PHYS 1020 Final Exam

Monday, December 17, 6 - 9 pm

The whole course
30 multiple choice questions
Formula sheet provided

Seating (from exam listing on Aurora)

Brown Gym

A - SIM

Gold Gym

SIN - Z

GENERAL PHYSICS I: PHYS 1020

Schedule - Fall 2007
(lecture schedule is approximate)

11	M	12		**Remembrance Day**		Experiment 4: Centripetal Force
	W	14	28	Chapter 11 exclude 11.11	Fluids	
	F	16	29			
12	M	19	30	Chapter 12 sections 1 - 8	Temperature and heat (some small sections, notably thermal stress will be omitted)	Tutorial and Test 4 (chapters 8, 9, 10)
	W	21	31			
	F	23	32			
13	M	26	33	Chapter 13	Transfer of Heat -- Self study only. **Required for last lab.** This chapter **IS** examinable on the final.	Experiment 5: Thermal Conductivity of an Insulator
	W	28	34	Chapter 14	The Ideal Gas Law & Kinetic Theory	
	F	30	35			
14	M	**Dec 3**	36			No lab or tutorial
	W	5	37	**Last Day of Classes**		

Week of November 26

Experiment 5: Thermal conductivity

Mastering Physics Assignment #5

On chapters 8, 9, 10, 11

Due Monday, December 3 at 11 pm

Chapter 12: Temperature and Heat

- Temperature scales, thermometers
- Linear and volume expansion
- Internal energy
- Specific heat
- Change of phase, latent heat

Leave out sections 9, 10: equilibrium between phases of matter, humidity

Temperature Scales

Common temperature scales are based on the freezing and boiling points of water:

0° C, or 32° F = freezing point
100° C, or 212° F = boiling point

and are measured conveniently by thermal expansion of mercury in a thermometer.

Fahrenheit's scale: 0°F = coldest temperature in Danzig in winter of 1708-09, 100°F = body temperature?? Origin of scale very uncertain.

The Kelvin, or absolute, scale is of greater scientific significance.

Temperature differences have the same magnitude in Celsius and Kelvin.

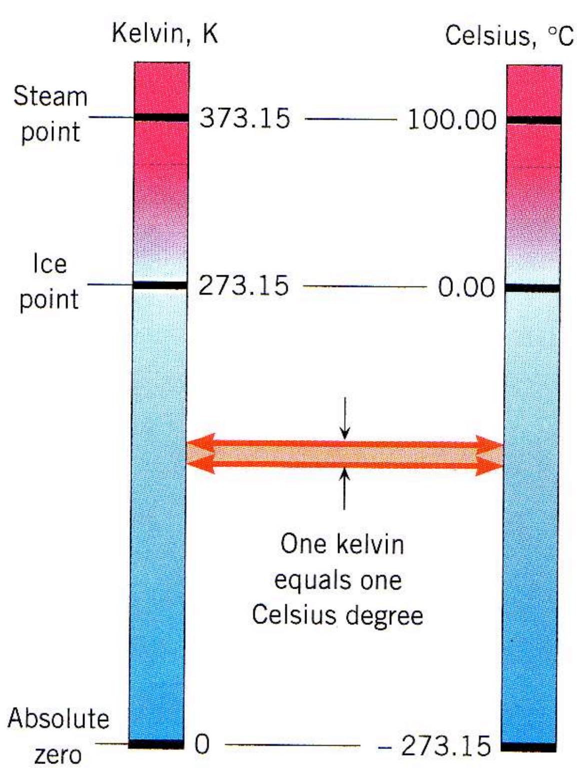
Kelvin and Celsius

0° C = 273.15 K (no degree symbol for K)

Absolute zero, the lowest temperature attainable (or, more accurately, not quite attainable) is:

0 K = –273.15° C

So, T (°C) = T (K) – 273.15

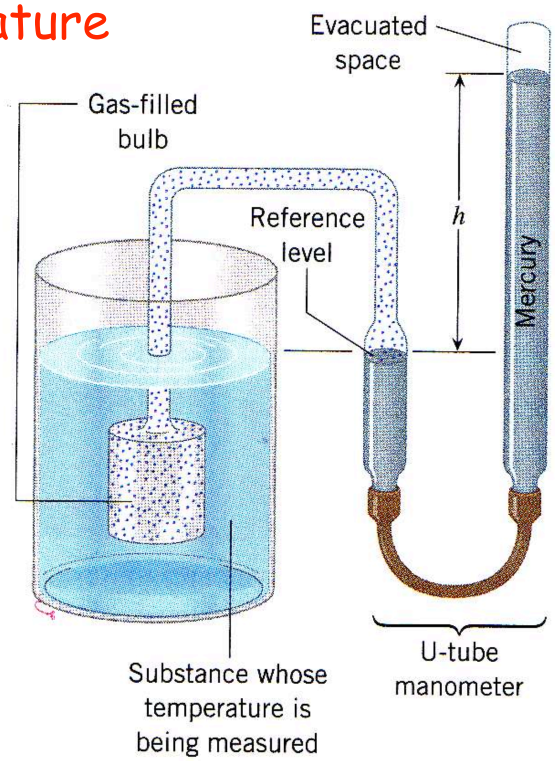


Measuring Temperature

Constant volume gas thermometer

Bulb contains low density hydrogen or helium gas – they liquefy at very low temperature. The right arm of the manometer is raised to keep the level of mercury in the left arm at constant height, so the gas has constant volume.

