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

Motion of Fluids

Equation of continuity:

$$\rho_1 v_1 A_1 = \rho_2 v_2 A_2 = \text{mass flowing per second}$$

If the density does not change:

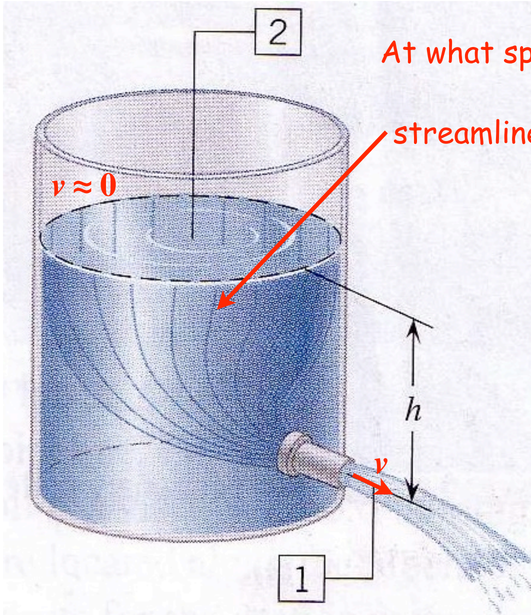
$$v_1 A_1 = v_2 A_2 = \text{volume flowing per second}$$

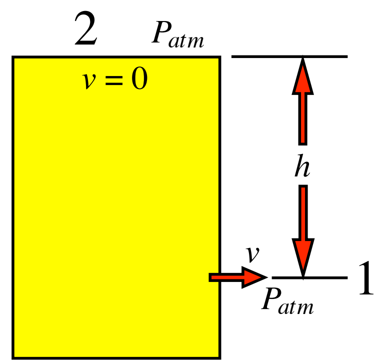
Bernoulli's Equation:

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2 = \text{constant}$$

– based on work-energy theorem, assumes streamline flow

At what speed does the water leave the hole?





Bernoulli: at 2 and 1

$$\cancel{P_{atm}} + \rho g h = \cancel{P_{atm}} + \frac{1}{2}\rho v^2 \to \; v^2 = 2gh,$$ as if the water had fallen a distance h

What the water loses in potential energy, it gains in kinetic energy

11.96/68: (a) Find v

Bernoulli:

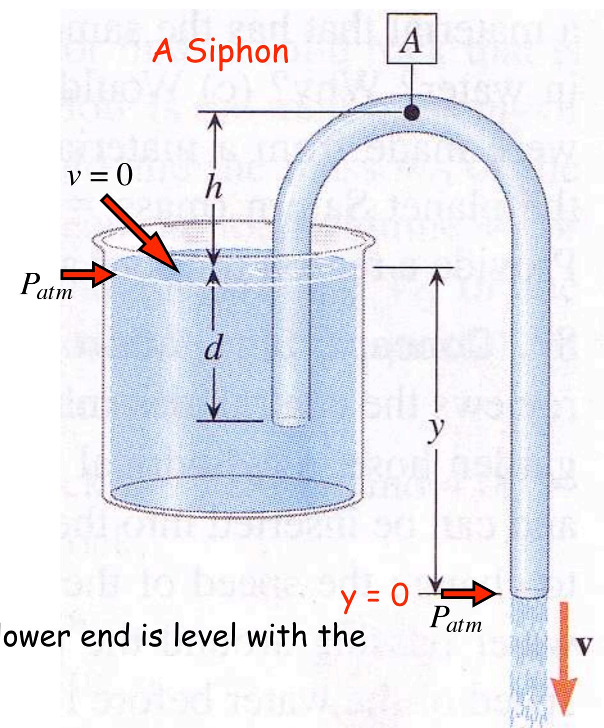
$$P_{atm} + \rho g y = P_{atm} + \frac{1}{2}\rho v^2$$

