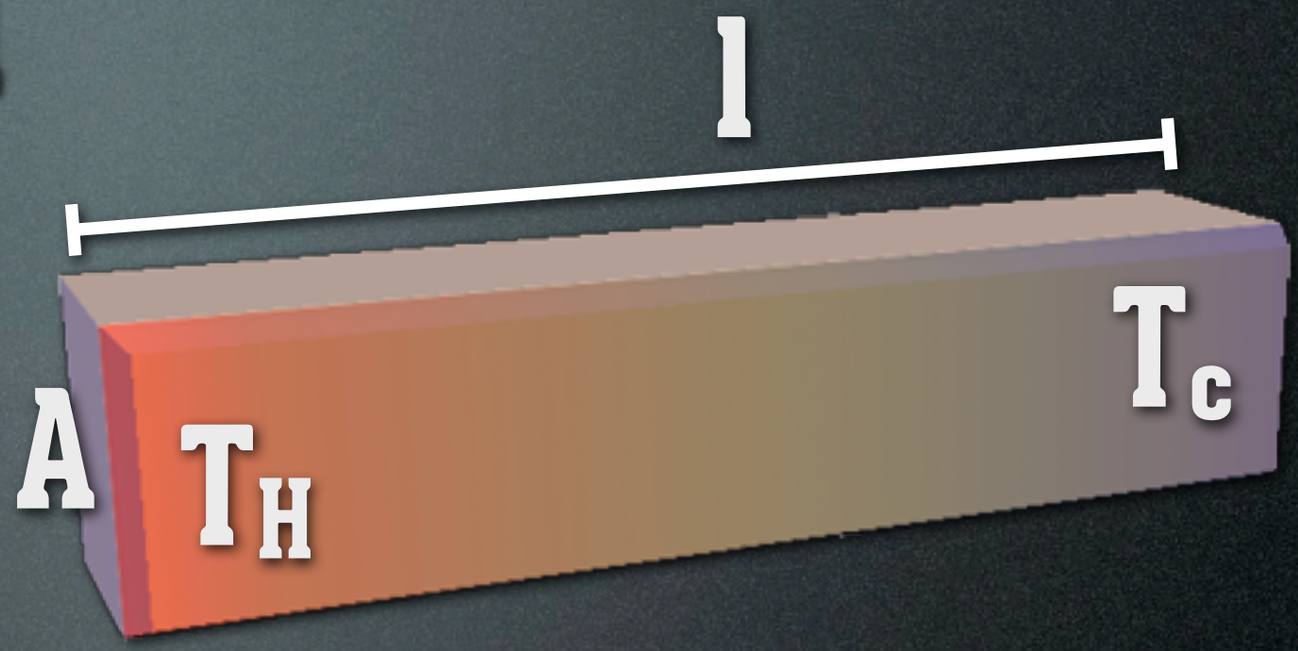
Heat Transfer

H Heat Transfer rate

My Old Cat

Conduction

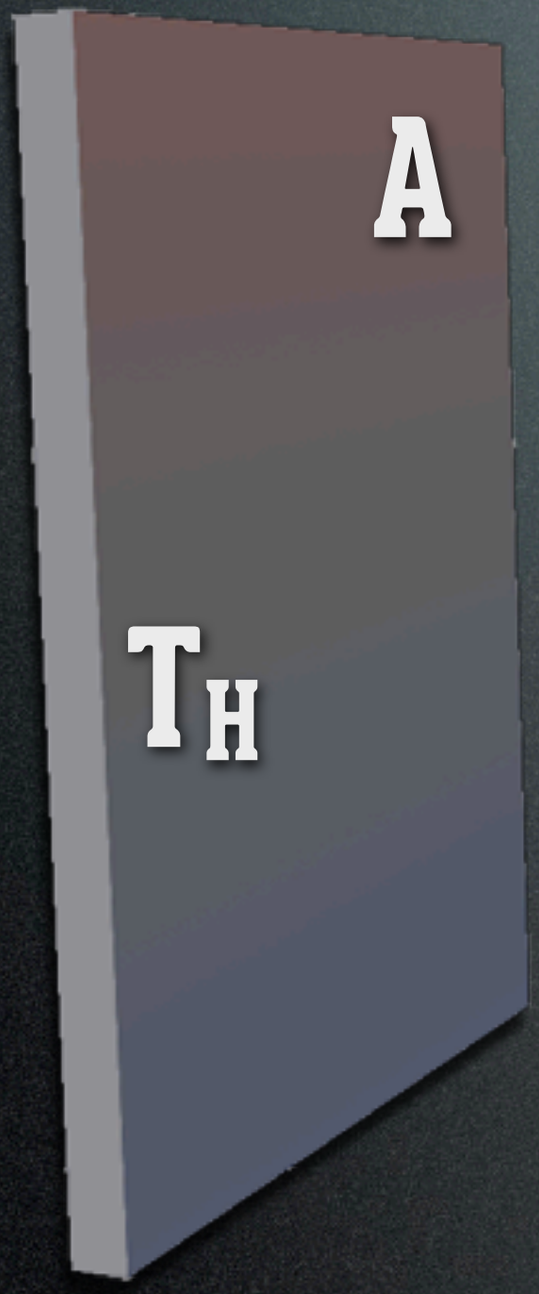
$k_{gold} = 315$ W/mK

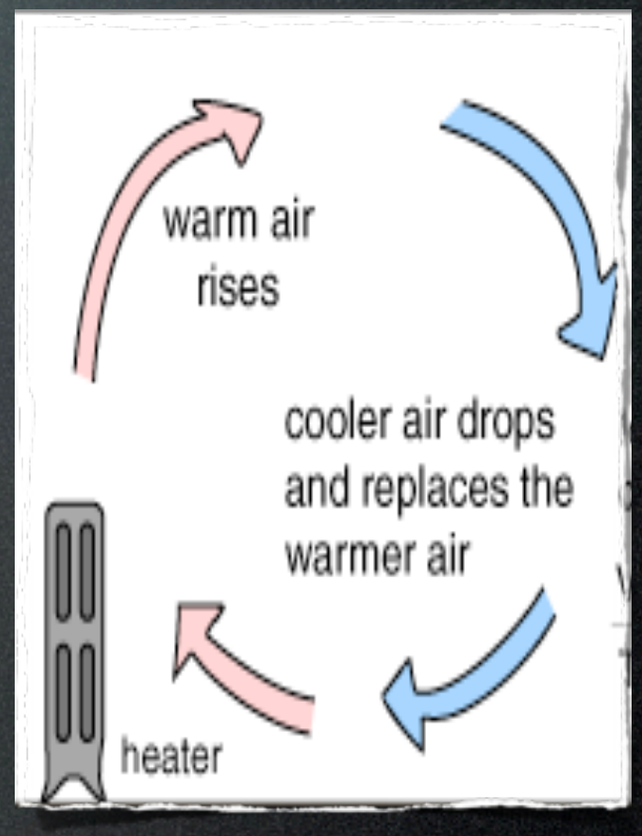


$$H = \frac{kA\Delta T}{l}$$

My Great-Great Grandfather

$$H = hA\Delta T$$

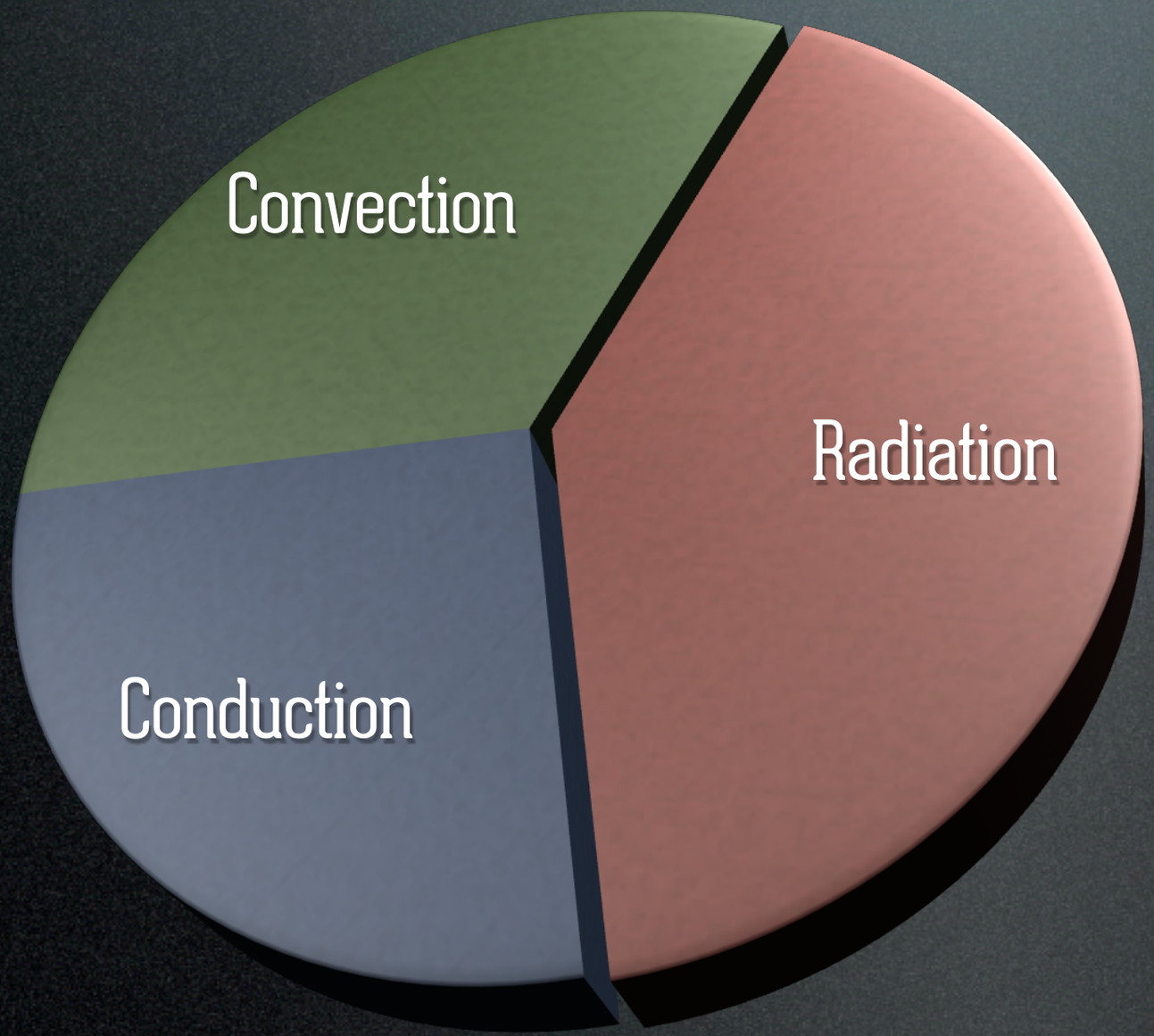




$h = 600$ W / m² K

Convection

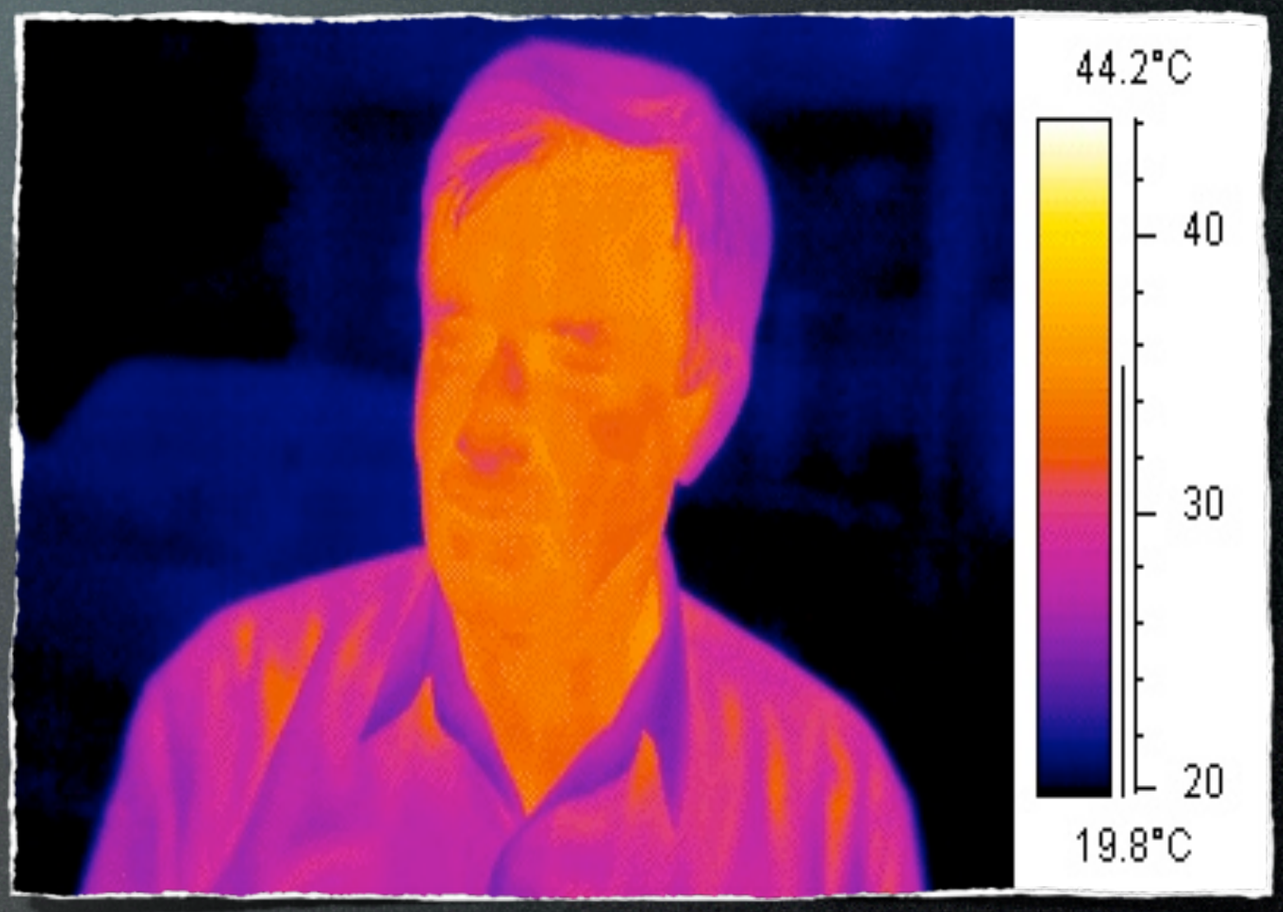
All the rest



- Conduction
- Convection
- Radiation

Radiation

- $R = e\sigma T^4$
- R intensity W/m^2
- $R = H/A$
- e emissivity
- $\sigma = 5.67 \times 10^{-8}\ W/m^2 K^4$



Practice Problem

A piece of metal rests on a hot plate with a temperature of 140 °C. The room temperature is maintained at 20 °C. A temperature sensor at the top of the metal reads 110 °C. The metal measures 2 x 10 x 15 cm.

A] How many Joules conduct through the metal every minute?

B] What is the heat flow rate from convection from the top of the plate?