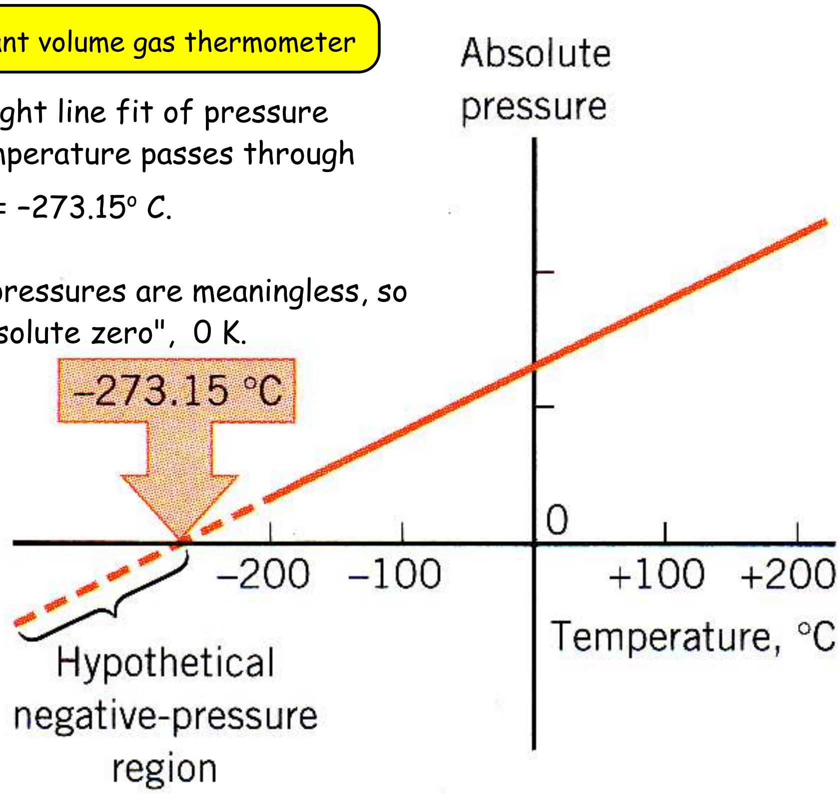
Measure the pressure of the gas as a function of temperature. Find that...



Constant volume gas thermometer

...the straight line fit of pressure versus temperature passes through zero at T = –273.15° C.

Negative pressures are meaningless, so this is "absolute zero", 0 K.



12.7: A constant-volume thermometer has a pressure of 5000 Pa when the gas temperature is 0° C. What is the temperature when the pressure is 2000 Pa?

Pressure is proportional to absolute (Kelvin) temperature. So –

$$\frac{T_2}{T_1} = \frac{P_2}{P_1}$$

$$\frac{T_2}{273.15} = \frac{2000}{5000}$$

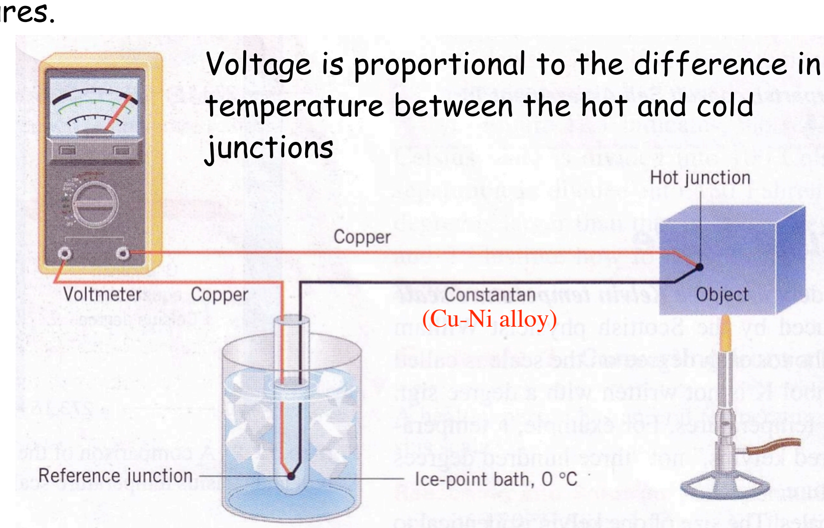
$$T_2 = 109.26\ \mathrm{K} = -163.9^\circ\ \mathrm{C}$$

Types of Thermometers

- Expansion as a function of temperature – eg mercury thermometers.

- Thermocouple – current induced by metals at different temperatures.

Voltage is proportional to the difference in temperature between the hot and cold junctions

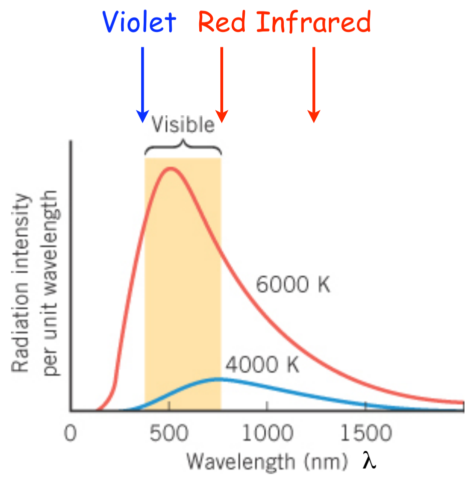


Types of Thermometers

- Resistance thermometers – use fact that electrical resistance varies with temperature.

- Spectrum of light from heated objects – the colour varies with temperature. Infrared at lower temperatures, shifting to blue at high temperature.

  Deduce the temperature of the surface of the sun from the spectrum of sunlight. Or of distant stars, or the filament of a light bulb.