At surface of water ↑   At exit of tube ↑

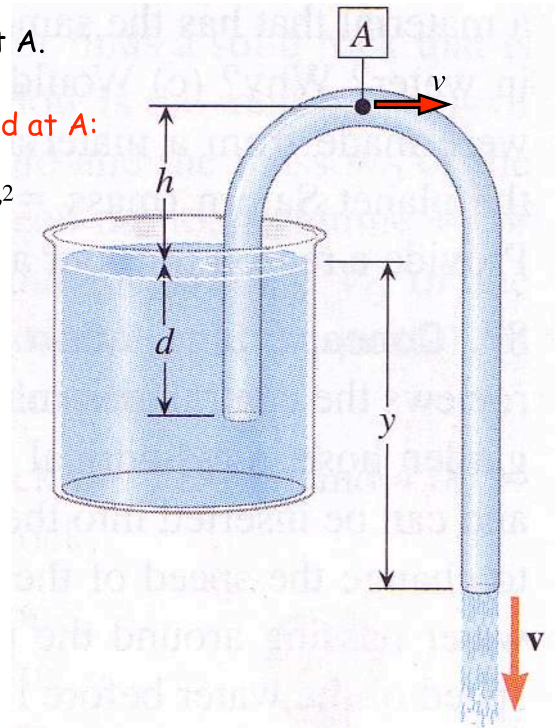
So, $v = \sqrt{2gy}$

(b) At what value of y will the siphon stop working?

v = 0 when y = 0, i.e. when the lower end is level with the water surface.



(c) Find the absolute pressure at A.



Bernoulli, at surface of water and at A:

$$P_{atm} + \rho g y = P_A + \rho g(y+h) + \frac{1}{2}\rho v^2$$

$$P_A = P_{atm} - \rho g h - \frac{1}{2}\rho v^2$$

Since, $v = \sqrt{2gy}$,

$$P_A = P_{atm} - \rho g h - \frac{1}{2}\rho \times 2gy$$

$$= \underline{P_{atm} - \rho g(h+y)}$$

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.

