = -\omega^2 x(t).$$

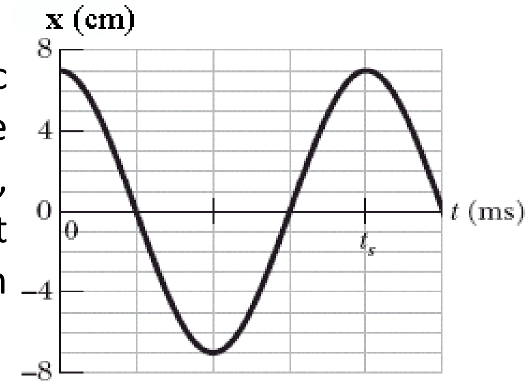
period (symbol T, units: s) vs. frequency (symbol f, unit: Hz): $f = \frac{1}{T}$.

$$\omega = 2\pi f = \frac{2\pi}{T}$$

SHW #10

The figure gives the position function of a 50g block in simple harmonic oscillation on the end of a spring. The period of the oscillation is 2s. 1) Find the velocity and acceleration function? 2) Find the maximum kinetic energy, potential energy, and total energy. 3) Find the maximum force. 4) If you want to stop the oscillation in a quarter of period, what is minimum kinetic friction coefficient required?

(Answer: $\mu_k = 0.02$)



Solutions:

$$a)\quad x(t) = x_m \cos(\omega t) \quad \text{with } \omega = \frac{2\pi}{T} = 3.14(1/s) \quad \text{and } x_m = 0.07m$$

$$v(t) = -\omega x_m \sin(\omega t)$$

$$a(t) = -\omega^2 x_m \cos(\omega t)$$

$$(b)\quad F_{\max} = -kx_m; \quad U_{\max} = \frac{kx_m^2}{2}; \quad K_m = \frac{mv_m^2}{2} = \frac{m(\omega x_m)^2}{2} = \frac{kx_m^2}{2}$$

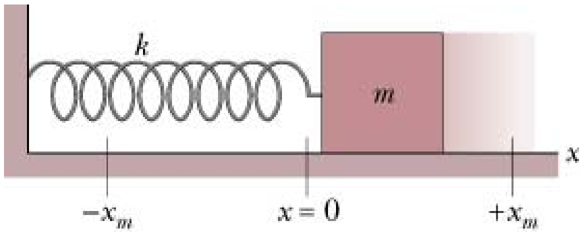
$$(c)\quad T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}} \quad \text{so that } k = \frac{4\pi^2 m}{T^2}$$

$$\text{Since} \quad W = F \cdot x_m = \mu_k mgx_m = \frac{1}{2}kx_m^2$$

$$\mu_k = \frac{1}{2mg}kx_m = \frac{1}{2mg}\left(\frac{4\pi^2 m}{T^2}\right)x_m = \frac{2\pi^2}{T^2 g}x_m = 0.02$$

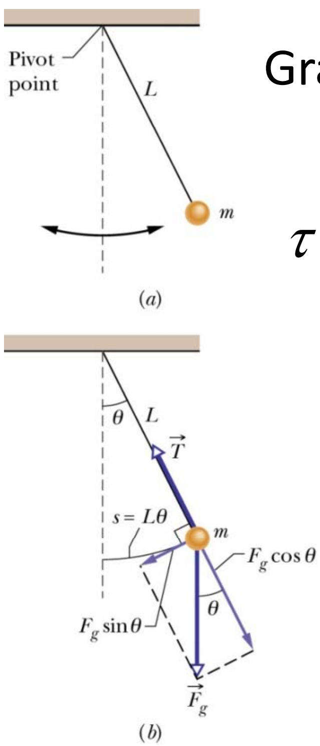
Simple Harmonic Motion : Dynamics

Newton's second law we get: $F = -kx = ma = -m\omega^2 x = -\left(m\omega^2\right)x.$



$$\omega = \sqrt{\frac{k}{m}} \quad \text{and} \quad T = 2\pi\sqrt{\frac{m}{C}} = 2\pi\sqrt{\frac{m}{k}}$$

