Physics 2101
Section 3
Apr 19^{th}

Announcements:

- SHW #11 has been posted
- Midterm #4, April 28^{th} 6 pm
- Final: May 11^{th}-7:30am
- Make up Final: May 15^{th}-7:30am

Class Website:

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

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

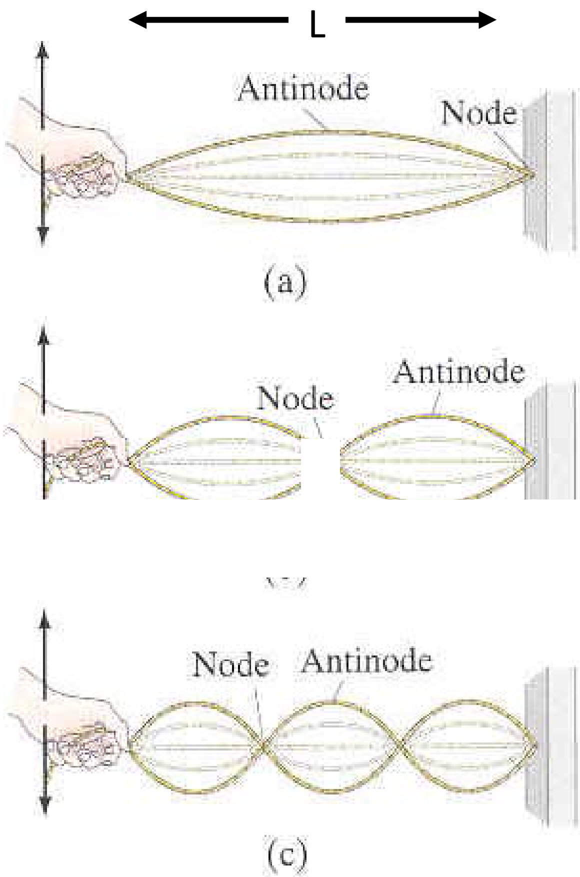
Standing Waves: Resonance on string

Here, two sinusoidal waves with same wavelength travel in <u>opposite</u> directions

Interference produces <u>Standing waves</u>

$$x = n\frac{\lambda}{2}$$ **NODES**

What happens if we fixed the length of the string
= enforce that nodes are at the ends



Node at x =0 & L: $L = n\frac{\lambda}{2}$

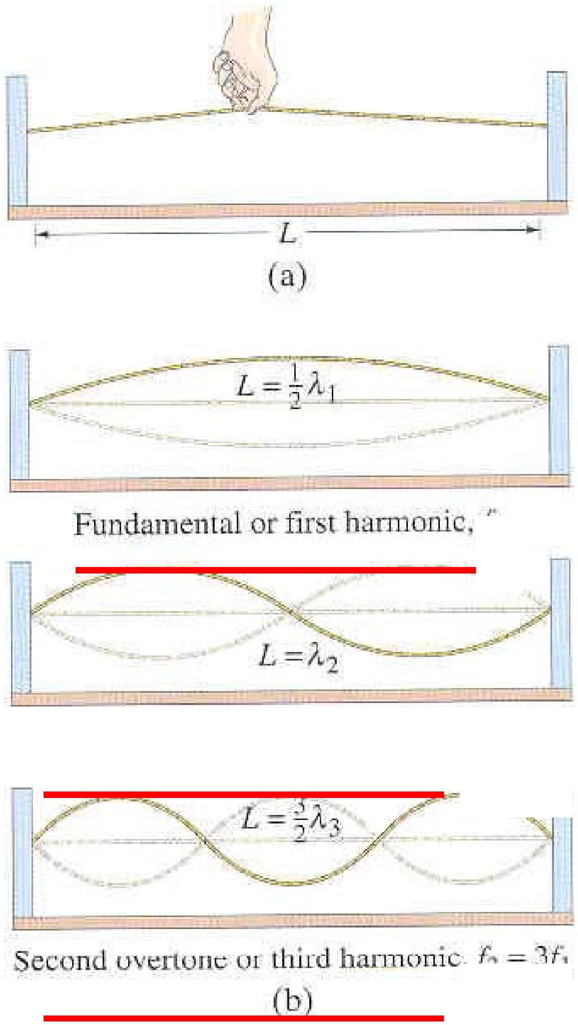
$$n = 1 \quad \Rightarrow \quad 2L = \lambda_1$$

$$n = 2 \quad \Rightarrow \quad L = 2\frac{\lambda_2}{2} = \lambda_2$$

$$n = 3 \quad \Rightarrow \quad L = 3\frac{\lambda_3}{2} = \frac{3}{2}\lambda_3$$