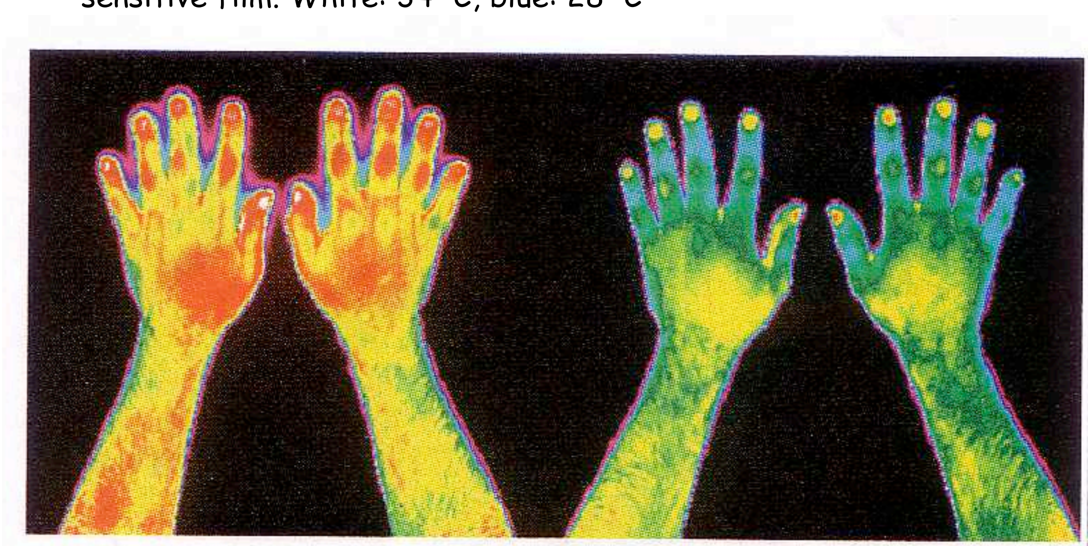


$$\lambda_{max} T = \text{constant}, T \text{ in Kelvin}$$

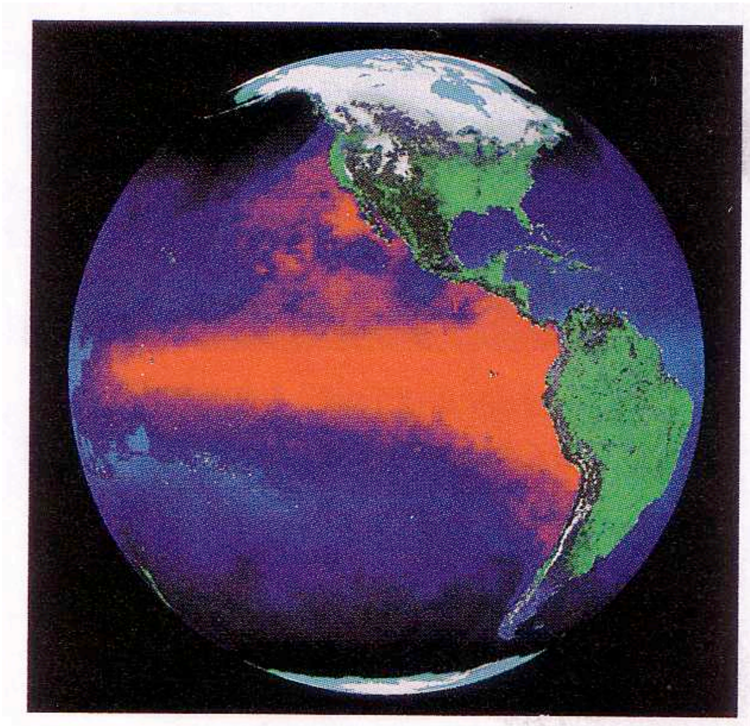
Wavelength at peak of spectrum

Thermograms of smoker's hands before and after smoking a cigarette. Vasoconstriction reduces blood flow and temperature.

These are "false colours" – the pictures are taken with infrared-sensitive film. White: 34° C, blue: 28° C



Infrared picture taken from space showing the warm El Niño ocean current



Thermal Expansion

Linear expansion – the increase in length, width or thickness when an object is heated.

$$\Delta L = \alpha L_0 \Delta T$$

α = coefficient of linear expansion

Typical values for metals ≈15×10^{-6} per C°.

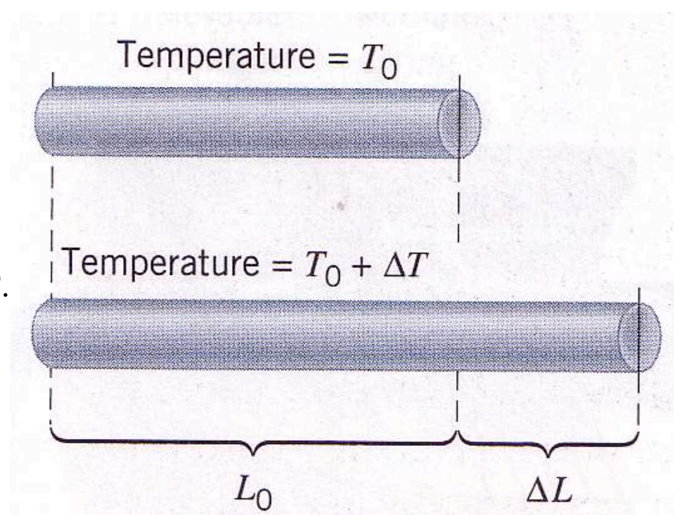


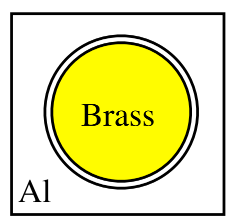
Table 12.1 Coefficients of Thermal Expansion for Solids

Substance	Coefficient of Thermal Expansion $(C°)^{-1}$ Linear (α)
Solids	
Aluminum	23×10^{-6}
Brass	19×10^{-6}
Concrete	12×10^{-6}
Copper	17×10^{-6}
Glass (common)	8.5×10^{-6}
Glass (Pyrex)	3.3×10^{-6}
Gold	14×10^{-6}
Iron or steel	12×10^{-6}
Lead	29×10^{-6}
Nickel	13×10^{-6}
Quartz (fused)	0.50×10^{-6}
Silver	19×10^{-6}

12.C3: A circular hole is cut through a flat aluminum plate. A spherical brass ball has a diameter that is slightly smaller than the diameter of the hole. If the ball and plate have equal temperature at all times, should the ball and plate be heated or cooled to prevent the ball from falling through the hole?

Linear expansion coefficients:
Aluminum: $23 \times 10^{-6}\ (C°)^{-1}$
Brass: $19 \times 10^{-6}\ (C°)^{-1}$

$$\alpha_{Al} > \alpha_{brass}$$



The aluminum expands more than the brass as the temperature is increased, so the diameter of the hole increases more than the diameter of the ball.

As they are cooled, the diameter of the hole in the aluminum decreases more than does the diameter of the ball.

12.-/10: The Concorde aircraft is 62 m long when its temperature is 23°C. In flight, the outer skin can reach 105°C due to air friction. Find the amount Concorde expands.

The coefficient of linear expansion of the skin is α = 2x10^{-5} per C°.