Simple Pendulum



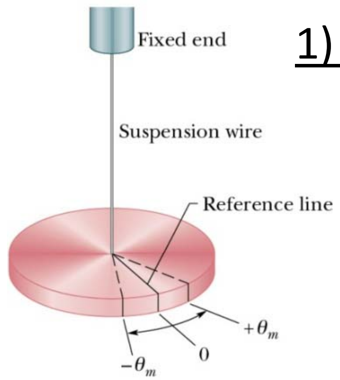
Gravity plays as the "restoring force"

$$\tau = I\alpha = -L(mg\sin\theta) \quad \Rightarrow \alpha \cong -\frac{mgL}{I}\theta \Rightarrow \alpha \cong -\omega^2\theta$$

$$SHM: \ \theta(t) = \theta_{\max}\cos(\omega t + \varphi) \ \Rightarrow \omega = \sqrt{\frac{mgL}{I}} = \sqrt{\frac{mgL}{\left(mL^2\right)}} = \sqrt{\frac{g}{L}}$$

- Independent of amplitude and mass (in small angle approximation) !
- Dependent only on L and g

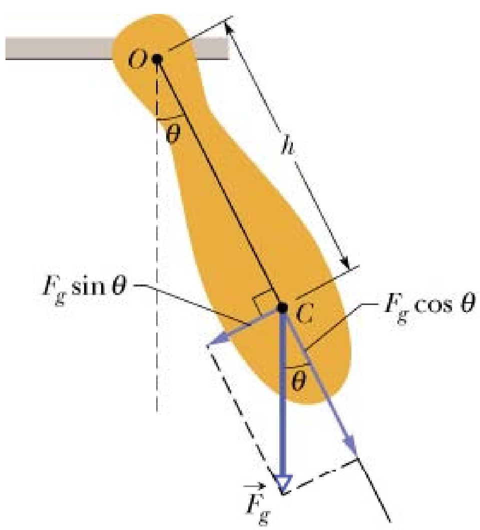
Physical Pendulums



1) Torsion pendulum

$$\tau = I\alpha = -\kappa\theta \quad \Rightarrow \alpha = -\frac{\kappa}{I}\theta$$

$$SHM: \ \theta(t) = \theta_{max}\cos(\omega t + \varphi) \quad \Rightarrow \omega = \sqrt{\frac{\kappa}{I}}$$



$$\tau = I\alpha = -L(mg\sin\theta) \quad \Rightarrow \alpha \cong -\frac{mgL}{I}\theta$$

$$\omega = \sqrt{\frac{mgh}{I}}$$

What is *I* ? $\quad I = I_{com} + mh^2.$

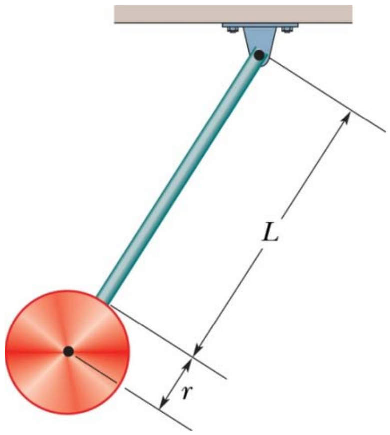
$$T = 2\pi\sqrt{\frac{I}{mgh}}$$

Problem: The pendulum consists of a uniform disk with radius R and mass M attached to a uniform rod of length L and mass m.

(a) what is the rotational inertia of the pendulum?

(b) What is the distance between the pivot and the COM?

(c) What is the period?



(a) The disc has an $I=MR^2/2$ about the COM so.

$$I(Disc) = \frac{MR^2}{2} + Mh^2 = \frac{MR^2}{2} + M(r+L)^2$$

$$I(Rod) = \frac{mL^2}{12} + mh^2 = \frac{nL^2}{12} + m\left(\frac{L}{2}\right)^2 = \frac{mL}{3}$$

(b) COM $d_{COM} = \frac{Ml_d + ml_r}{M+m}$ With l_d and l_r being the the COM of the disc and rod.

(c) The period

$$T = 2\pi\sqrt{\frac{I}{(M+m)gd}}$$

Chapter 16: Waves

wave phenomena.