Standing Waves: Resonant frequencies

Frequencies at which standing waves are produced are the **Resonant Frequencies**



$$v_{wave} = \lambda_n f_n$$

$$\lambda_n = \frac{2L}{n} \qquad f_n = \frac{n v_{wave}}{2L}$$

$$n = 1 \qquad \lambda_1 = 2L \qquad f_1 = \frac{v_{wave}}{2L}$$

$$n = 2 \qquad \lambda_2 = L \qquad f_2 = 2 f_1$$

$$n = 3 \qquad \lambda_3 = \frac{2}{3} L \qquad f_3 = 3 f_1$$

Resonant frequencies are given by n and properties of system (length, tension, and mass density)

Problem

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

$$v_{wave} = \lambda_n f_n$$

$$f_n = \frac{n v_{wave}}{2L}$$

A string that is stretched between fixed supports separated by 75 cm has resonant frequencies of 420 Hz and 315 Hz, with no intermediate resonant frequencies.

a) What is the lowest resonant frequency?

For a fixed length, the resonant wavelengths are given by: $kx = n\pi$ $\quad \left(\frac{2\pi}{\lambda}\right)L = n\pi$

The resonant frequencies are then: $\left(\frac{2\pi}{\lambda}\right)L = n\pi \Rightarrow \left(\frac{2f_n}{v}\right)L = n \Rightarrow f_n = \frac{nv}{2L}$

Between adjacent resonant frequencies:

$$\frac{f_{n+1}}{f_n} = \frac{\left(\frac{(n+1)v}{2L}\right)}{\left(\frac{nv}{2L}\right)} = \frac{n+1}{n} = \frac{420 \cdot Hz}{315 \cdot Hz} \Rightarrow n = 3$$

With n = 1:

$$\frac{f_3}{f_1} = \frac{\left(\frac{3v}{2L}\right)}{\left(\frac{1v}{2L}\right)} = \frac{315 \cdot Hz}{f_1} \Rightarrow f_1 = \frac{315 \cdot Hz}{3} = 105 \cdot Hz$$

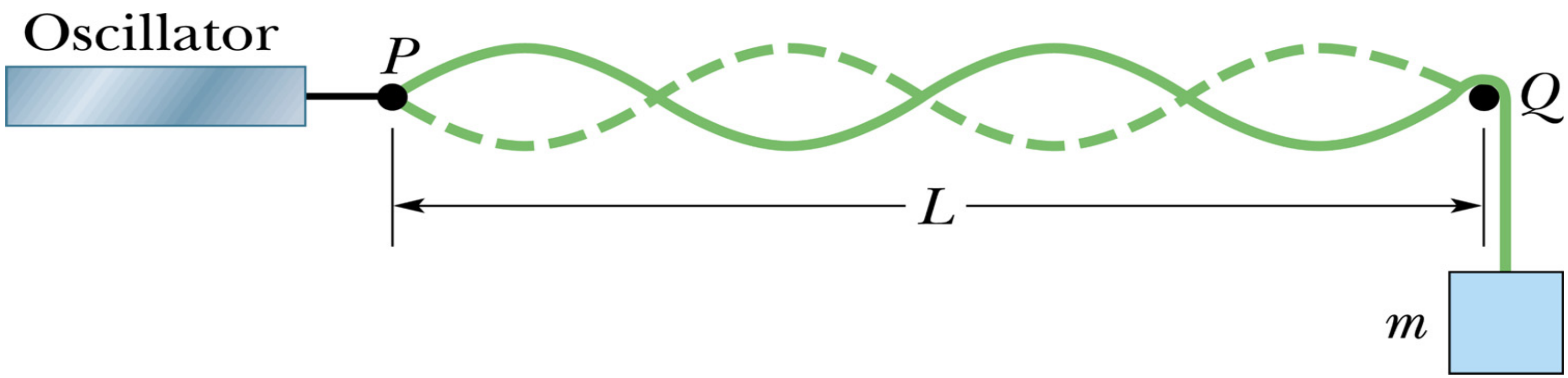
b) What is the wave speed?