C] What is the heat flow rate from radiation from the top of the plate? [ignore the energy the metal absorbs from the surroundings]

Constants

SPECIFIC HEAT OF SOLID.....	200 J/kg ℃
SPECIFIC HEAT OF LIQUID.....	500 J/kg ℃
SPECIFIC HEAT OF GAS.....	300 J/kg ℃
DENSITY AT 300K	6000 kg/m^3
LATENT HEAT OF FUSION...	100,000 J/kg
LATENT HEAT OF VAPORIZATION	400,000 J/kg
COEFFICIENT OF LINEAR EXPANSION	3.3 x 10^{-4} /℃
COEFFICIENT OF VOLUMETRIC EXPANSION	9.9 x 10^{-4} /℃
COEFFICIENT OF CONDUCTION	880 J/ m s ℃
EMISSIVITY	0.35
COEFFICIENT OF CONVECTION FLAT TOP SURFACE	7400 J/ s m^2 ℃
MELTING POINT	450 ℃
BOILING POINT	600 ℃

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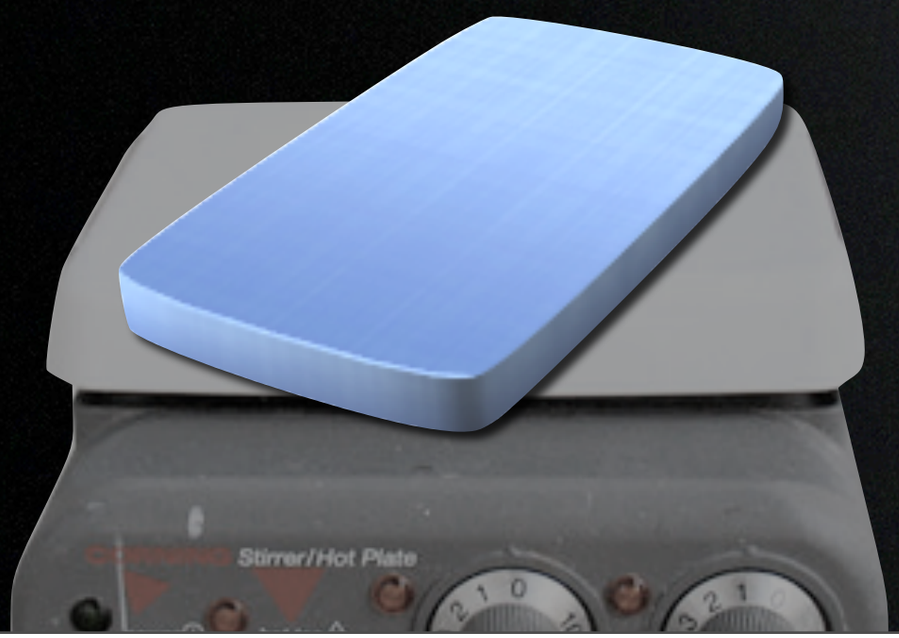
A] How many Joules conduct through the metal every minute?

$$H = \frac{kA\Delta T}{l}$$

COEFFICIENT OF CONDUCTION	880 J/ m s °C



A piece of metal rests on a hot plate with a temperature of 140 °C. The room temperature is maintained at 20 °C. A temperature sensor at the top of the metal reads 110 °C. The metal measures 2 x 10 x 15 cm.

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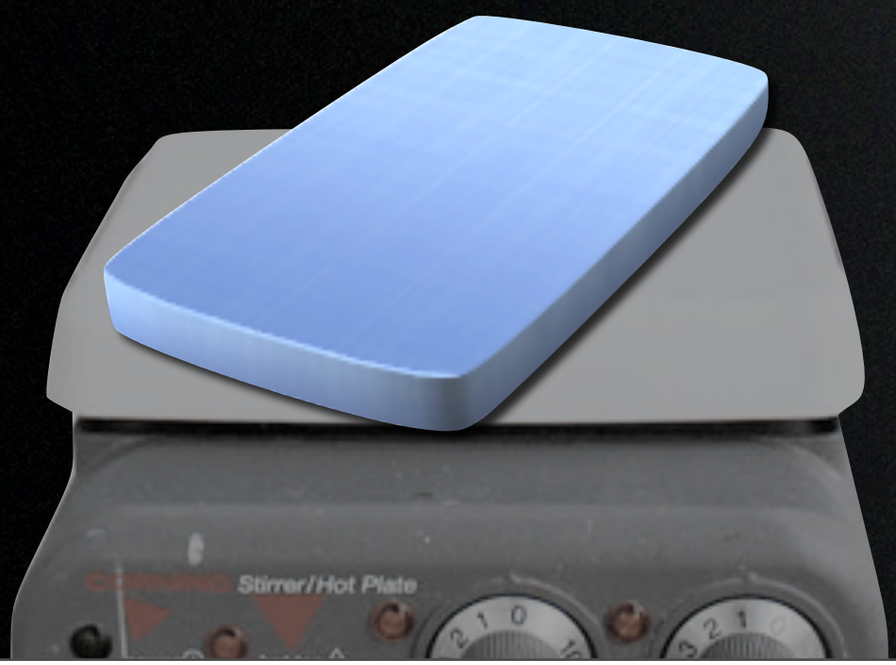
COEFFICIENT OF CONVECTION FLAT TOP SURFACE	7400 J/ s m^2 °C

$$H = hA\Delta T$$



A piece of metal rests on a hot plate with a temperature of 140 °C. The room temperature is maintained at 20 °C. A temperature sensor at the top of the metal reads 110 °C. The metal measures 2 x 10 x 15 cm.

C] What is the heat flow rate from radiation from the top of the plate? [ignore the energy the metal absorbs from the surroundings]

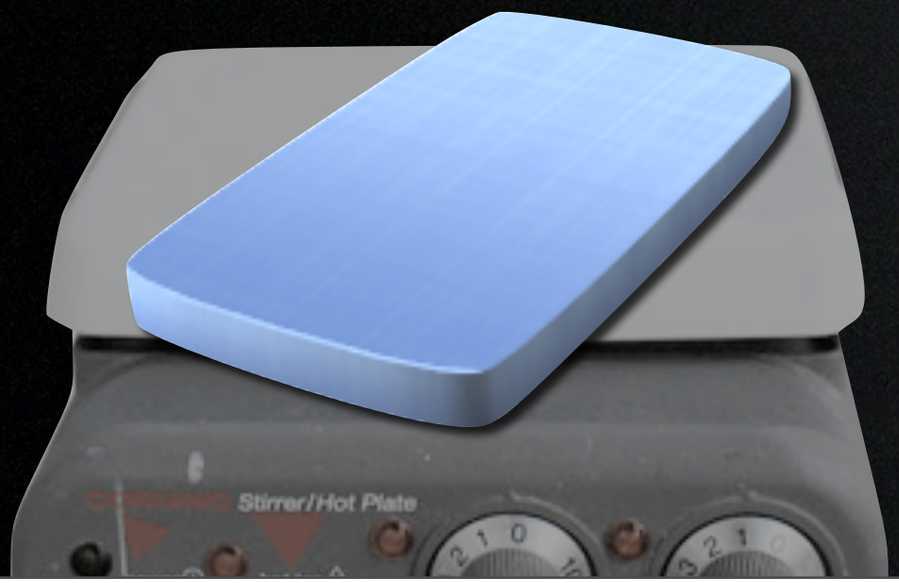
$\dot{R} = e \sigma T^4$

$\dot{R} = \dot{H} / A$

$\dot{H} = e A \sigma T^4$

EMISSIVITY 0.35

$\sigma = 5.67 \times 10^{-8}\ W/m^2\ K^4$



Thermal Expansion

Linear Expansion

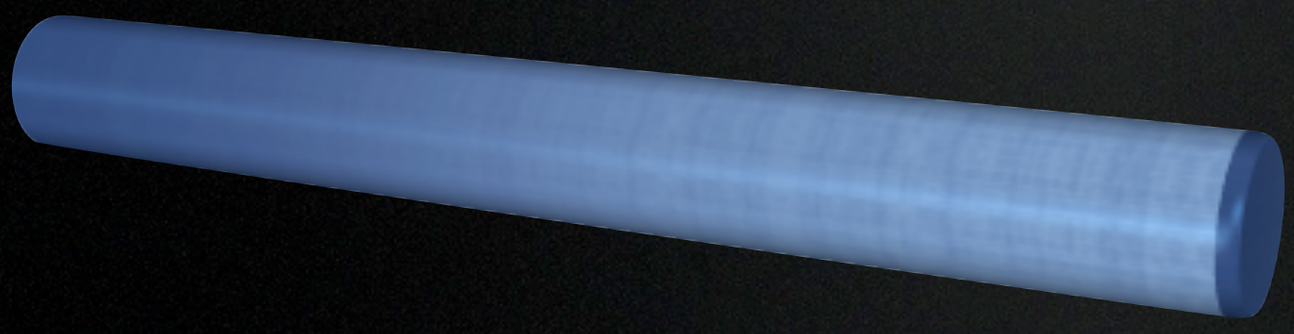
$$\Delta L = L_o \alpha \Delta T$$

- ΔL change of length
- L_o original length
- ΔT change of temperature
- α coefficient of linear expansion