Types of waves

Amplitude, phase, frequency, period, propagation speed of a wave

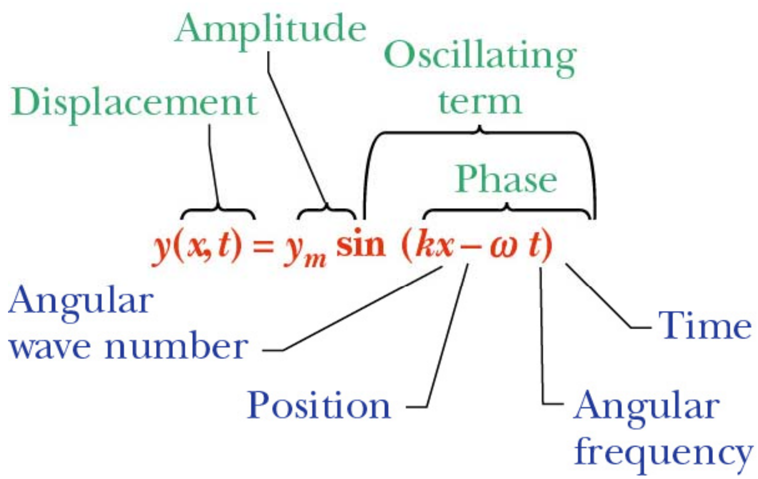
Mechanical waves propagating along a stretched string

Principle of superposition of waves

Wave interference

Standing waves, resonance

Description of traveling wave:



$$k = \frac{2\pi}{\lambda}$$ Angular wave number

$$\omega = \frac{2\pi}{T}$$ Angular frequency

Phase and Direction

$$\underline{phase\ :\ kx \pm \omega t}$$

$kx - \omega t \Rightarrow$ Wave traveling in + x direction

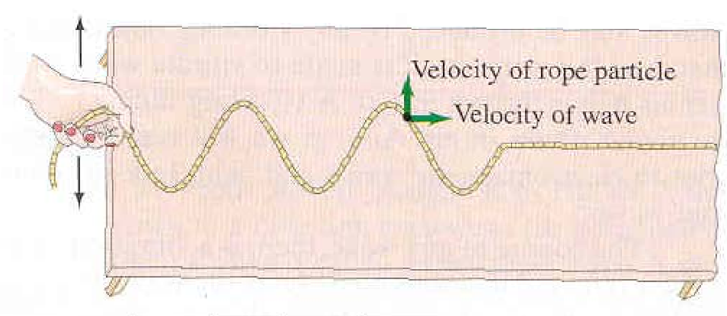
$kx + \omega t \Rightarrow$ Wave traveling in - x direction

Wave Velocity

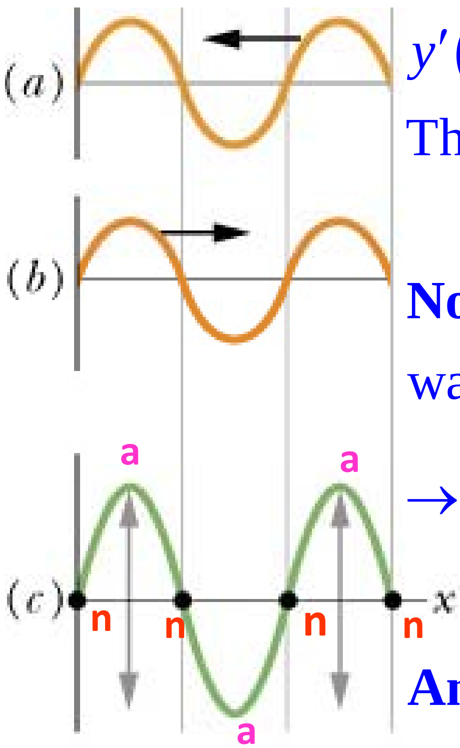
Velocity at which the wave crests move : $v_{wave} = \lambda / T = \lambda f$

Wave on a stretched string

$$v_{wave} = \sqrt{\frac{\tau}{\mu}} = \lambda f$$



Standing Wave:



The displacement of a standing wave is given by the equation

$y'(x,t) = [2y_m \sin kx]\cos \omega t.$

The position-dependent amplitude is equal to $2y_m \sin kx.$

Nodes. These are defined as positions where the standing wave amplitude vanishes. They occur when $kx = n\pi$ for $n = 0, 1, 2,$

$$\rightarrow \frac{2\pi}{\lambda} x = n\pi \rightarrow x_n = n\frac{\lambda}{2} \quad \text{for } n = 0, 1, 2, ...$$

Antinodes. These are defined as positions where the standing wave amplitude is maximum.