Lowest possible wavelength is $\lambda_1 = 2L$ and thus

$$v_{wave} = \lambda_1 f_1 = (2(75 \cdot cm))(105 \cdot \text{Hz}) = 157.5 \cdot \text{m/s}$$

Problem 16-58: A string, 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.

a) what mass allows the to set up the fourth harmonic?



$$v_{wave} = \lambda_n f_n$$

$$f_n = \frac{n v_{wave}}{2L}$$

$$f_n = \frac{n}{2L}\sqrt{\frac{\tau}{\mu}} \quad (\text{for } n = 4)$$

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

58. With the string fixed on both ends, using Eq. 16-66 and Eq. 16-26, the resonant frequencies can be written as

$$f = \frac{nv}{2L} = \frac{n}{2L}\sqrt{\frac{\tau}{\mu}} = \frac{n}{2L}\sqrt{\frac{mg}{\mu}}, \qquad n = 1, 2, 3, \ldots$$

(a) The mass that allows the oscillator to set up the 4th harmonic ($n = 4$) on the string is

$$m = \left.\frac{4L^2 f^2 \mu}{n^2 g}\right|_{n=4} = \frac{4(1.20\ \text{m})^2(120\ \text{Hz})^2(0.00160\ \text{kg/m})}{(4)^2(9.80\ \text{m/s}^2)} = 0.846\ \text{kg}$$

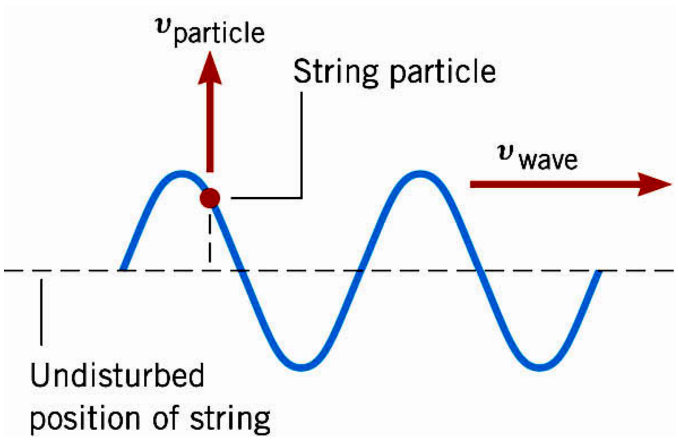
(b) If the mass of the block is $m = 1.00\ \text{kg}$, the corresponding n is

$$n = \sqrt{\frac{4L^2 f^2 \mu}{g}} = \sqrt{\frac{4(1.20\ \text{m})^2(120\ \text{Hz})^2(0.00160\ \text{kg/m})}{9.80\ \text{m/s}^2}} = 3.68$$

which is not an integer. Therefore, the mass cannot set up a standing wave on the string.

Wave Speed vs Particle Speed

The speed of a wave is different than the speed of the particles on the string.



$$v = \sqrt{\frac{F}{m/L}}$$ **speed of the wave**

the particles on the string go up and down according to

$$y = A\cos\omega t$$
$$v = -A\omega\sin\omega t$$
$$a = -A\omega^2\cos\omega t$$

so the speed of the particle has a maximum of Aω

$$\omega = 2\pi f$$
$$v_{particle} = 2\pi f A$$

Chapter 18: Temperature, Heat, and Thermodynamics

Definitions

"System"- particular object or set of objects

"Environment" - everything else in the universe

What is "State" (or condition) of system?