The increase in length is: $\Delta L = \alpha L_0 \Delta T$

$$\Delta L = (2 \times 10^{-5} \text{ per C}^\circ) \times (62 \text{ m}) \times (105 - 23\ ^\circ\text{C})$$

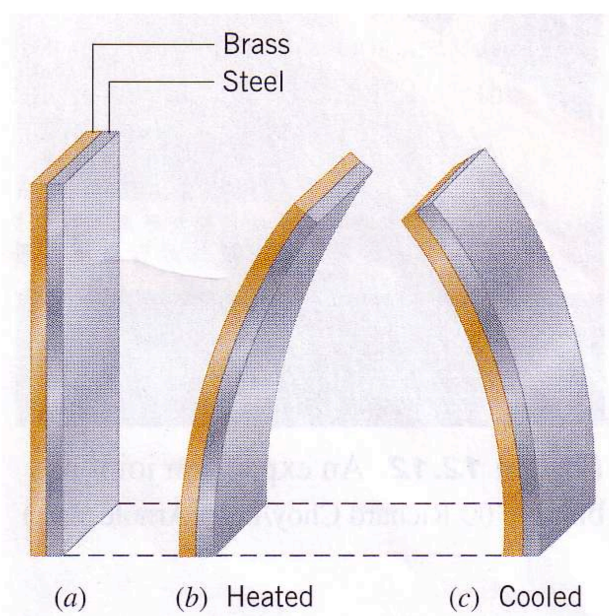
$$\Delta L = 0.102 \text{ m}$$

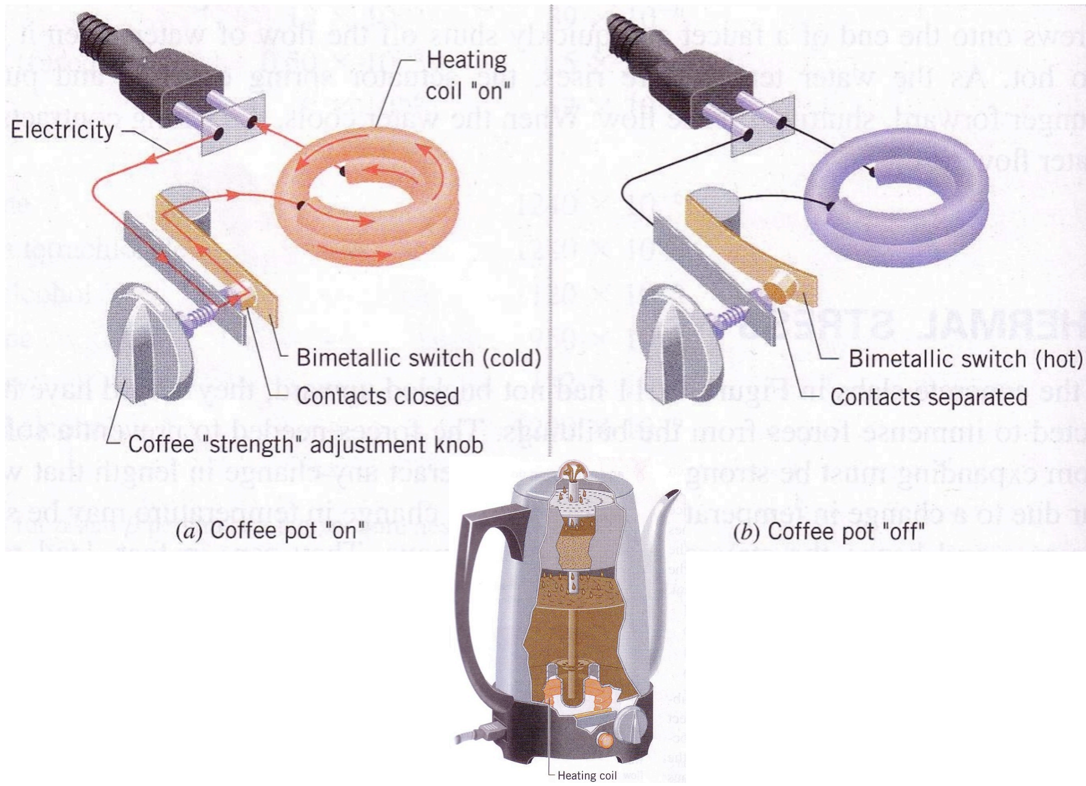
The Bimetallic Strip

Two thin strips of metals of different temperature coefficient of expansion, welded or riveted together.

The strip bends when it is heated or cooled.

Used as switches for heating elements, thermostats.





Volume Expansion

When heated, objects expand in all three dimensions:

$$L_x = L_{x0}(1+\alpha\Delta T)$$
$$L_y = L_{y0}(1+\alpha\Delta T)$$
$$L_z = L_{z0}(1+\alpha\Delta T)$$

The same coefficient of expansion in all dimensions

The volume increases to:

$$V = L_x \times L_y \times L_z$$
$$= L_{x0}L_{y0}L_{z0}(1+\alpha\Delta T)(1+\alpha\Delta T)(1+\alpha\Delta T)$$
$$\simeq V_0(1+3\alpha\Delta T)$$

The volume coefficient of temperature expansion is defined by:

$$\boxed{V = V_0(1+\beta\Delta T)}$$

So, $\beta \simeq 3\alpha$

Table 12.1 **Coefficients of Thermal Expansion for Solids and Liquids**[a]

Substance	Coefficient of Thermal Expansion $(C°)^{-1}$ Linear (α)	Volume (β)
Solids	$\beta \simeq 3\alpha$	
Aluminum	23×10^{-6}	69×10^{-6}
Brass	19×10^{-6}	57×10^{-6}
Concrete	12×10^{-6}	36×10^{-6}
Copper	17×10^{-6}	51×10^{-6}
Glass (common)	8.5×10^{-6}	26×10^{-6}
Glass (Pyrex)	3.3×10^{-6}	9.9×10^{-6}
Gold	14×10^{-6}	42×10^{-6}
Iron or steel	12×10^{-6}	36×10^{-6}
Lead	29×10^{-6}	87×10^{-6}
Nickel	13×10^{-6}	39×10^{-6}
Quartz (fused)	0.50×10^{-6}	1.5×10^{-6}
Silver	19×10^{-6}	57×10^{-6}
Liquids[b]		
Benzene	—	1240×10^{-6}
Carbon tetrachloride	—	1240×10^{-6}
Ethyl alcohol	—	1120×10^{-6}
Gasoline	—	950×10^{-6}
Mercury	—	182×10^{-6}
Methyl alcohol	—	1200×10^{-6}
Water	—	207×10^{-6}

[a]The values for α and β pertain to a temperature near 20 °C.
[b]Since liquids do not have fixed shapes, the coefficient of linear expansion is not defined for them.

The coolant reservoir catches the radiator fluid that overflows when an engine becomes hot. The radiator is made of copper.