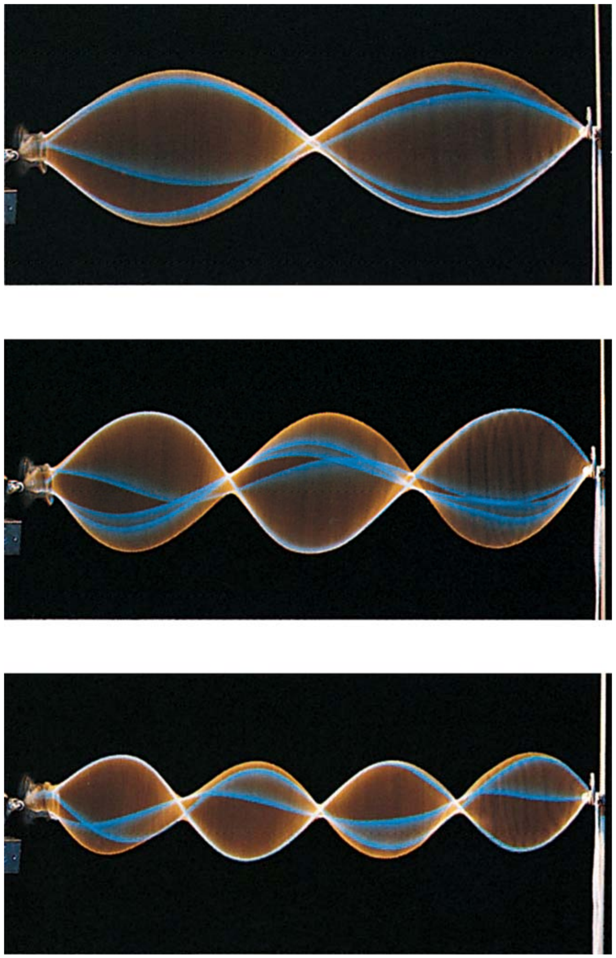
They occur when $kx = \left(n + \frac{1}{2}\right)\pi$ for $n = 0, 1, 2, ...$

$$\rightarrow \frac{2\pi}{\lambda} x = \left(n + \frac{1}{2}\right)\pi \rightarrow x'_n = \left(n + \frac{1}{2}\right)\frac{\lambda}{2} \quad \text{for } n = 0, 1, 2, ...$$

Note 1: The distance between adjacent nodes and antinodes is $\lambda/2$.

Note 2: The distance between a node and an adjacent antinode is $\lambda/4$.

Standing Waves Summary



n^{th} harmonic resonance

Notations:

- Length L
- Nodes at both ends
- Tension in String: τ
- Given mass density: μ
- Driven at a frequency f