- macroscopic description - in terms of detectable quantities:

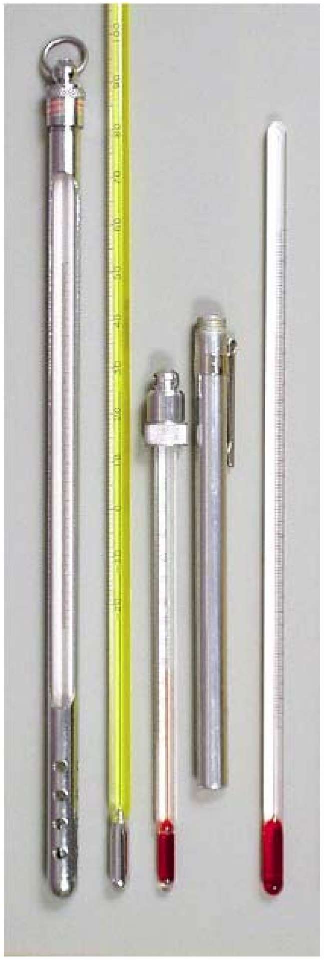
volume, pressure, mass, temperature

("State Variables")

Study of thermal energy --> temperature

Temperature

How do we know about temperature? → **thermometers**



Linear scale : need 2 points to define

Fahrenheit [° F] body temp and ~1/3 of body temp
~100 ° F ~33 ° F

Celsius [° C] "freezing point" and "boiling point" of water
0 ° C 100 ° C

Kelvin [K] Absolute zero and triple point of water
0 K 273.16 K

Conversion factors

K→ ° C $T_C = T_K - 273.15^\circ \qquad (1\ \Delta K = 1\ \Delta^\circ C)$

° C → ° F $T_F = \frac{9}{5} T_C + 32^\circ$

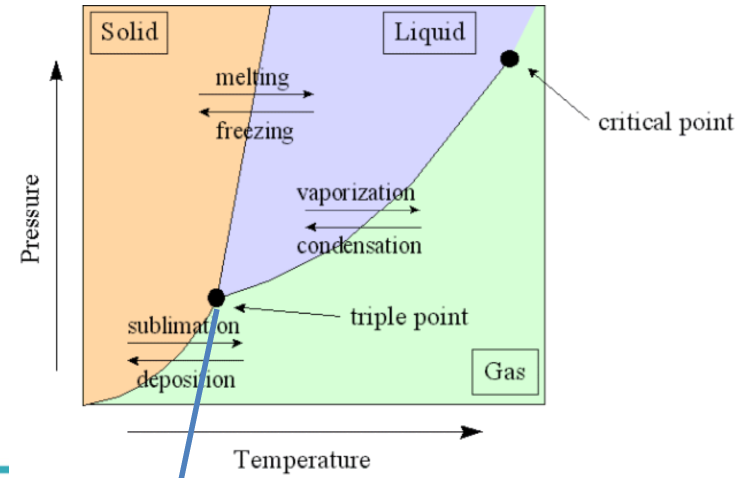


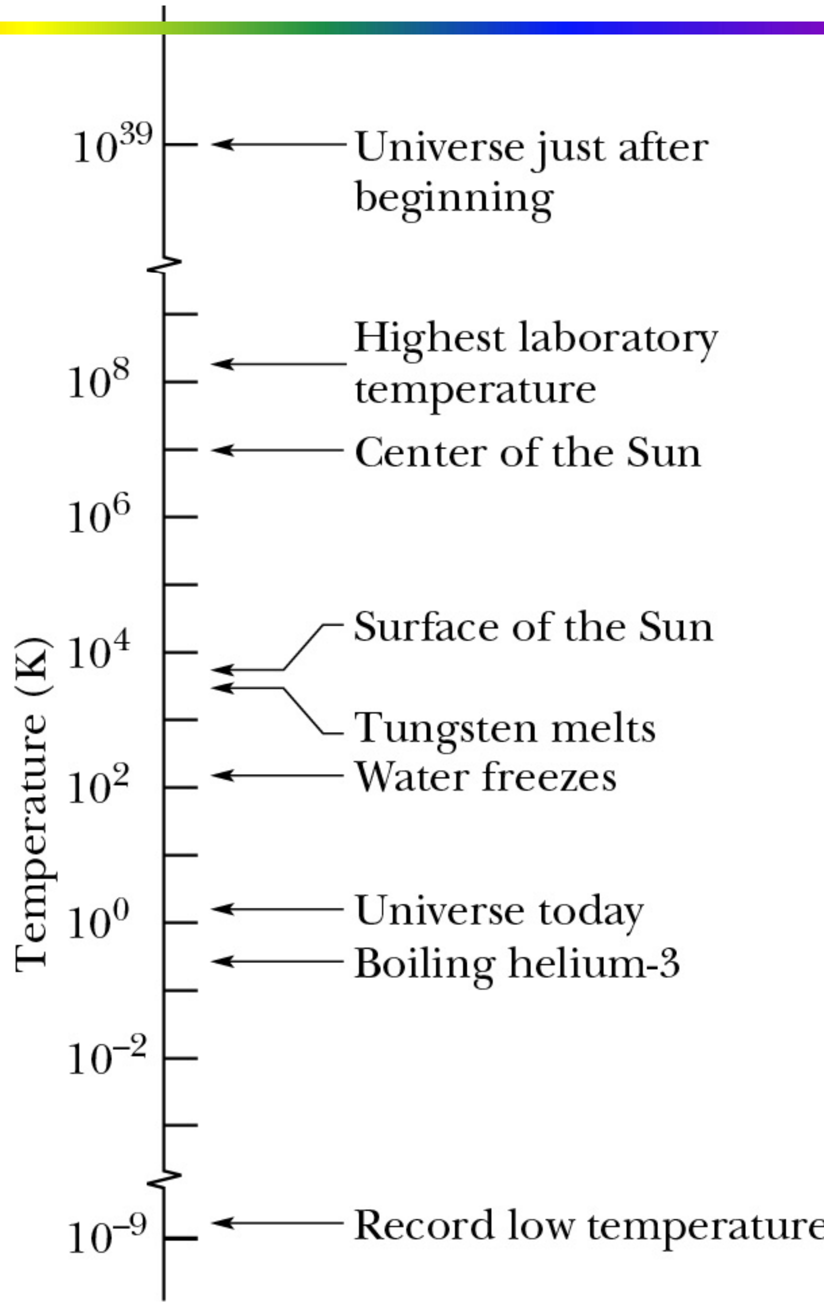
TABLE 18-1

Some Corresponding Temperatures

Temperature	°C	°F
Boiling point of water[a]	100	212
Normal body temperature	37.0	98.6