$\beta_{coolant} = 4.10\times10^{-4}$ per C°.

The radiator is filled to its 15 litre capacity at 6° C. How much fluid overflows when the temperature reaches 92° C?

Both the coolant and the copper radiator expand. $\beta_{Cu} = 51\times10^{-6}$ per C°.

The coolant expands by: $\Delta V_{coolant} = \beta_{coolant} V_o \Delta T = (4.10\times10^{-4})(15)(86)$

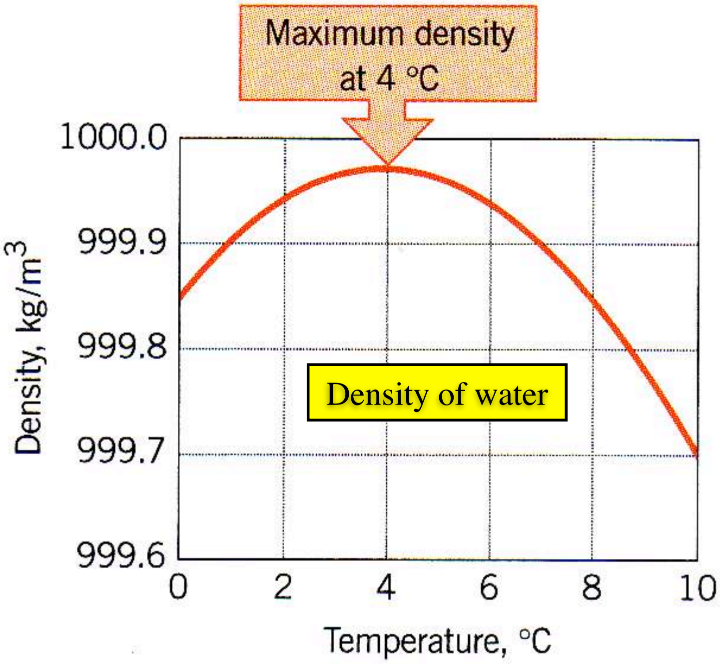
$\Delta V_{coolant} = 0.53$ litres.

The radiator expands by: $\Delta V_{Cu} = \beta_{Cu} V_o \Delta T = (51\times10^{-6})(15)(86) = 0.07$ l.

So, amount of overflow is (0.53 – 0.07) = 0.46 litres.

Water is different from most liquids – it expands as it freezes, from 4°C to 0°C.

Water at 4°C is more dense than freezing water, so freezing water rises to the surface, forming an insulating ice layer, while life can continue below in the liquid water.



Heat and Internal Energy

- Heat is a flow of energy from one object to another.
- It originates from an internal energy – the random motion and the potential energy of molecules making up a substance.
- Temperature is a measure of an object's internal energy. The greater the internal energy, the greater the temperature.
- The flow of energy (heat) is from higher temperature to lower temperature.
- The SI unit of heat is the Joule.
- Also used, the calorie (cal). 1 cal = 4.186 J.
- NB the food calorie is 1000 cal.

Heat and Temperature Change

The amount of heat, Q, to raise the temperature of a mass m of a substance by ΔT °C is:

$$Q = mc\Delta T$$

c = specific heat capacity (or specific heat) in J/(kg.C°).

Water: c = 4186 J/(kg.C°), that is, 1000 cal/(kg.C°)

In 30 minutes, a 65 kg jogger generates 800 kJ of heat. If the heat were not dissipated, how much would the jogger warm up?

Average specific heat of the body = 3500 J/(kg.C°)

$$\Delta T = \frac{Q}{mc} = \frac{8 \times 10^5 \text{ J}}{65 \times 3500} = 3.5°\text{C}$$

Table 12.2 Specific Heat Capacities[a] of Some Solids and Liquids

Substance	Specific Heat Capacity, c J/(kg · C°)
Solids	
Aluminum	9.00×10^2
Copper	387
Glass	840
Human body (37 °C, average)	3500
Ice (−15 °C)	2.00×10^3
Iron or steel	452
Lead	128
Silver	235
Liquids	
Benzene	1740
Ethyl alcohol	2450
Glycerin	2410
Mercury	139
Water (15 °C)	4186

[a]Except as noted, the values are for 25 °C and 1 atm of pressure.

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The whole course
30 multiple choice questions
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A - SIM

Gold Gym

SIN - Z

GENERAL PHYSICS I: PHYS 1020

Schedule - Fall 2007
(lecture schedule is approximate)

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Week of November 26

Experiment 5: Thermal conductivity

Mastering Physics

Welcome to Physics 1020!

Instructors	Required Materials	Schedule	Policies/Evaluation	Suggested Problems	Formula Sheet

Answers to Even-Numbered Problems	Answers for tutorial test problems
Answers for midterm test	Answers for final exam
Marks files	

→ Mastering Physics Assignment #5 ←
Due Monday, December 3 at 11 pm

Information on "Mastering Physics"

→ Mastering Physics Survey ←

Temperature and Heat

Temperature: T (°C) = T (K) – 273.15

Thermal expansion:

Linear expansion: $\Delta L = \alpha L_0 \Delta T$

Volume expansion: $\Delta V = \beta V_0 \Delta T$

$\beta \approx 3\alpha$

Specific heat:

Heat required to warm mass m by ΔT: $Q = mc\,\Delta T$

c = specific heat

Heat flows from high temperature to low

12.41/39: Blood carries excess energy from the interior to the surface, where energy is dispersed. While exercising, 0.6 kg of blood flows to the surface at 37°C and releases 2000 J of energy. Find the temperature at which blood leaves the surface.