$$f = \frac{1}{T} = \frac{\omega}{2\pi} \qquad \text{(frequency).}$$

$$y'(x,t) = [2y_m \sin kx] \cos \omega t,$$

$$kx = n\pi, \qquad \text{for } n = 0, 1, 2, \ldots .$$

This assures nodes at 0 and L

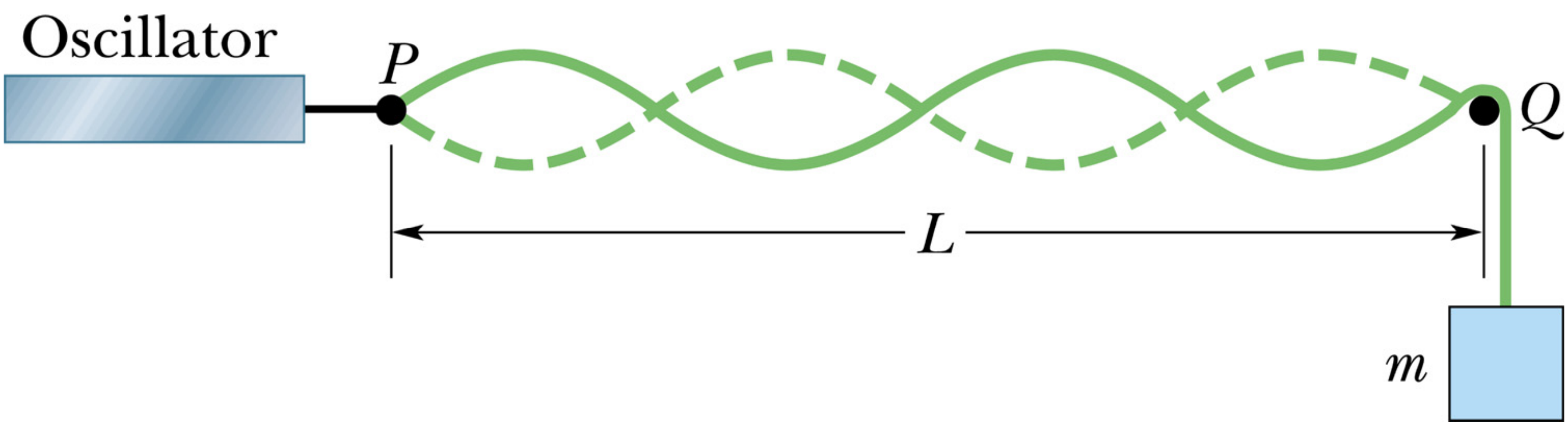
$$x = n\frac{\lambda}{2}, \qquad \text{for } n = 0, 1, 2, \ldots$$

$$\lambda = \frac{2L}{n}$$

$$f = \frac{v}{\lambda} = n\frac{v}{2L}, \qquad \text{for } n = 1, 2, 3, .$$

Problem 16-58: A sting, tied to a sinusodial oscillator at P and running over a support Q, is stretched by a block of mass m. The length is L and the linear density is μ, and the frequency is f.
What mass allows the system to set up the fourth harmonic?

n = 4



$$f = \frac{n}{2L}\sqrt{\frac{\tau}{\mu}} = \frac{4}{2L}\sqrt{\frac{\tau}{\mu}} = \frac{2}{L}\sqrt{\frac{mg}{\mu}}$$

Chapter 18

Temperature, Heat, and Thermodynamics

Temperature and the zeroth law of thermodynamics

Thermometers and temperature scales $^\circ F$ vs $^\circ C$ vs K

Thermal expansion

Temperature and heat

Specific heat

Heat of transformation

Heat, work, and the first law of thermodynamics

Heat transfer mechanisms

First Law of Thermodynamics

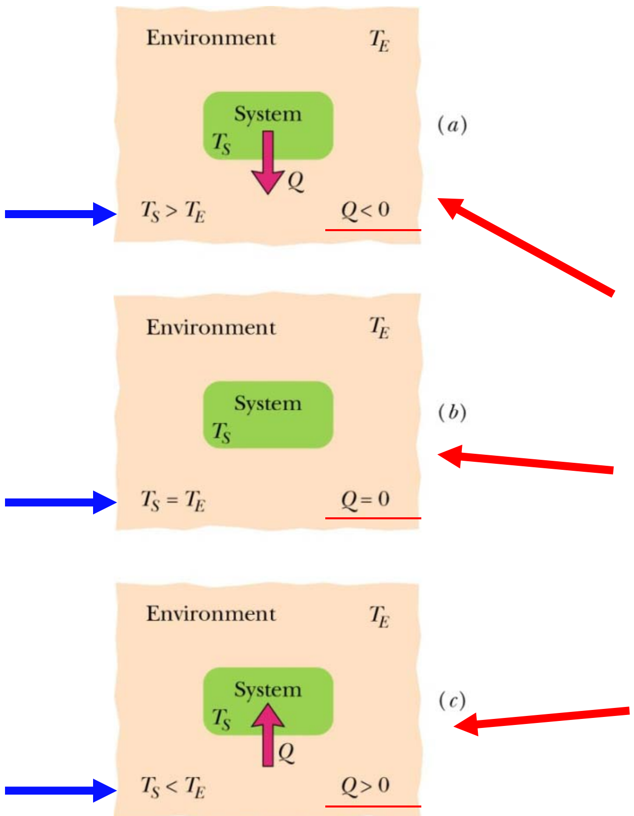
Temperature and Heat

- If two objects are NOT in thermal equilibrium, their temperatures must be different.