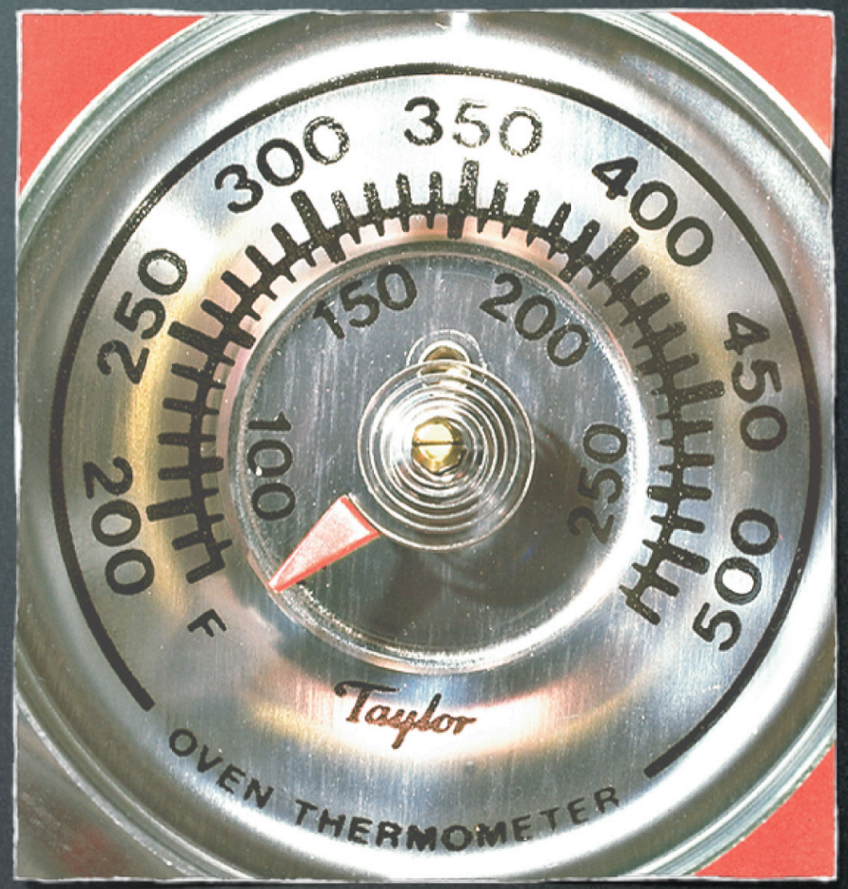
A bar of metal has a length of 70 cm at 22 °C . What is the final length of the bar when it is heated to 220 °C ?

$$\Delta L = L_o \alpha \Delta T$$

COEFFICIENT OF LINEAR EXPANSION	3.3×10^{-4} / °C
MELTING POINT	450 °C

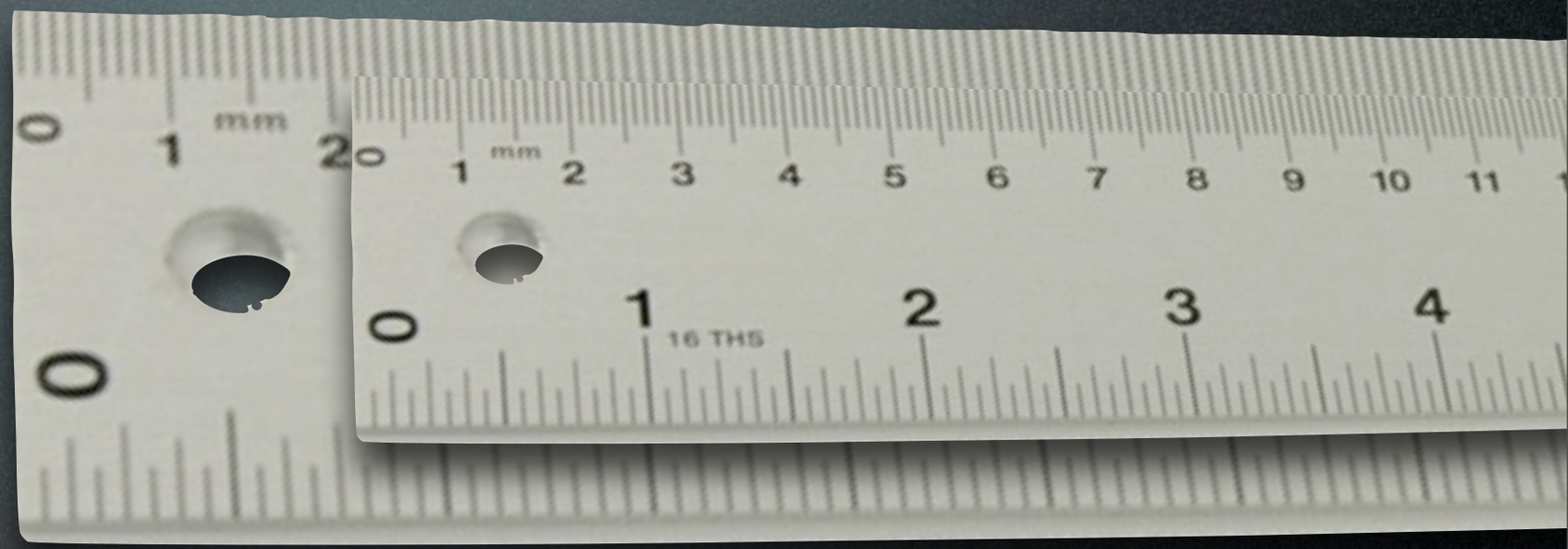


Expansion



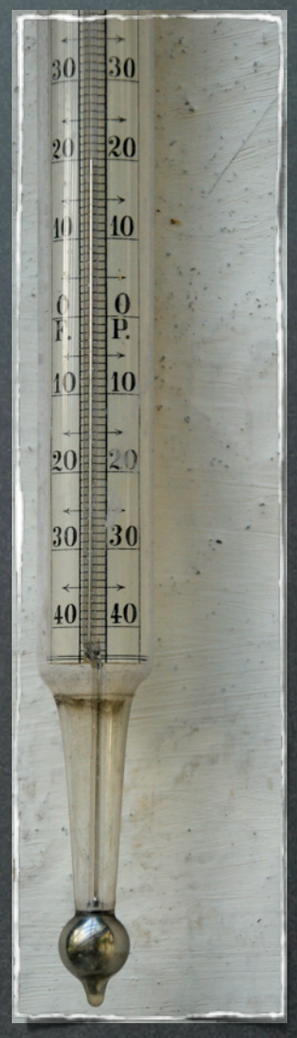
- Expansion Joints
- An oven thermometer
- A bimetallic strip