Accepted comfort level	20	68
Freezing point of water[a]	0	32
Zero of Fahrenheit scale	≈ −18	0
Scales coincide	−40	−40

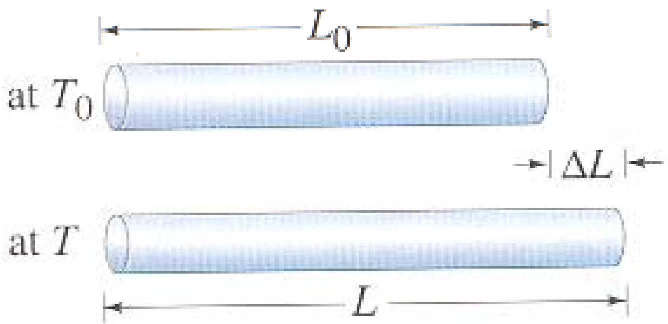
[a]Strictly, the boiling point of water on the Celsius scale is 99.975°C, and the freezing point is 0.00°C. Thus, there is slightly less than 100 C° between those two points.

Temperature

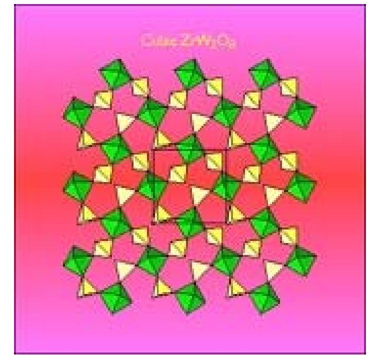


Thermal Expansion

Most substances expand when heated
and contract when cooled



ZrW_2O_8 is a ceramic with negative thermal expansion over a wide temperature range, 0-1050 K



The change in length, ΔL (= L - L_0), of almost all solids is ~ directly proportional to the change in temperature, ΔT (= T - T_0)

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

$$L = L_0(1 + \alpha \Delta T)$$

α = coefficient of thermal expansion

TABLE 19-2 Some Coefficients of Linear Expansion[a]