To make their temperatures equal (i.e. thermal equilib), HEAT MUST FLOW.

HEAT has to do with the transfer of thermal energy.

Symbol for HEAT: **Q** - **BE VERY CAREFUL ABOUT THE SIGN**



"System"- particular objecrtor set of objects

"Environment" - everything else in the universe

Heat is negative when energy is transferred from the system's thermal energy to its environment (heat is released or lost)

Heat is zero when no energy is transferred between the system's thermal energy and its environment (AT THERMAL EQUILIB)

Heat is positive when energy is transferred to the system's thermal energy from its environment (heat is absorbed)

Thermal expansion

Linear $$\Delta L = \alpha L_0 \Delta T \qquad L = L_0 \left(1 + \alpha \Delta T\right)$$

Volume $$\Delta V = \beta V_0 \Delta T \qquad V = V_0 \left(1 + \beta \Delta T\right)$$

Absorption of Heat by solids/liquids (in the same phase)

Heat Capacity

$$Q = C\Delta T = C(T_f - T_i)$$

"Change of system energy with change of temperature"

Heat Transfer (Q)

Heat Capacity [J/ºC or cal/ºC] (C)
- depends on the material

Specific Heat (heat capacity/mass)

$$Q = cm\Delta T = cm(T_f - T_i)$$

Water : c_{water} = 1 cal/g·C = 1 Btu /lb· F = 4190 J/kg· C

~ independent of temperature $c \sim\neq c(T)$

Heats of Transformation due to phase transition

Heat is transferred in or out of system, but temperature does NOT change:

Change of phase

Solid — Heat of Fusion → Liquid — Heat of Vaporization → Gas

$\Delta T = 0$

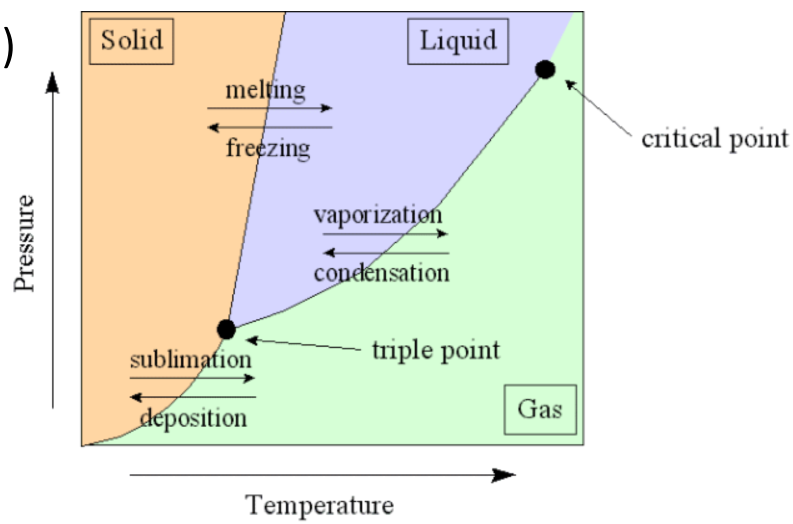
$Q = \pm L\, m$

Amount of heat transferred during phase change depends on L and mass (M)

L_F Heat of fusion -- Solid to liquid (heat is adsorbed : atomic bonds are broken

L_V Heat of Vaporization --Liquid to gas (heat is adsorbed)

L_S Heat of Sublimation --Solid to gas (heat is adsorbed)



H_2O

L_F = 79.5 cal/g = 6.01 kJ/mol = 333 kJ/kg

L_V = 539 cal/g = 40.7 kJ/mol = 2256 kJ/kg