Take a guess



- Area Expansion
- $\Delta A = A_o [2\alpha] \Delta T$

classic thermometer

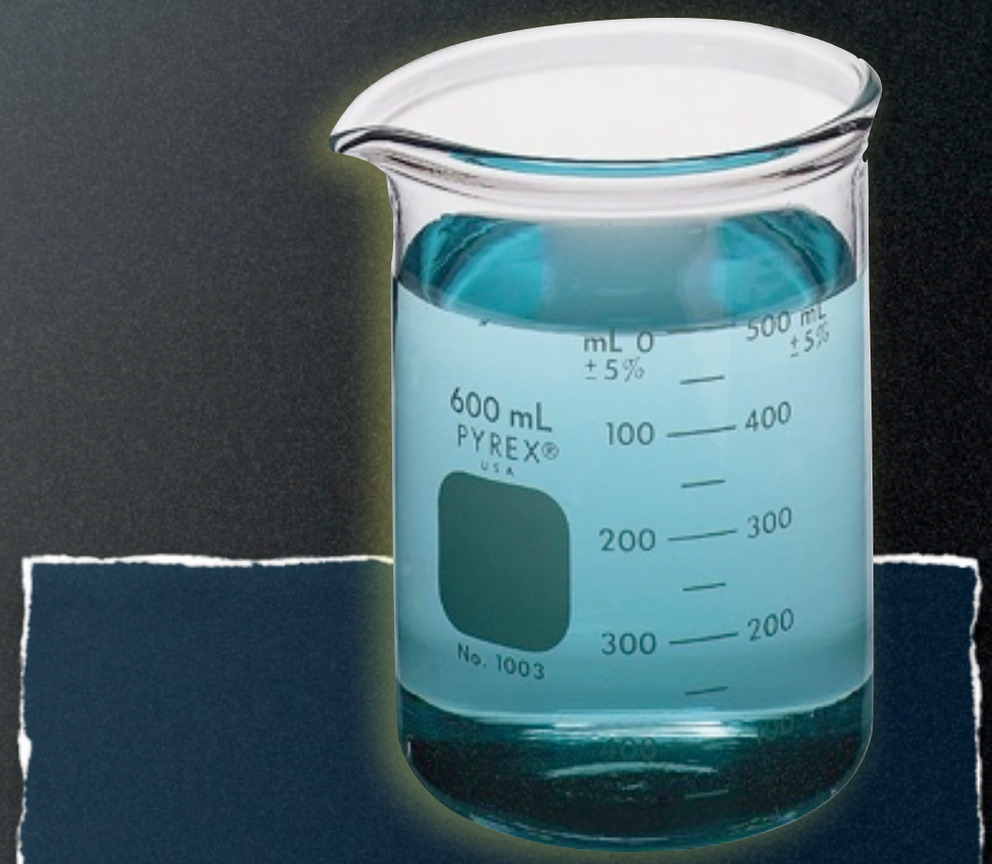


- expansion of Hg

Volumetric Expansion

- $\Delta V = V_o \beta \Delta T$

$\beta = 3\alpha$



With the Volumetric Constants

Material	Coefficient of Linear Expansion, α $(C°)^{-1}$	Coefficient of Volume Expansion, β $(C°)^{-1}$
Solids		
Aluminum	25×10^{-6}	75×10^{-6}
Brass	19×10^{-6}	56×10^{-6}
Copper	17×10^{-6}	50×10^{-6}
Gold	14×10^{-6}	42×10^{-6}
Iron or steel	12×10^{-6}	35×10^{-6}
Lead	29×10^{-6}	87×10^{-6}
Glass (Pyrex®)	3×10^{-6}	9×10^{-6}
Glass (ordinary)	9×10^{-6}	27×10^{-6}
Quartz	0.4×10^{-6}	1×10^{-6}
Concrete and brick	$\approx 12 \times 10^{-6}$	$\approx 36 \times 10^{-6}$
Marble	$1.4–3.5 \times 10^{-6}$	$4–10 \times 10^{-6}$
Liquids		
Gasoline		950×10^{-6}
Mercury		180×10^{-6}
Ethyl alcohol		1100×10^{-6}
Glycerin		500×10^{-6}
Water		210×10^{-6}
Gases		
Air (and most other gases at atmospheric pressure)		3400×10^{-6}

A beaker contains 300ml of fluid at 10 °C. What does the beaker read when they are heated to 90 °C?

$$\Delta V = V_o \beta \Delta T$$

FLUID COEFFICIENT OF VOLUMETRIC EXPANSION	30×10^{-5} /°C
GLASS COEFFICIENT OF VOLUMETRIC EXPANSION	9×10^{-6} /°C

$\Delta V = (300)\ (80)\ (30 \times 10^{-5})$

$\Delta V = 7.2$ mL of fluid

$V_f = 307.2$ mL total

What part of the beaker expands up to hold the 307.2 mL of fluid?