Specific heat of blood = 4186 J/(kg.C°)

The blood loses 2000 J of energy and cools, Q = –2000 J:

$$\Delta T = \frac{Q}{mc} = \frac{-2000 \text{ J}}{0.6 \times 4186} = -0.8°\text{C}$$

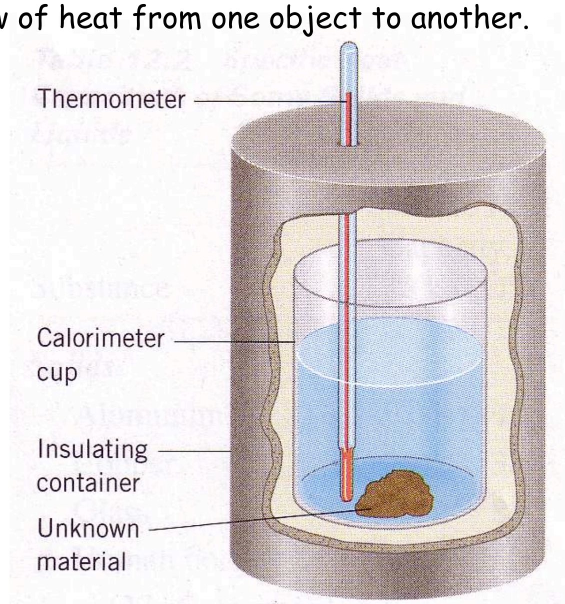
So, blood returns at 37 – 0.8 = 36.2°C

Calorimetry

Heat is a flow of energy, so should be included in the conservation of energy equation. Energy is conserved, no matter what its form. Calorimetry: studies the flow of heat from one object to another.

Calorimeter – a thermally insulated container – no flow of heat to or from outside.

Measure specific heat of an unknown material by heating or cooling to a known temperature, putting into the calorimeter full of liquid of known specific heat, and measuring the equilibrium temperature.



Q12, Final Exam 2005: A 0.2 kg lead shot is heated to 90°C and dropped into an ideal calorimeter containing 0.5 kg of water initially at 20°C. What is the final temperature of the lead shot?

Specific heat capacities:
Pb: c_1 = 128 J/(kg.C°)
H_2O: c_2 = 4186 J/(kg.C°)

The thermal energy is not lost or gained, it just moves around:

$$Q_{Pb} + Q_{H_2O} = 0$$

Final temperature is T

That is, $m_1 c_1 \Delta T_1 + m_2 c_2 \Delta T_2 = 0$

$$0.2 \times 128(T - 90) + 0.5 \times 4186(T - 20) = 0$$

T = 20.8°C

12.44/40: A piece of glass is at 83°C. An equal mass of liquid at 43°C is poured over the glass. An equilibrium temperature of 53°C is reached. Assuming negligible heat loss, find the specific heat of the liquid.

Specific heat of glass = 840 J/(kg.C°)

If no loss of heat: $Q_{glass} + Q_{liquid} = 0$

$$mc_{glass}\Delta T_{glass} + mc_{liquid}\Delta T_{liquid} = 0$$

That is, $840(53 - 83) + c_{liquid}(53 - 43) = 0$

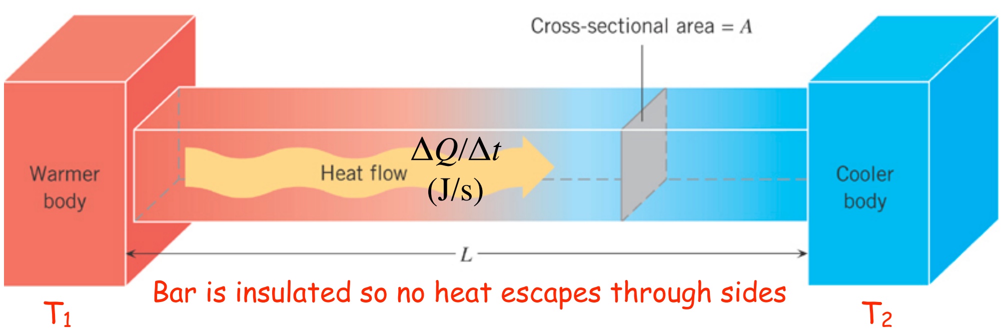
$$c_{liquid} = \frac{840 \times 30}{10} = 2520 \text{ J/(kg.C}^\circ)$$

A Detour into Thermal Conduction, Chapter 13

for

Experiment 5
Thermal Conductivity of an Insulator

Conduction of Heat



Heat flows along the bar at a rate that is proportional to:

- temperature difference between ends, $T_1 - T_2$
- area of cross section of the bar, A

and is inversely proportional to:

- length of bar, L

(J/s, that is, W)

$$\frac{\Delta Q}{\Delta t} = \frac{kA(T_1 - T_2)}{L}$$

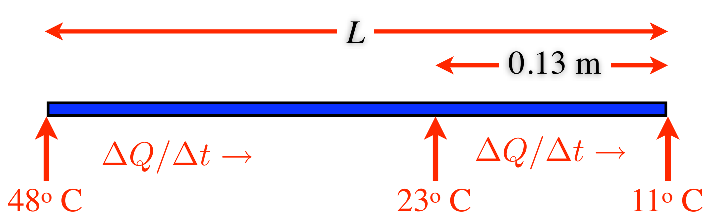
k = thermal conductivity

Table 13.1 Thermal Conductivities[a] of Selected Materials

Substance	Thermal Conductivity, k [J/(s·m·C°)]
Metals	
Aluminum	240
Brass	110
Copper	390
Iron	79
Lead	35
Silver	420
Steel (stainless)	14
Gases	
Air	0.0256
Hydrogen (H_2)	0.180
Nitrogen (N_2)	0.0258
Oxygen (O_2)	0.0265
Other Materials	
Asbestos	0.090
Body fat	0.20
Concrete	1.1
Diamond	2450
Glass	0.80
Goose down	0.025
Ice (0 °C)	2.2
Styrofoam	0.010
Water	0.60
Wood (oak)	0.15
Wool	0.040

[a] Except as noted, the values pertain to temperatures near 20 °C.

$$k = \frac{\Delta Q/\Delta t \times L}{A \times (T_1 - T_2)} \quad \text{J/(s.m.C}^{\text{o}}\text{)}$$



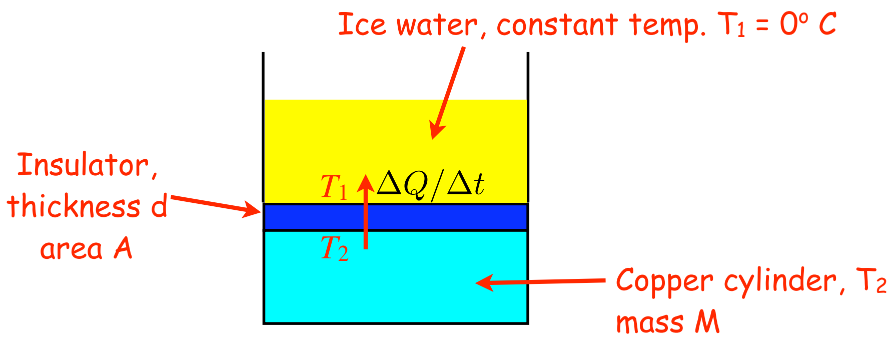
13.12/-: If the bar is of uniform cross-section and no heat is lost through the sides, what is the length of the bar?

