PHY 113 A General Physics I
9-9:50 AM MWF Olin 101

Plan for Lecture 28:

Chapter 19:

The notion of temperature

1. **Comments on Exam 3**
2. **Temperature equilibrium**
3. **Temperature scales**
4. **Temperature in ideal gases**

22	10/29/2012	Kepler's laws and satellite motion	13.4-13.6	13.28, 13.34	10/31/2012
	10/31/2012	Review	10-13,15		
	11/02/2012	Exam	10-13,15		
23	11/05/2012	Fluid mechanics	14.1-14.4	14.8, 14.24	11/07/2012
24	11/07/2012	Fluid mechanics	14.5-14.7	14.39, 14.51	11/09/2012
25	11/09/2012	Temperature	19.1-19.5	19.1, 19.20	11/12/2012
26	11/12/2012	Heat	20.1-20.4		11/14/2012
27	11/14/2012	First law of thermodynamics	20.5-20.7		11/16/2012
28	11/16/2012	Ideal gases	21.1-21.5		11/19/2012
29	11/19/2012	Engines	22.1-22.8		11/26/2012
	11/21/2012	*Thanksgiving Holiday*			
	11/23/2012	*Thanksgiving Holiday*			
	11/26/2012	Review	14,19-22		
	11/28/2012	Exam	14,19-22		
30	11/30/2012	Wave motion	16.1-16.6		12/03/2012
31	12/03/2012	Sound & standing waves	17.1-18.8		12/05/2012
	12/05/2012	Review	1-22		
	12/13/2012	Final Exam -- 9 AM			

Temperature

Dictionary definition: **temperature** – a measure of the the warmth or coldness of an object or substance with reference to some standard value. The temperature of two systems is the same when the systems are in thermal equilibrium.

Not equilibrium:

T_1 T_2

Equilibrium:

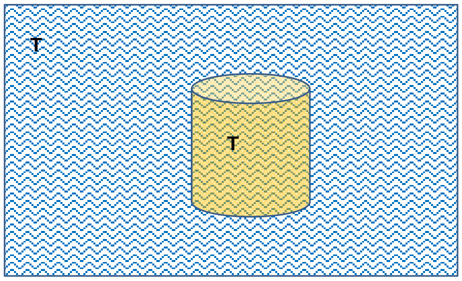
T_3

"Zeroth" law of thermodynamics:

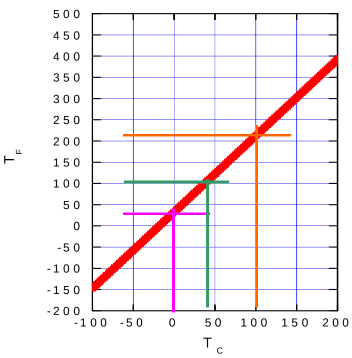
If objects A and B are separately in thermal equilibrium with a third object C, then objects A and B are in thermal equilibrium with each other.

Constant temperature "bath"

At equilibrium:



Temperature scales $T_F = 9/5\ T_C + 32$



Kelvin scale:

$T = T_C + 273.15^o$

$T \geq 0$

iclicker question:

Suppose you find yourself in a hotel in Europe or Canada. Which Celsius temperature would you set the thermostat for comfort?

- **A. -20ºC**
- **B. +20ºC**
- **C. +40ºC**
- **D. +60ºC**
- **E. +80ºC**

There is a lowest temperature:

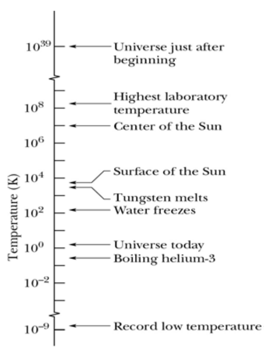
$T_0 = -273.15^o\ C = 0\ K$

Kelvin ("absolute temperature") scale

$T_C = -273.15 + T_K$

Example –

Room temperature = 68^o F = 20^o C = 293.15 K



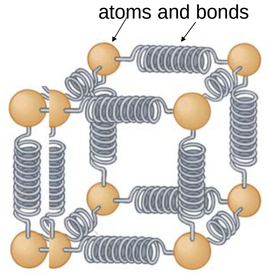
Effects of temperature on matter

Solids and liquids

Model of a solid composed of atoms and bonds

Thermal exansion:

$\Delta L = \alpha L_i \Delta T$



ΔL L_i (equilibrium bond length at T_i)

Typical expansion coefficients at $T_C = 20^o$ C:

Linear expansion: $\Delta L = \alpha\, L_i\, \Delta T$

Steel: $\alpha = 11 \times 10^{-6} / {}^oC$

Concrete: $\alpha = 12 \times 10^{-6} / {}^oC$

Volume expansion:

$V = L^3 \;\Rightarrow\; \Delta V = 3\alpha\, V_i\, \Delta T = \beta\, V_i\, \Delta T$

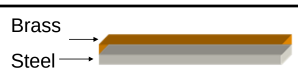
Alcohol: $\beta = 1.12 \times 10^{-4} / {}^oC$

Air: $\beta = 3.41 \times 10^{-3} / {}^oC$

TABLE 19.1 *Average Expansion Coefficients for Some Materials Near Room Temperature*

Material (Solids)	Average Linear Expansion Coefficient $(\alpha)(°C)^{-1}$	Material (Liquids and Gases)	Average Volume Expansion Coefficient $(\beta)(°C)^{-1}$
Aluminum	24×10^{-6}	Acetone	1.5×10^{-4}
Brass and bronze	19×10^{-6}	Alcohol, ethyl	1.12×10^{-4}
Concrete	12×10^{-6}	Benzene	1.24×10^{-4}
Copper	17×10^{-6}	Gasoline	9.6×10^{-4}
Glass (ordinary)	9×10^{-6}	Glycerin	4.85×10^{-4}
Glass (Pyrex)	3.2×10^{-6}	Mercury	1.82×10^{-4}
Invar (Ni–Fe alloy)	0.9×10^{-6}	Turpentine	9.0×10^{-4}
Lead	29×10^{-6}	Air[a] at 0°C	3.67×10^{-3}
Steel	11×10^{-6}	Helium[a]	3.665×10^{-3}

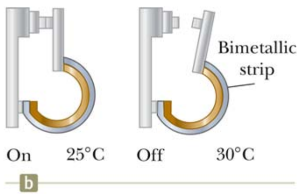
[a]Gases do not have a specific value for the volume expansion coefficient because the amount of expansion depends on the type of process through which the gas is taken. The values given here assume the gas undergoes an expansion at constant pressure.



Serway, Physics for Scientists and Engineers, 5/e
Figure 19.9c

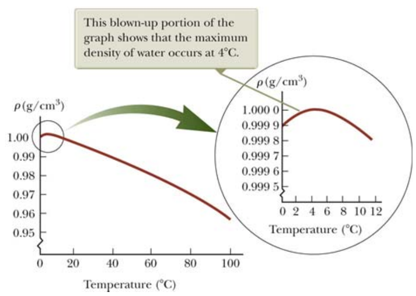
Harcourt, Inc.

Switch in thermostat



Modern thermostats use electrical circuits to detect temperature

Effects of temperature on materials – continued strange case of water:



Effects of temperature on materials – continued -- ideal gas "law" (thanks to Robert Boyle (1627-1691), Jacques Charles (1746-1823), and Gay-Lussac (1778-1850)

$$PV = nRT$$

- P: pressure in Pascals
- V: volume in m^3
- n: # of moles
- R: 8.314 J/(mol K)
- T: temperature in K

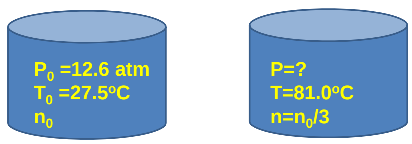
1 mole corresponds to 6.022×10^{23} molecules

–/0 points My Notes | SerPSE8 19.P019

Gas is confined in a tank at a pressure of 12.6 atm and a temperature of 27.5°C. If two-thirds of the gas is withdrawn and the temperature is raised to 81.0°C, what is the pressure of the gas remaining in the tank?

atm

$$PV = nRT$$



$$P_0V_0 = n_0RT_0 \qquad PV = nRT \quad V = V_0 \quad n = n_0/3$$

$$\frac{PV}{P_0V_0} = \frac{nRT}{n_0RT_0} \qquad \frac{P}{P_0} = \frac{T}{3T_0} \qquad P = 12.6\ atm\left(\frac{354.15}{3 \cdot 300.65}\right) = 4.9atm$$

11/09/2012 PHY 113 A Fall 2012 -- Lecture 28 16

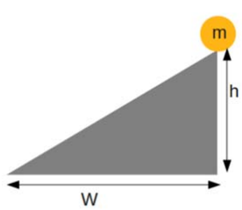
Comments about Exam 3

iclicker question:

Possible review of Exam 3 material

- **A. I would like to attend a review class session to go over the exam**
- **B. I would like to meet individually or in a small group to go over the exam**
- **C. I would like to forget the exam and take my chances that it is possible to live a full life without knowing about rotations, equilibrium, simple harmonic motion, and gravity**

11/09/2012 PHY 113 A Fall 2012 -- Lecture 28 17



1.