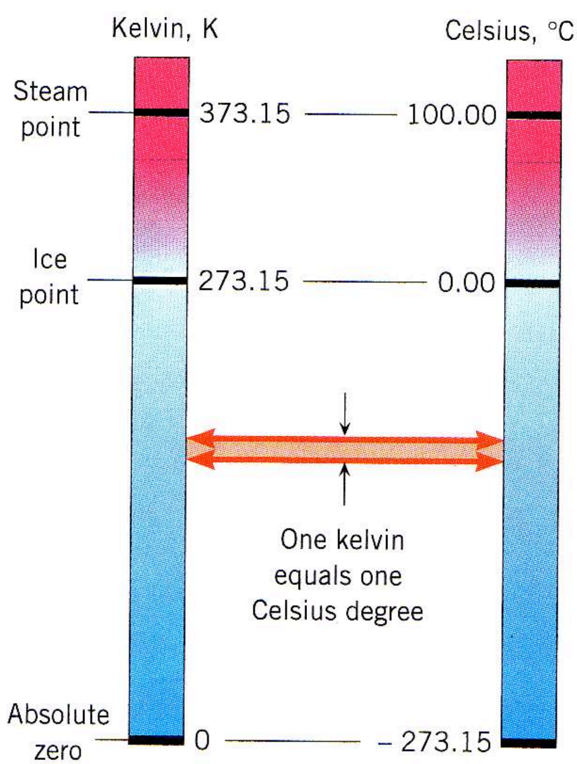
Kelvin and Celsius

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

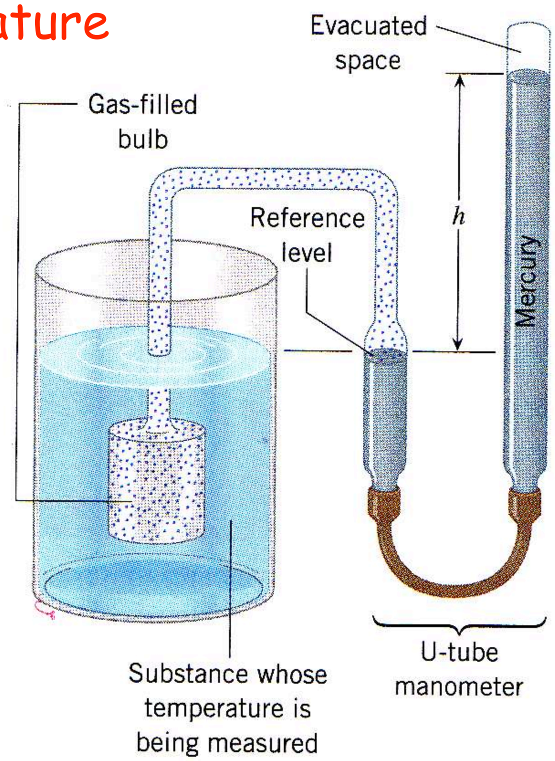


Measuring Temperature

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.

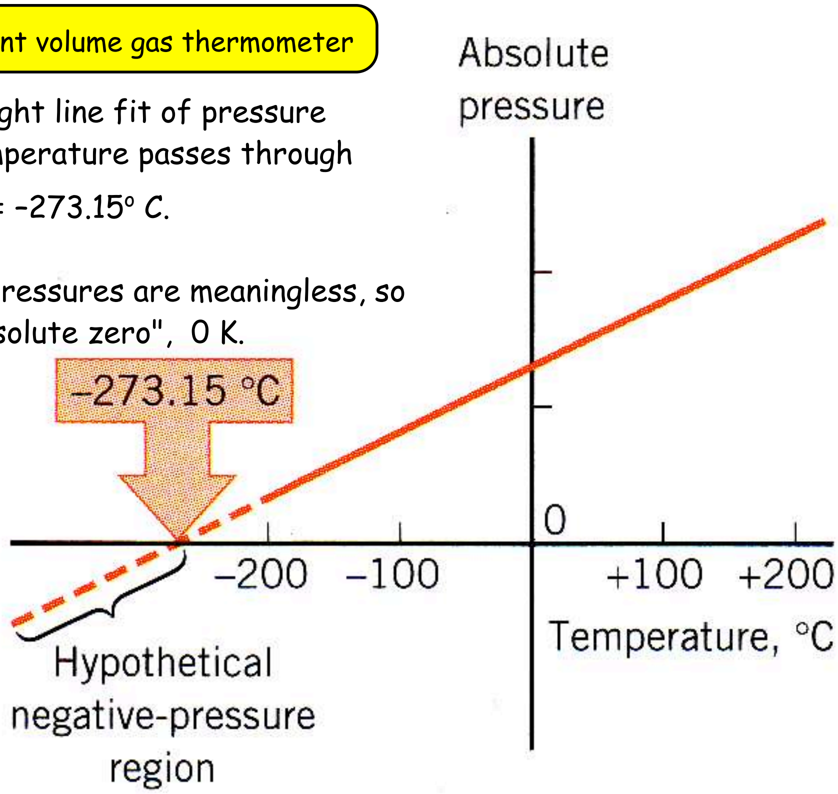