$$\Delta V = V_o \beta \Delta T$$

$$V_f = V_o + \Delta V$$

$$V_f = V_o [1 + \beta \Delta T]$$

$$307.2 = V_o (1 + (9 \times 10^{-6})(80))$$

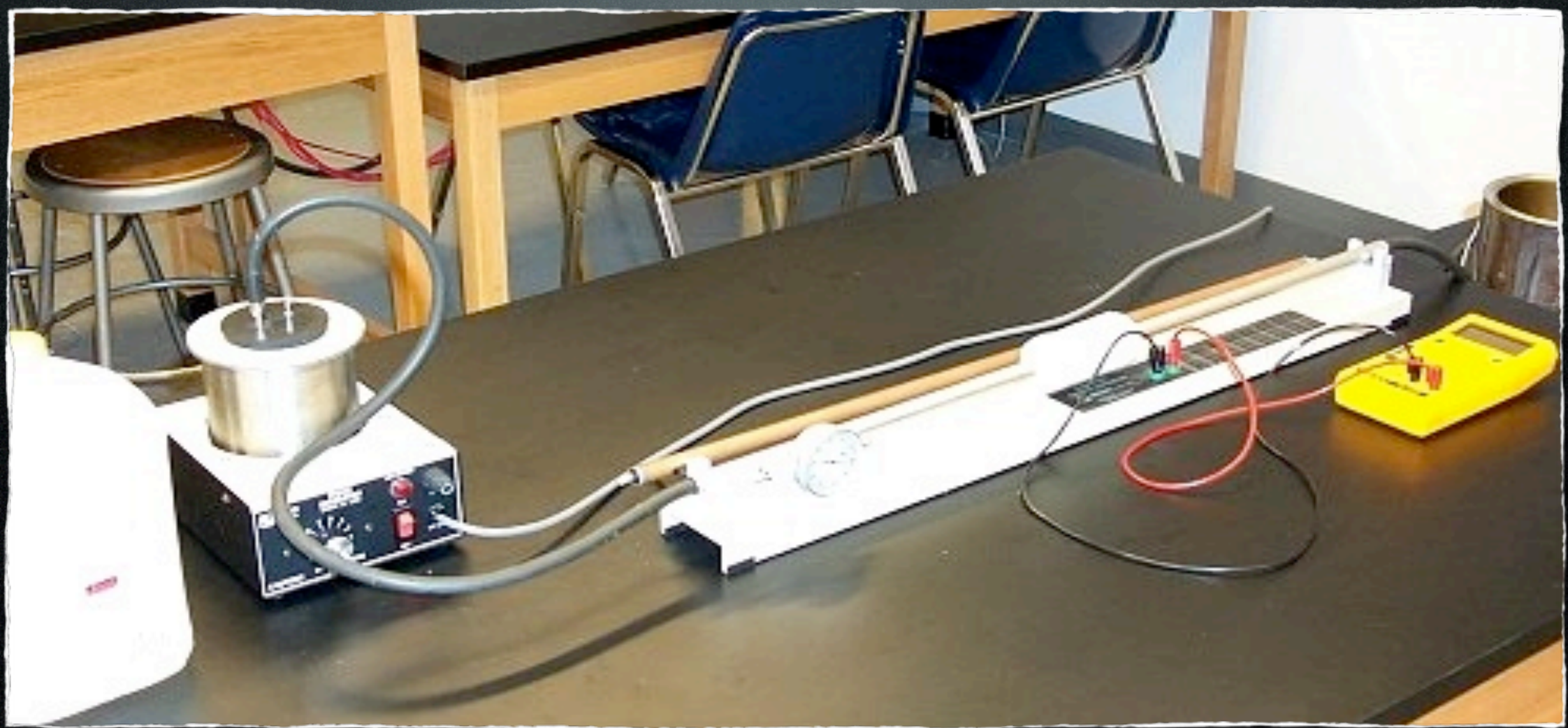
$$307.2 = V_o (1 + 0.00072)$$

$$307.2 = V_o (1.00072)$$

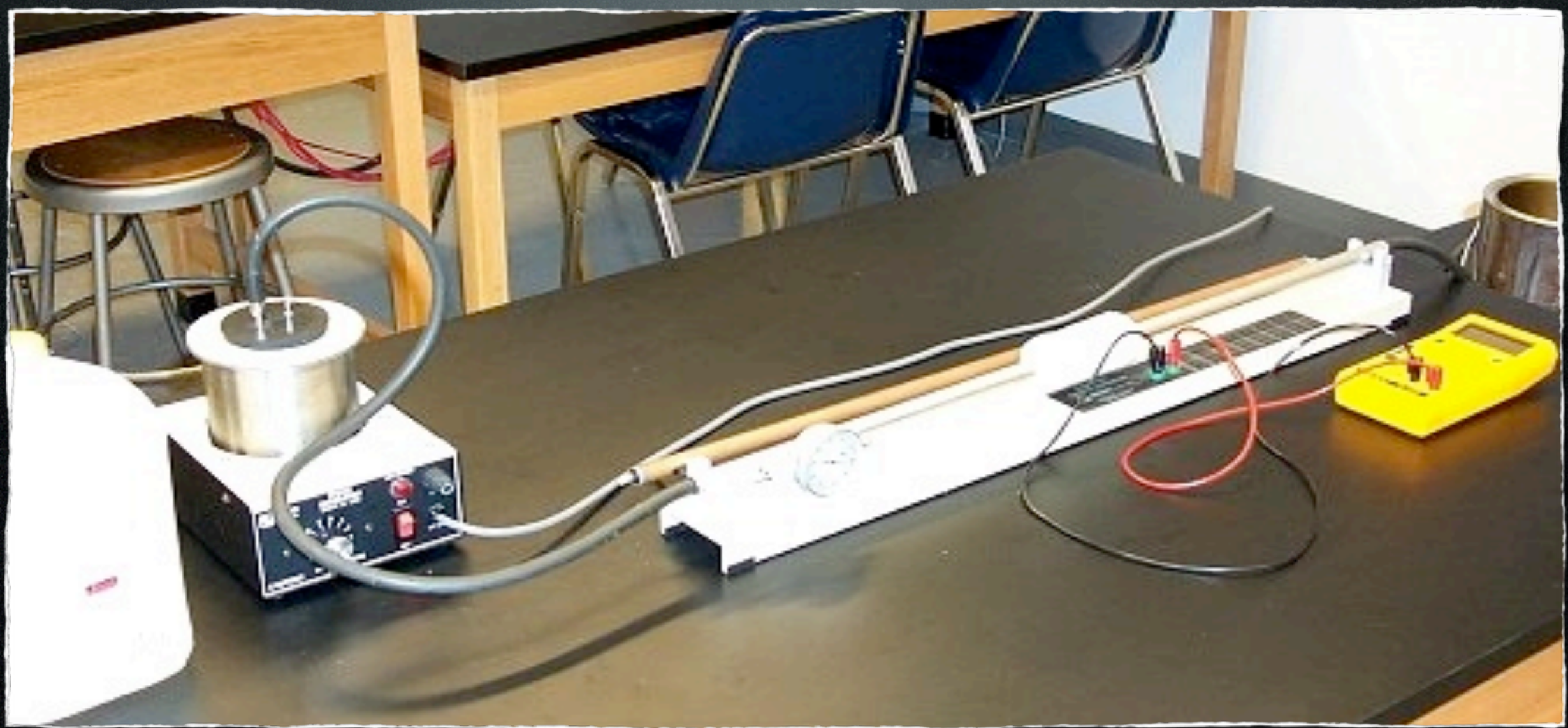
$$306.9 = V_o$$

FLUID COEFFICIENT OF VOLUMETRIC EXPANSION	30×10^{-5} /°C
GLASS COEFFICIENT OF VOLUMETRIC EXPANSION	9×10^{-6} /°C

Linear Expansion Lab

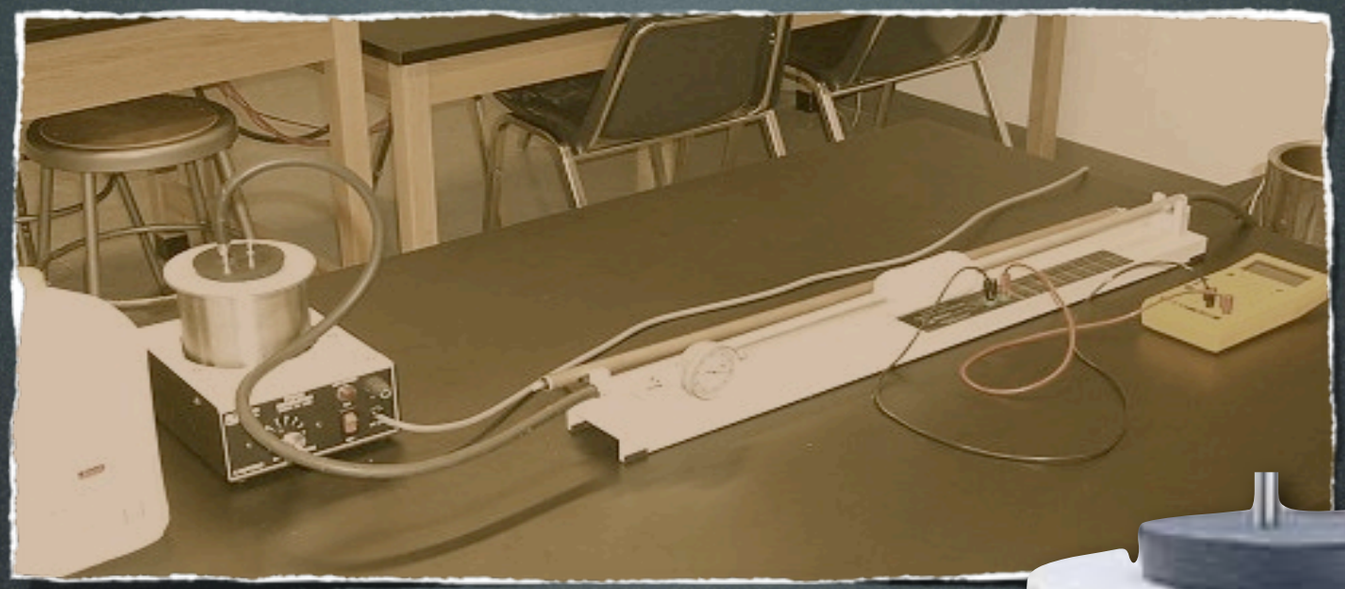


Linear Expansion Lab



$$\Delta L = L_o \alpha \Delta T$$

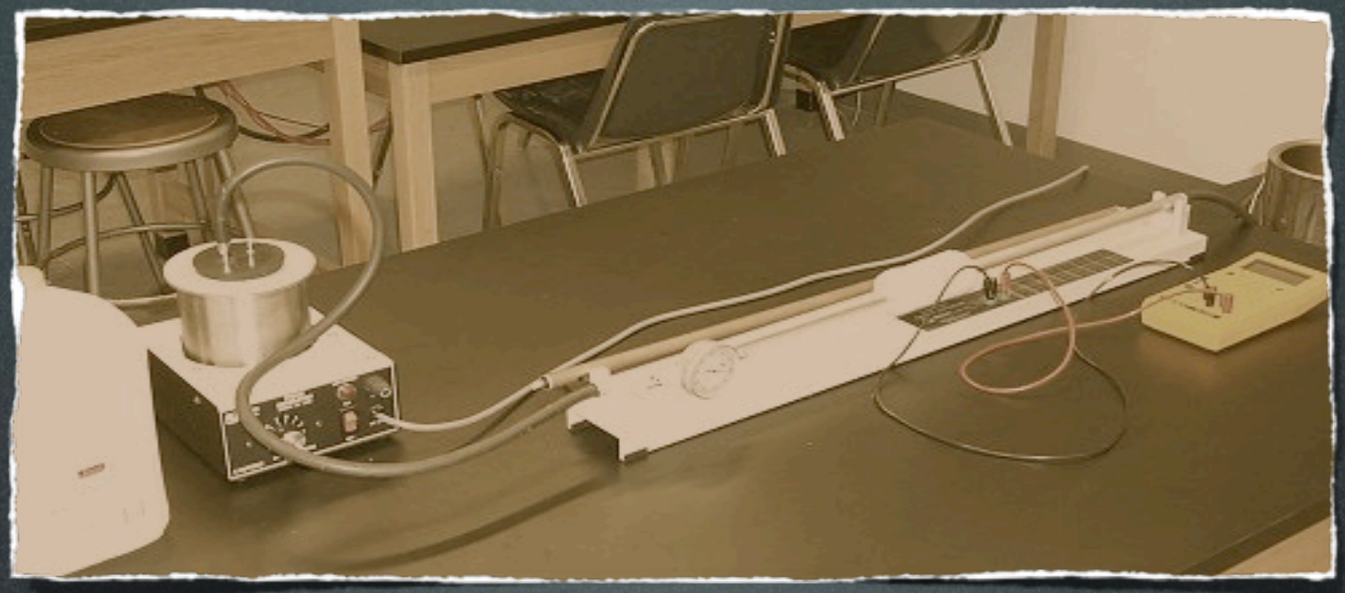
Linear Expansion Lab



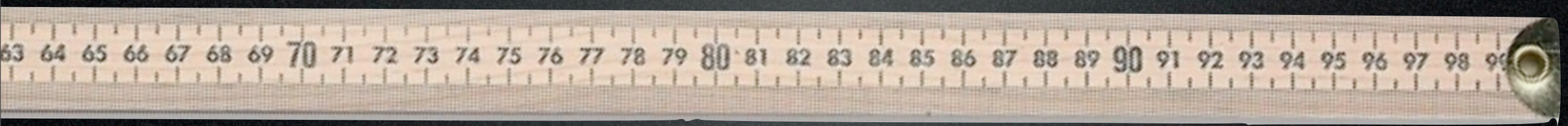
Steam Generator

$$\Delta L = L_o \alpha \Delta T$$

Linear Expansion Lab



Meter Stick



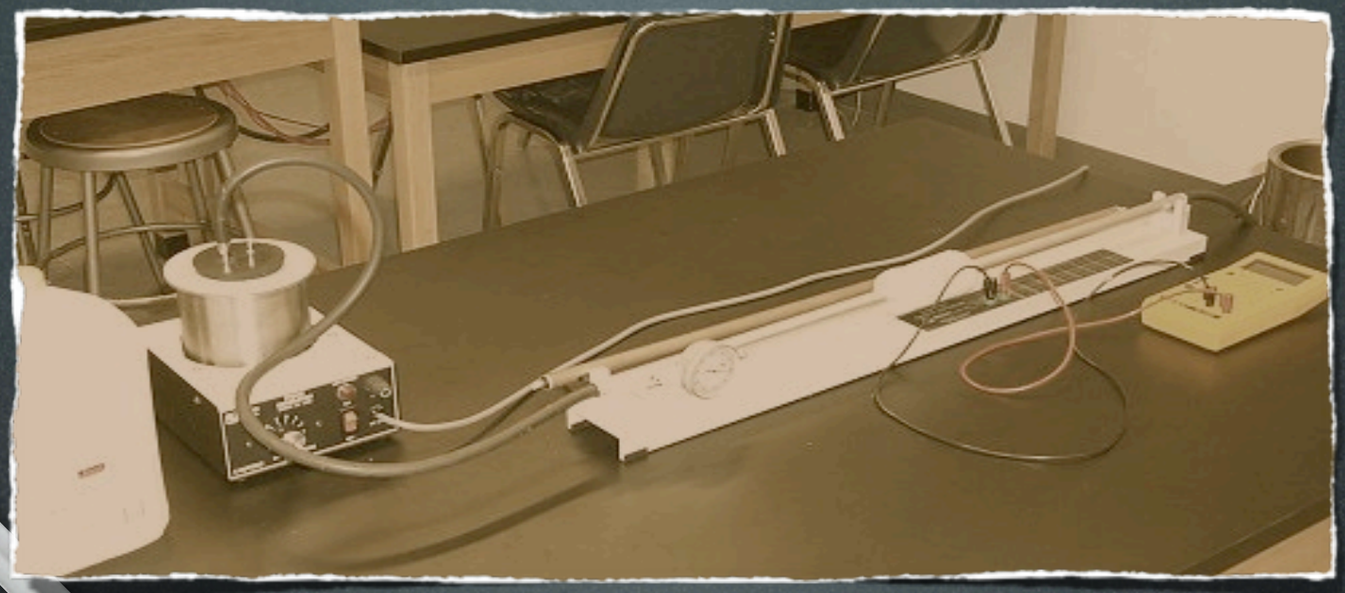
$$\Delta L = L_o \alpha \Delta T$$

Linear Expansion Lab

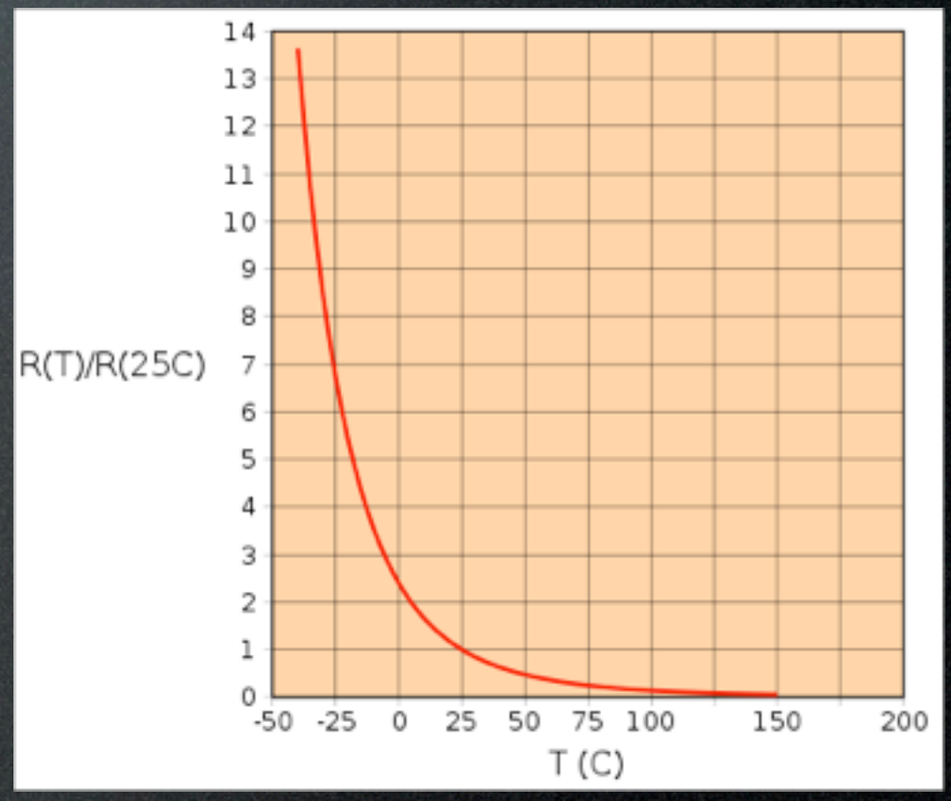