This problem concerns notions of energy conservation as well as rotational motion. The figure shows an object with mass $m = 5kg$, radius $R = 0.04m$, and moment of inertia $I = 0.006$ kg·m^2, initially at rest on the top of an incline of height $h = 0.6$ m and width $W = 1.2$ m. The 2 questions involve 2 different conditions for the interaction of the object with respect to the surface of the incline. You can assume that the mass in the object is distributed so that the center of mass of the object coincides with center of the object.

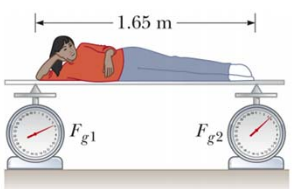
11/09/2012 PHY 113 A Fall 2012 -- Lecture 28 18

(a) In the first case, consider what happens when the object slides down the incline without friction and without rotating.

i. What is the initial energy (kinetic, potential, and total) of the system?
ii. What is the final energy (kinetic, potential, and total) of the system when the object reaches in the end of the incline?
iii. What is the final speed of the center of mass of the object?

(b) In the second case, consider what happens when the object rolls without slipping down the incline.

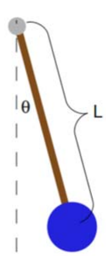
i. What is the initial energy (kinetic, potential, and total) of the system?
ii. What is the final energy (kinetic, potential, and total) of the system when the object reaches in the end of the incline?
iii. What is the final speed of the center of mass of the object?
iv. What is the final angular velocity of the object?



2.

The image above shows a plank having a uniform density and total weight of 100 N placed symmetrically between two identical scales separated by a distance of 1.65 m. A woman is lying on the plank with her feet located just above the point of contact of the right scale. The two scale readings are $F_{g1} = 450$ N and $F_{g2} = 250$ N. Note: In a similar homework problem, the weight of the plank was negligible.

(a) What is the weight of the woman?
(b) What is the distance of the center of her mass from her feet?



3.

The figure above shows a thin rod of length $L = 3$ m and of negligible mass. A mass m=5 kg is attached to the end of the rod. For the purpose of analyzing this problem, it is a good approximation to assume that the angular displacement θ measured in radians is small enough so that

$$\sin\theta \approx \theta.$$

(a) Initially, the rod-mass system is displaced from equilibrium by an angle $\theta(t = 0) = 0.26$ radians.

i. At $t = 0$, the rod-mass system is released from rest. Find the angular displacement $\theta(t)$ for $t > 0$. In expressing your answer, evaluate all of the parameters except for the variable time t.

ii. Find the maximum angular speed $\omega(t)$ of the rod-mass system.

iii. Find the maximum angular acceleration $\alpha(t)$ of the rod-mass system.

(b) Now the rod-mass system is connected to a motor which applies a harmonic driving torque of the form

$$\tau_{driving} = \tau_0 \sin(\Omega t),$$

where $\tau_0 = 1.5$ Nm and $\Omega = 2$ rad/s.

i. Show that a solution to the driving rod-mass system can be written in the form

$$\theta(t) = \Theta_0 \sin(\Omega t),$$

where Θ_0 is a constant (independent of time).

ii. Evaluate the magnitude of Θ_0 from the given information.

11/09/2012 PHY 113 A Fall 2012 -- Lecture 28 22

4. Imagine that you are a member of team to design a satellite that will collect data on sun spots. Suppose that this satellite will have a mass of $m = 1000$ kg and that it will be placed in a circular orbit about the *sun* at a radius of 5×10^{10} m from the center of the sun. For solving this problem, neglect gravitational effects on the satellite due to objects (planets, etc.) other than the sun.

(a) What is the magnitude of the gravitational force acting on the satellite due to the sun?

(b) What is the centripetal acceleration of the satellite in its circular orbit?

(c) What is the speed of the satellite in its circular orbit?

(d) What is the interval of time for the satellite to make one complete circle about the sun?

(e) What is the total energy of the satellite due to the kinetic and potential energy of its circular obit?

11/09/2012 PHY 113 A Fall 2012 -- Lecture 28 23