Measure the pressure of the gas as a function of temperature. Find that...



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 –

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

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

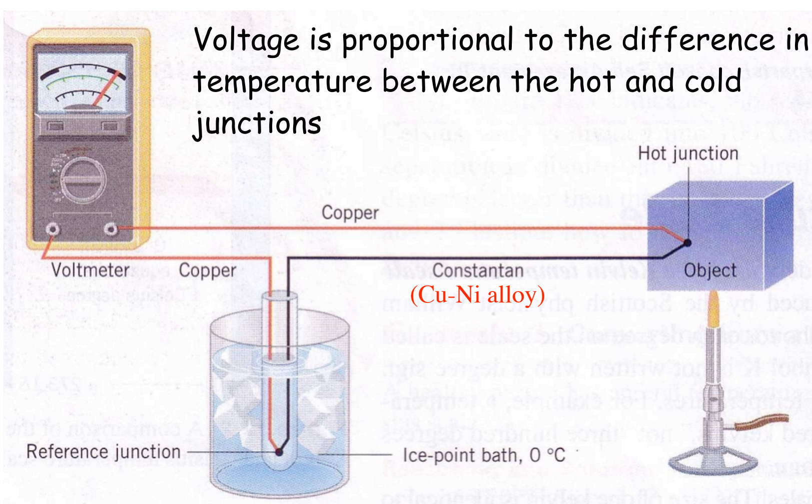
$$T_2 = 109.26 \text{ K} = -163.9^\circ \text{ C}$$