As no heat is lost from the sides, the rate of heat flow is constant along the bar.

$$\frac{\Delta Q}{\Delta t} \propto \frac{\Delta T}{L}$$

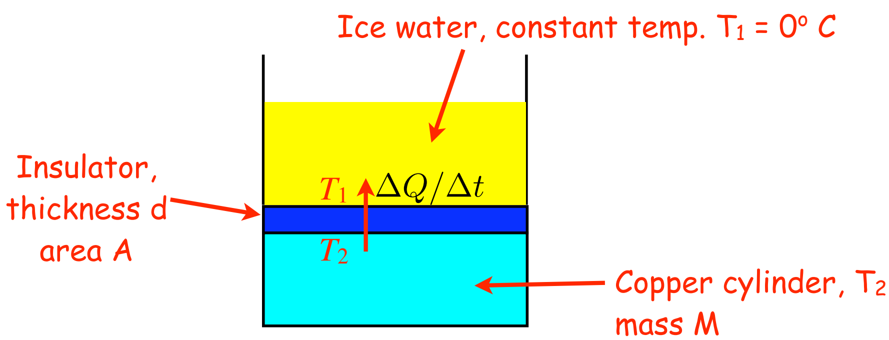
$$\text{So, } \frac{48-11}{L} = \frac{23-11}{0.13} \quad \rightarrow L = 0.4 \text{ m}$$

Experiment 5: Measure thermal conductivity of an insulator



Heat flows from the copper cylinder, through the insulator to the ice water, which is kept at T_1 = 0° C by the ice.

The copper cools down at a rate proportional to the heat flow, which depends on the thermal conductivity of the insulator.



The rate of heat flow through the insulator is: $\dfrac{\Delta Q}{\Delta t} = \dfrac{kA(T_2 - T_1)}{d}$

This heat comes from the copper, which is insulated from its surroundings

The rate of heat flow out of the copper is: $\dfrac{\Delta Q}{\Delta t} = -\dfrac{Mc\Delta T_2}{\Delta t}$

c = specific heat capacity of copper = 387 J/(kg.C°), table 12.2

$$\text{So, } \frac{\Delta Q}{\Delta t} = \frac{kA(T_2 - T_1)}{d} = -\frac{Mc\Delta T_2}{\Delta t}$$

$$\frac{\Delta Q}{\Delta t} = \boxed{\frac{kA(T_2 - T_1)}{d} = -\frac{Mc\Delta T_2}{\Delta t}}$$

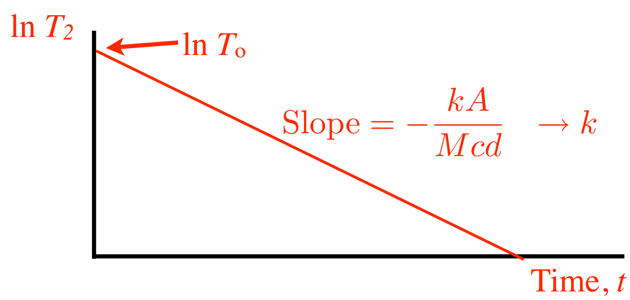
With T_1 fixed at 0° C, $\frac{\Delta T_2}{T_2} = -\frac{kA}{Mcd}\Delta t$

The solution is (rabbit out of hat integral calculus):

$$\ln T_2 = -\frac{kAt}{Mcd} + \ln T_0$$

(ln = natural log, "ln" or "$\log_e$" on calculator)

T_0 = temperature of copper when t = 0



13.27/1: A person's body is covered with 1.6 m^2 of wool clothing that is 2 mm thick. The temperature of the outside surface of the wool is 11°C and the skin temperature is 36°C. How much heat per second does the person lose by conduction?

Wool: k = 0.04 J/(s.m.C°)

The rate of heat conduction is: $\frac{\Delta Q}{\Delta t} = \frac{kA(T_1 - T_2)}{L}$

$$\frac{\Delta Q}{\Delta t} = \frac{0.04 \times 1.6 \times (36 - 11)}{0.002} = 800 \text{ J/s}$$

Metabolic rate when resting is 80 – 100 W

(15 litres/hour of oxygen consumed, each litre supplying 20,000 J of energy)

13.3/4: The amount of heat per second conducted from the blood capillaries beneath the skin to the surface is 240 J/s. The energy is transferred a distance of 2 mm through a body whose surface area is 1.6 m^2. Assuming that the thermal conductivity is that of body fat, determine the temperature difference between the capillaries and the surface of the skin.

Substance	Thermal Conductivity, k [J/(s·m·C°)]
Body fat	0.20

Rate of heat conduction: $\frac{\Delta Q}{\Delta t} = \frac{kA(T_1 - T_2)}{L}$

$$240 \text{ J/s} = \frac{0.2 \times 1.6(T_1 - T_2)}{0.002}$$

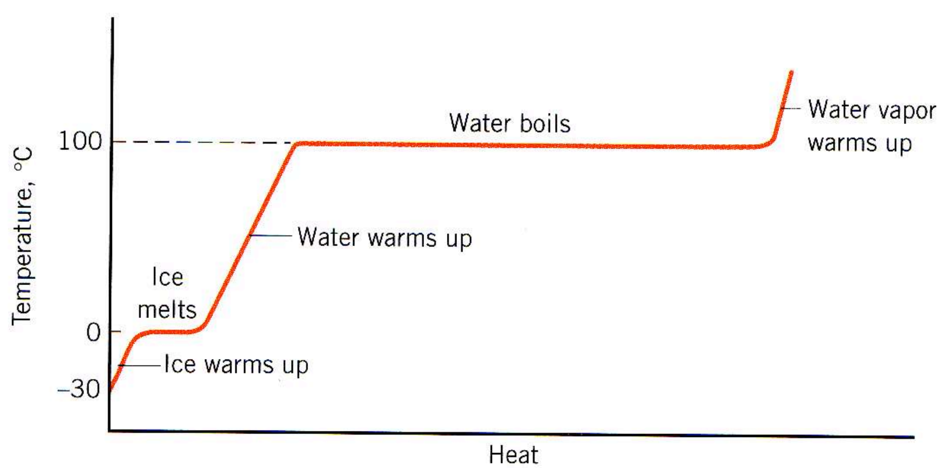
$$T_1 - T_2 = 1.5°\text{C}$$

Latent Heat: Change of Phase

The three phases of matter: gas, liquid, solid.