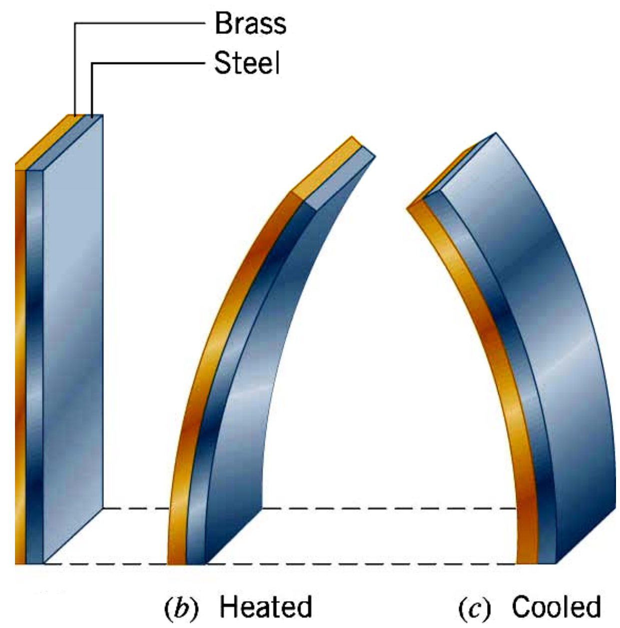
Substance	α (10^{-6}/C°)	Substance	α (10^{-6}/C°)
Ice (at 0°C)	51	Steel	11
Lead	29	Glass (ordinary)	9
Aluminum	23	Glass (Pyrex)	3.2
Brass	19	Diamond	1.2
Copper	17	Invar[b]	0.7
Concrete	12	Fused quartz	0.5

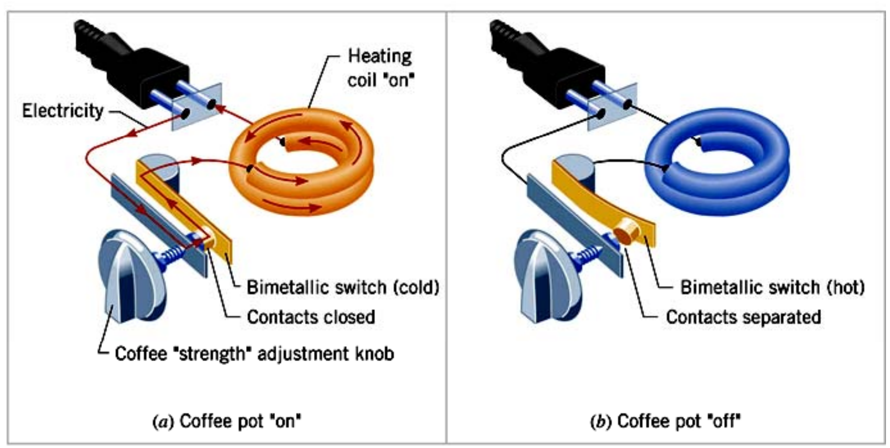
What causes thermal expansion?

Example: Bimetal Strip

Common device to measure and control temperature

$$|F| = kx = kL_0\left(1 + \alpha\Delta T\right)$$





Thermal Expansion of a Pendulum Clock

$$T = 2\pi\sqrt{\frac{L}{g}}$$

$$L = L_0 + \Delta L$$
$$= L_0 + \alpha_{brass} L_0 \Delta T$$

If the original period was 1 second

$$L_0 = \left(\frac{1s}{2\pi}\right)^2 g = 24.824\ cm$$

Problem 2: Pendulum Clock

A pendulum clock made of brass is designed to keep accurate time at 20°C. If the clock operates at 0°C, does it run fast or slow?

If so, how much?

Click Picture to Enlarge

$$L = 24.824\ cm\left(1 + (19\times10^{-6}/°C)(-20°C)\right)$$
$$= 24.824\ cm(0.9996)$$
$$= 24.814$$

The new period is:

$$T = 2\pi\sqrt{\frac{24.814}{9.8}} = 0.9998\ s$$

It runs slow (less time per tick)

at 20°C

$$\#\,ticks = 24 * 60 * 60 = 86400$$

at 0°C:

$$\#\,ticks = 86400 * 0.999 = 86383$$

fewer ticks = 1.7hr/yr