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

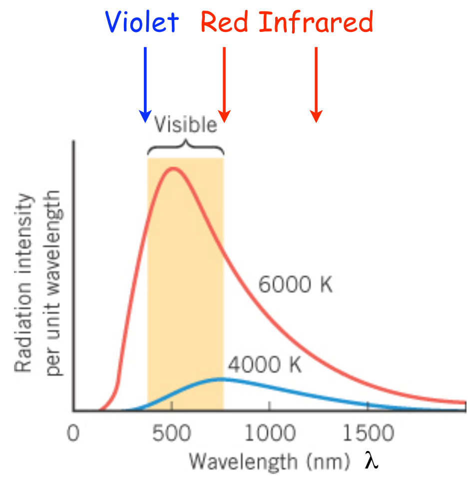


Types of Thermometers

- 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.

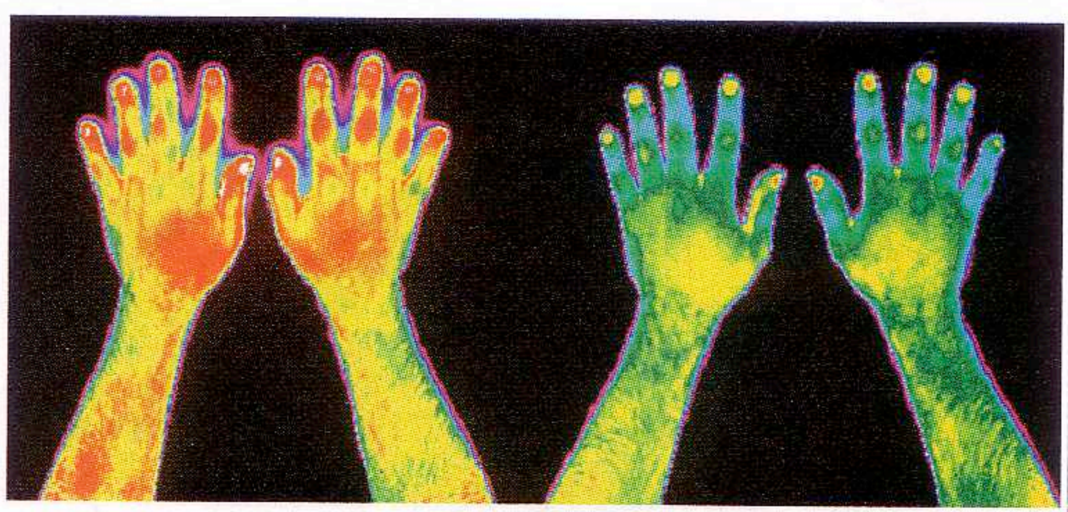


$$\lambda_{max} T = \text{constant}, T \text{ in Kelvin}$$

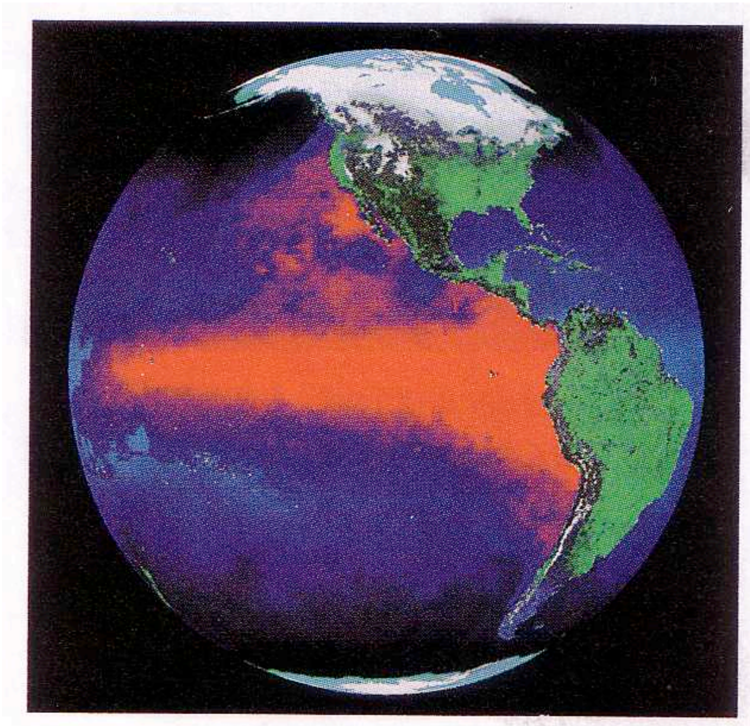
Wavelength at peak of spectrum

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°.

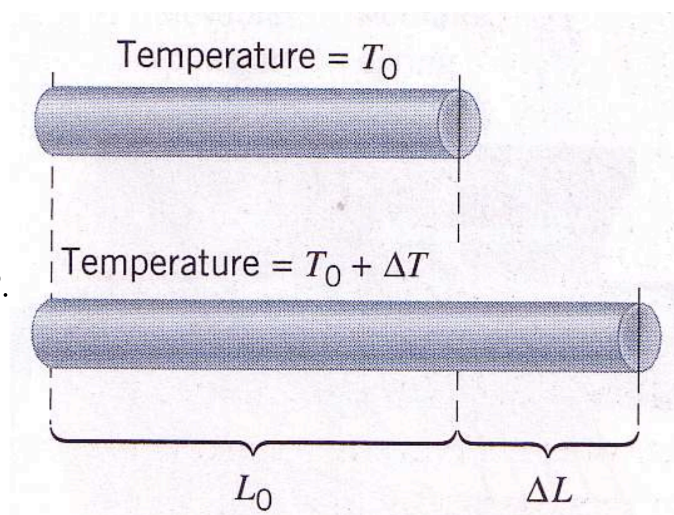


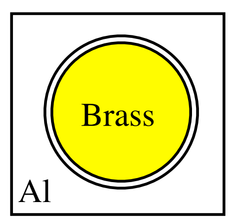
Table 12.1 Coefficients of Thermal Expansion for Solids

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: 23×10^{-6} $(C^o)^{-1}$
Brass: 19×10^{-6} $(C^o)^{-1}$