Micrometer

$$\Delta L = L_o \alpha \Delta T$$

Linear Expansion Lab

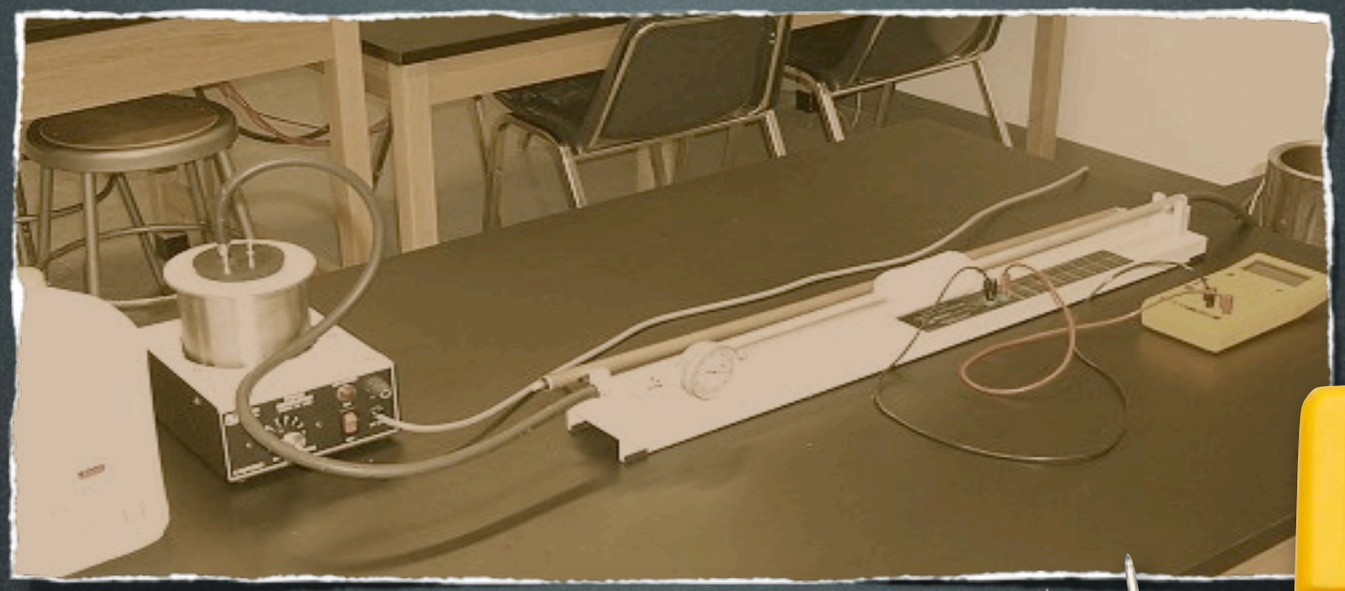


Thermistor



$$\Delta L = L_o \alpha \Delta T$$

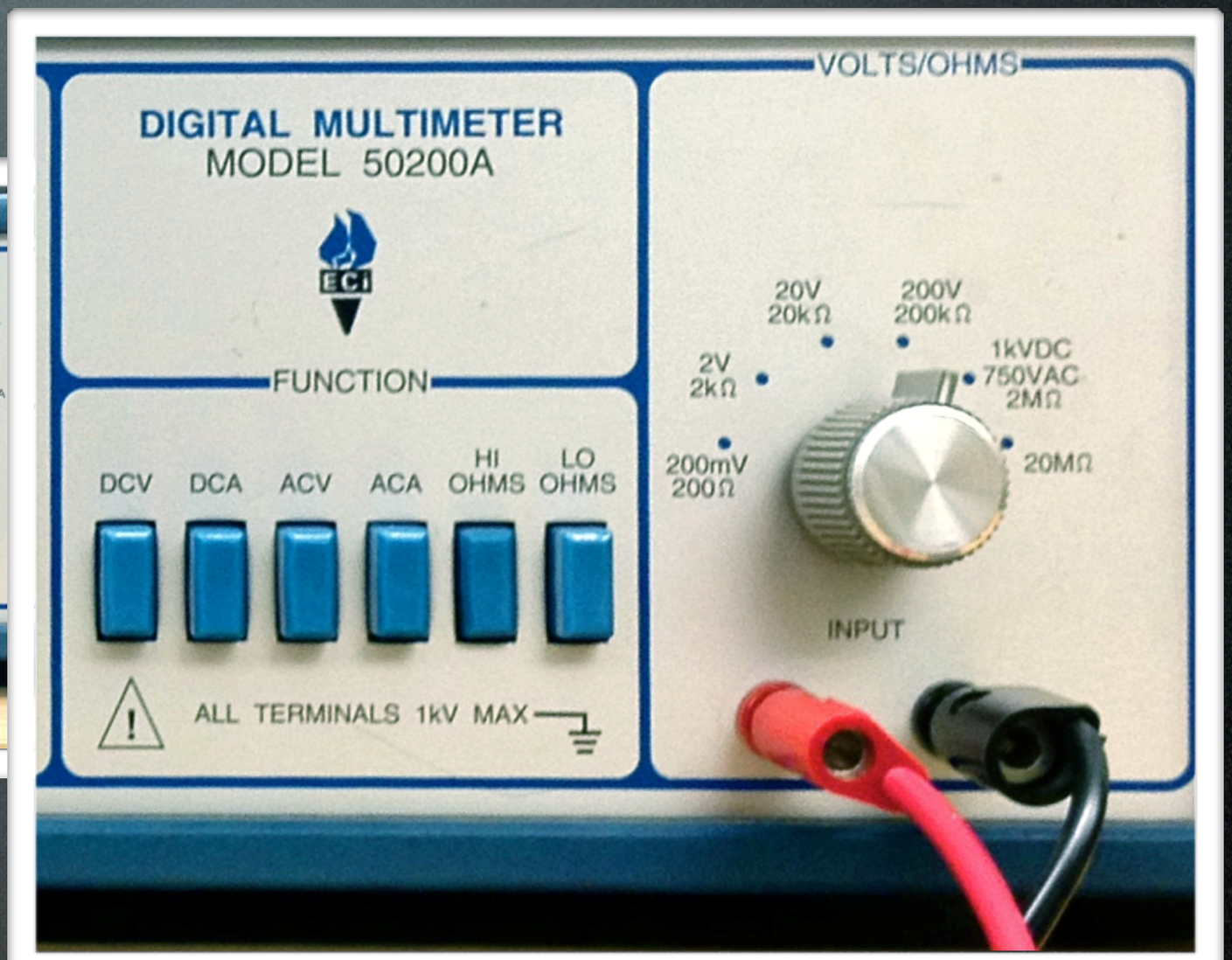
Linear Expansion Lab



Digital Multimeter
DMM

$$\Delta L = L_o \alpha \Delta T$$

Linear Expansion Lab



Digital Multimeter DMM

$$\Delta L = L_o \alpha \Delta T$$

Conversion

THERMISTOR CONVERSION TABLE:

Temperature versus Resistance

Res. (Ω)	Temp. (°C)	Res. (Ω)	Temp. (°C)	Res. (Ω)	Temp. (°C)	Res. (Ω)	Temp. (°C)
351,020	0	95,447	26	30,976	52	11,625	78
332,640	1	91,126	27	29,756	53	11,223	79
315,320	2	87,022	28	28,590	54	10,837	80
298,990	3	83,124	29	27,475	55	10,467	81
283,600	4	79,422	30	26,409	56	10,110	82
269,080	5	75,903	31	25,390	57	9,767.2	83
255,380	6	72,560	32	24,415	58	9,437.7	84
242,460	7	69,380	33	23,483	59	9,120.8	85