Heat is absorbed, or released, when melting/freezing or boiling/ condensation occurs, and temperature remains constant during the change.

Latent heat: the energy absorbed or released during a phase change.



Latent Heat

Heat absorbed/released, Q = mL, L = latent heat.

Melting/freezing:

Latent heat of fusion L_f = heat absorbed per kilogram on melting and released on freezing.

Boiling/condensing:

Latent heat of vaporization L_v = heat absorbed per kilogram on boiling and released on condensing.

Water: latent heat of fusion = 33.5×10^4 J/kg
latent heat of vaporization = 22.6×10^5 J/kg

Table 12.3 Latent Heats[a] of Fusion and Vaporization

Substance	Melting Point (°C)	Latent Heat of Fusion, L_f (J/kg)	Boiling Point (°C)	Latent Heat of Vaporization, L_v (J/kg)
Ammonia	−77.8	33.2×10^4	−33.4	13.7×10^5
Benzene	5.5	12.6×10^4	80.1	3.94×10^5
Copper	1083	20.7×10^4	2566	47.3×10^5
Ethyl alcohol	−114.4	10.8×10^4	78.3	8.55×10^5
Gold	1063	6.28×10^4	2808	17.2×10^5
Lead	327.3	2.32×10^4	1750	8.59×10^5
Mercury	−38.9	1.14×10^4	356.6	2.96×10^5
Nitrogen	−210.0	2.57×10^4	−195.8	2.00×10^5
Oxygen	−218.8	1.39×10^4	−183.0	2.13×10^5
Water	0.0	33.5×10^4	100.0	22.6×10^5

[a]The values pertain to 1 atm pressure.

An order of magnitude more energy is needed to vaporize as to melt – melting is more a rearrangement of the molecules, vaporization a change to a state in which they are much farther apart and the density much lower.

Q13, 2005 Final

Clickers!

Which would cause a more serious burn: 30 g of steam or 30 g of liquid water, both at 100°C; and why is this so?

(a) Water, because it is denser than steam.

(b) Steam, because of its specific heat capacity.

(c) Steam, because of its latent heat of vaporization.

(d) Water, because its specific heat is greater than that of steam.

(e) Either one would cause a burn of the same severity since they are both at the same temperature.

Steam releases its latent heat of vaporization, L_v, when it condenses...

2.26 MJ of thermal energy per kg of steam

and then you have water at 100°C...

12.78/56: The latent heat of vaporization of water at body temperature is 2.42×10^6 J/kg. To cool the body of a 75 kg jogger (average specific heat = 3500 J/(kg.C°)), by 1.5°C, how many kilograms of water in the form of sweat have to be evaporated?

The vaporization of 1 kg of water requires 2.42×10^6 J of energy.

Cooling a mass of 75 kg by 1.5°C releases an amount of energy equal to:

$$Q = m\, c\, \Delta T = 75 \times 3500 \times 1.5 = 393,800 \text{ J}$$

This thermal energy will vaporize a mass m of water:

$$m = \frac{393,800 \text{ J}}{2.42 \times 10^6 \text{ J/kg}} = 0.16 \text{ kg of water}$$

12.80/58: A 0.2 kg piece of aluminum has a temperature of -155°C and is added to 1.5 kg of water at 3°C. At equilibrium, the temperature is 0°C. Find the mass of ice that has become frozen.

Specific heat of aluminum = 900 J/(kg.C°)

Heat flows: 0.2 kg of aluminum warms from -155°C to 0°C
1.5 kg of water cools from 3°C to 0°C
mass m of water freezes at 0°C
(1.5 – m) kg does not freeze

$$[0.2 \times 900 \times (0+155)] + [1.5 \times 4186 \times (0-3)] - [m \times (33.5 \times 10^4)] = 0$$

warm 0.2 kg Al to 0°C — cool 1.5 kg water to 0°C — freeze m kg of water at 0°C

m = 0.027 kg

12.88/62: 2 g of liquid water are at 0°C and another 2 g are at 100°C. Heat is removed from the water at 0°C, completely freezing it at 0°C. This heat is used to vaporize some of the water at 100°C. How much liquid water remains?

L_v = 22.5×10^5 J/kg
L_f = 33.5×10^4 J/kg

Heat released in freezing water = mL_f = 0.002×(33.5×10^4) = 670 J

Mass of water at 100°C that is vaporized by 670 J of heat is:

$$m = \frac{Q}{L_v} = \frac{(670\ \text{J})}{(22.5 \times 10^5\ \text{J/kg})} = 0.00030\ \text{kg} = 0.3\ \text{g}$$

1.7 g of liquid water remain.

12.65: It is claimed that if a lead bullet goes fast enough, it can melt completely when it comes to a halt suddenly, and all its kinetic energy is converted into heat via friction. Find the minimum speed for this to happen for a bullet at 30°C.

Lead: c = 128 J/(kg.C°)
L_f = 23,200 J/kg, melting point 327.3°C

- Heat mass m of lead from 30°C to 327.3°C
- Melt mass m of lead

Heating: $Q_1 = m\,c\,\Delta T = m \times 128(327.3 - 30) = 38,054m$ J

Melting $Q_2 = m\,L_f = 23,200m$ J

Total heat needed $= (38,054 + 23,200)m = 61,254m$ J $= \frac{1}{2}mv^2$

$\rightarrow\ v = 350$ m/s

Summary of Temperature and Heat

Temperature: $T\,(^{\text{o}}\,\text{C}) = T\,(\text{K}) - 273.15$

Thermal expansion: $\Delta L = \alpha L_0 \Delta T$

$\Delta V = \beta V_0 \Delta T$

Specific heat: $Q = mc\Delta T$

Latent heat: $Q = mL_f$ melting/freezing

$Q = mL_v$ boiling/condensation

Heat flows from high temperature to low