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



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

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

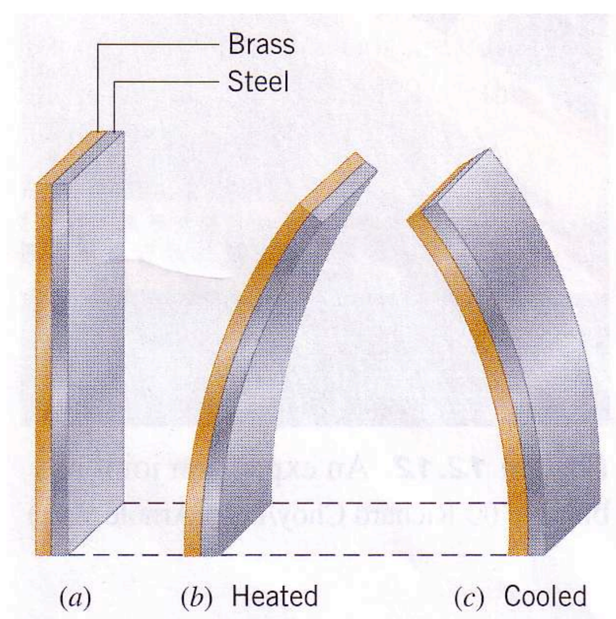
$$\Delta L = 0.102 \text{ m}$$

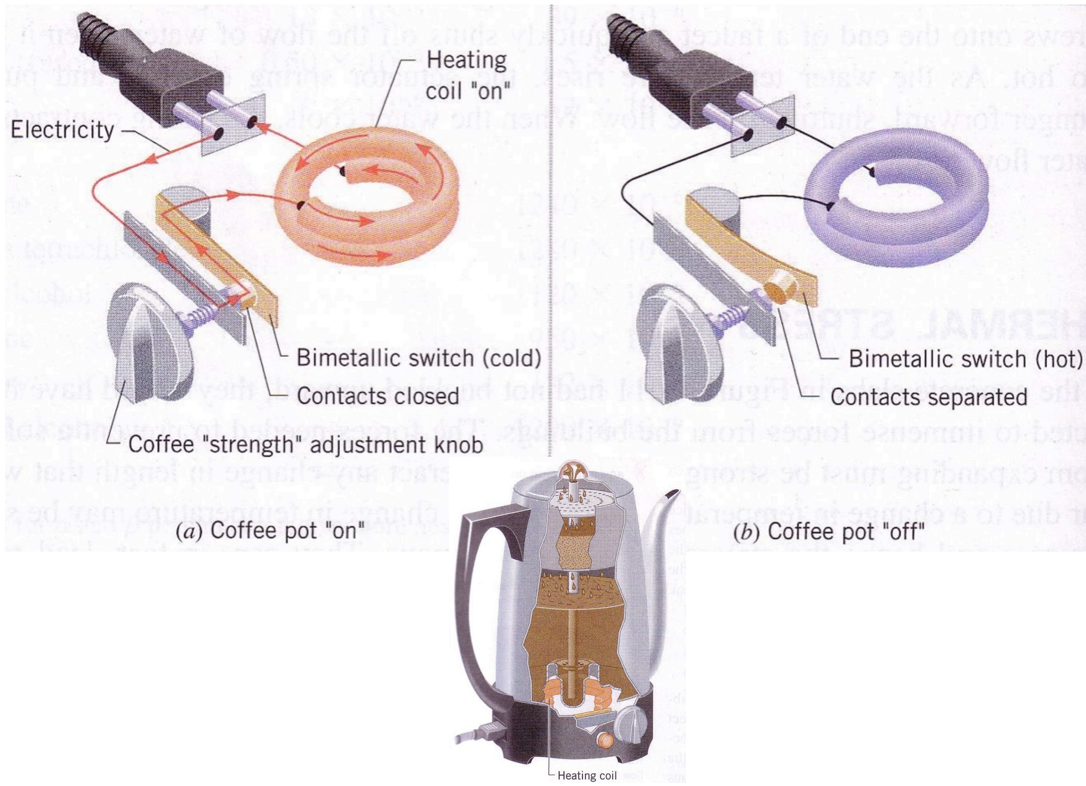
The Bimetallic Strip

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

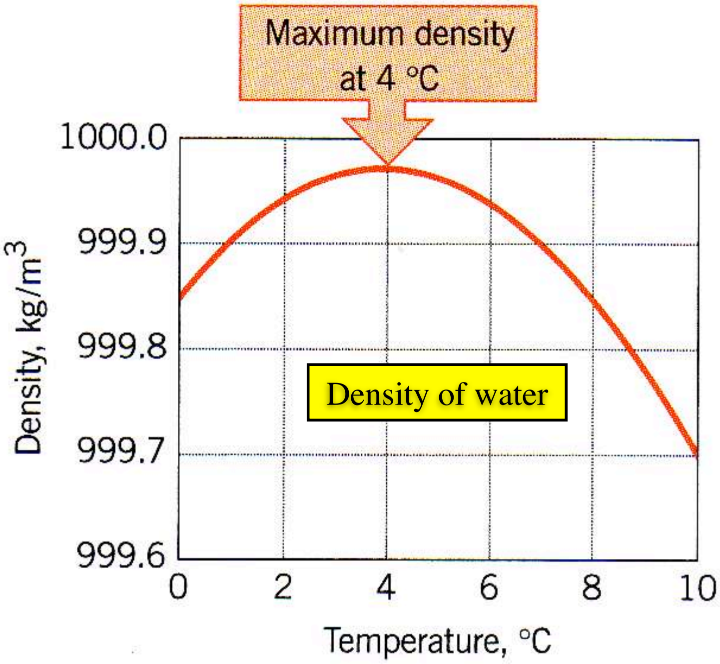
$\Delta V_{coolant} = 0.53$ litres.

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.