230,260	8	66,356	34	22,590	60	8,816.0	86
218,730	9	63,480	35	21,736	61	8,522.7	87
207,850	10	60,743	36	20,919	62	8,240.6	88
197,560	11	58,138	37	20,136	63	7,969.1	89
187,840	12	55,658	38	19,386	64	7,707.7	90
178,650	13	53,297	39	18,668	65	7,456.2	91
169,950	14	51,048	40	17,980	66	7,214.0	92
161,730	15	48,905	41	17,321	67	6,980.6	93
153,950	16	46,863	42	16,689	68	6,755.9	94
146,580	17	44,917	43	16,083	69	6,539.4	95
139,610	18	43,062	44	15,502	70	6,330.8	96
133,000	19	41,292	45	14,945	71	6,129.8	97
126,740	20	39,605	46	14,410	72	5,936.1	98
120,810	21	37,995	47	13,897	73	5,749.3	99
115,190	22	36,458	48	13,405	74	5,569.3	100
109,850	23	34,991	49	12,932	75		
104,800	24	33,591	50	12,479	76		
100,000	25	32,253	51	12,043	77		

DASHO®

5

- 118.8 kΩ
- 45.0 kΩ

The Tables

	Material?	$L_{unknown}$	R_1	R_2	ΔL

	T_1	T_2	ΔT	$\alpha_{unknown}$	$\alpha_{accepted}$	% Error
1						
2						
3						