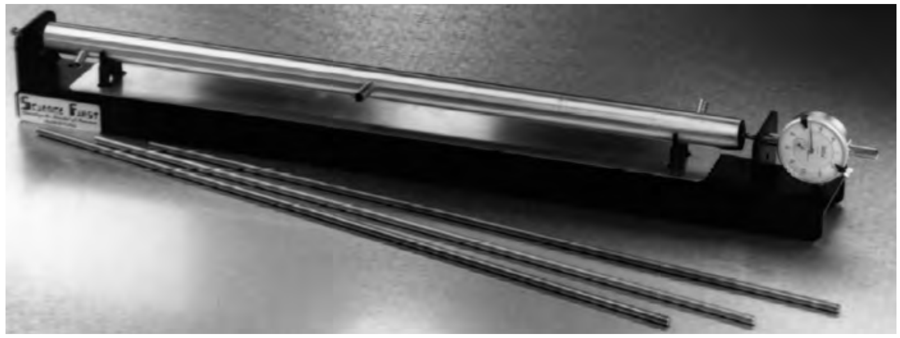
015-0300 (15-030) Metric Linear Expansion Apparatus

Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.



15-035 Precision Linear Expansion Apparatus

15-030 Micrometer Linear Expansion

Description:

This apparatus is used to measure the **linear expansion** of any solid material and to calculate the **coefficient of linear expansion.**

It consists of an aluminum channel base with an electrical terminal mounted on one end. The other end supports a micrometer dial (or Dial Indicator, #15-035) which measures the linear change in a metal bar in thousandths of an inch. The heating jacket rests on two support cradles attached to the base. Its hollow center contains 1 rod and 3 nipples. One nipple allows water to enter the jacket; the second allows a temperature reading to be taken; the third serves as a drain.

This apparatus is designed to permit great precision in measurement, fast setup and simplified procedures. The frame is rigid so contact can be made by "feel" alone, eliminating the conventional battery and buzzer method for finding contact.

Materials Needed:

Source of warm water
Source of steam
(Optional, not recommended)
Thermometer (0 to 100° C)
Battery
Any type as long as is same voltage as light bulb. I.e. 9 v battery with 9 v bulb-optional
Light or buzzer
(Optional)
Rubber tubing
1/4 inch diameter, to connect to hot water source

Linear Expansion Constants for Common Materials

Aluminum	0.000022
Brass	0.000019
Copper	0.000017
Glass	0.000007
Glass (Pyrex)	0.000032
Invar (Nickel/iron)	0.000007
Iron	0.000012
Platinum	0.000009
Quartz	0.000004
Steel	0.000013
Tungsten	0.000044

Important Note:

On our 15-035 English-Reading Precision Linear Expansion Apparatus, the readings on the dial indicator are in thousands of an inch (0.001.) We have replaced the metric dial indicator with its English counterpart for reasons of cost and availability.

To convert to millimeters, multiply by 25.4.

For example, a reading of .020 inches = approximately .51 mm.

Theory:

Nearly all matter expands when heated.

When you heat an iron rod, its molecules vibrate more violently. They shove one another away causing the rod to expand. When the rod cools, its molecules vibrate less violently and it contracts.

Each solid has a characteristic rate of expansion which is unique to that solid. The rate of expansion is determined by heating a measured length of solid through a definite temperature change and then measuring the change in length.

The coefficient of linear expansion, a, is a number which indicates the change in length per unit length per degree of temperature change. It is a characteristic property of the material and is calculated as:

$$a = \frac{L}{L_0 \text{ x } t}$$

where:		change
	L	length
	L_0	initial length
	t	temperature
	$t = t_2 - t_1$	temperature increase
	$L = L_H - L_L$	length increase or expansion
where:	L_H	high temperature (heated rod)
	L_L	low temperature (not heated)

Special Cases:

All materials expand upon heating except for those rare cases where molecular structure simultaneously changes to a more dense form. *Ice*, for example, shrinks upon melting and the alloy *invar* gradually changes crystal form to a more compact structure upon heating. These few exceptions to the general rule extend over a range of only a few degrees.

Materials with *high molecular cohesion* are affected very little by temperature change. Molecular or atomic cohesion is very high in some materials like tungsten and diamond and is highest at low temperatures. Molecular cohesion is very low in gases and their expansion with rise in temperature is large.

How To Use:

Note: Although rods are machined to a length of 60 cm, measure each rod first for accuracy of results.

Procedure (15-030) Metric

1. Measure length of rod to nearest mm. Record length $\mathbf{L_0}$.
2. Insert rod into heating jacket.
3. Place heating jacket onto base so that water intake nipple is at the end nearest the electrical terminals. The thermometer tube should be facing up at the jacket center and the water outlet should be on the upper half of the jacket near micrometer.
4. Measure length of rod with micrometer. Record reading as $\mathbf{L_L}$. After recording, back off the micrometer screw to allow for expansion.
5. To heat rod, attach a warm water source to the inlet valve.

Safety Note: *We recommend warm tap water, not steam. This avoids the possibility of burns. The total expansion is smaller for the smaller temperature difference but can still be measured precisely. If you choose to use steam, we recommend* ***15-075 Steam Generator*** *manufactured by* **Science First.**

6. Fill jacket with water. Allow at least **60 seconds** for rod temperature to equal water temperature.
7. Install thermometer by slipping short length of rubber tubing over thermometer tube and slipping thermometer into position. This makes it unnecessary to fit and remove stoppers.
8. Turn micrometer dial until screw just makes contact with rod. The micrometer reading is $\mathbf{L^H}$.
9. You may wish to use a circuit to determine when contact is made. To do so, connect a battery and light to the terminals as shown in *Figure 1*. When the dial is turned and contact is made, the light goes on. Now take your micrometer reading. Turn the dial slowly until the light goes out. Take another micrometer reading. Average the two readings to determine L_H.

Note: *you do not need a circuit to obtain an accurate reading. The examples that follow do not use the circuit. They can be modified to include its use if desired.*

Replacement Parts

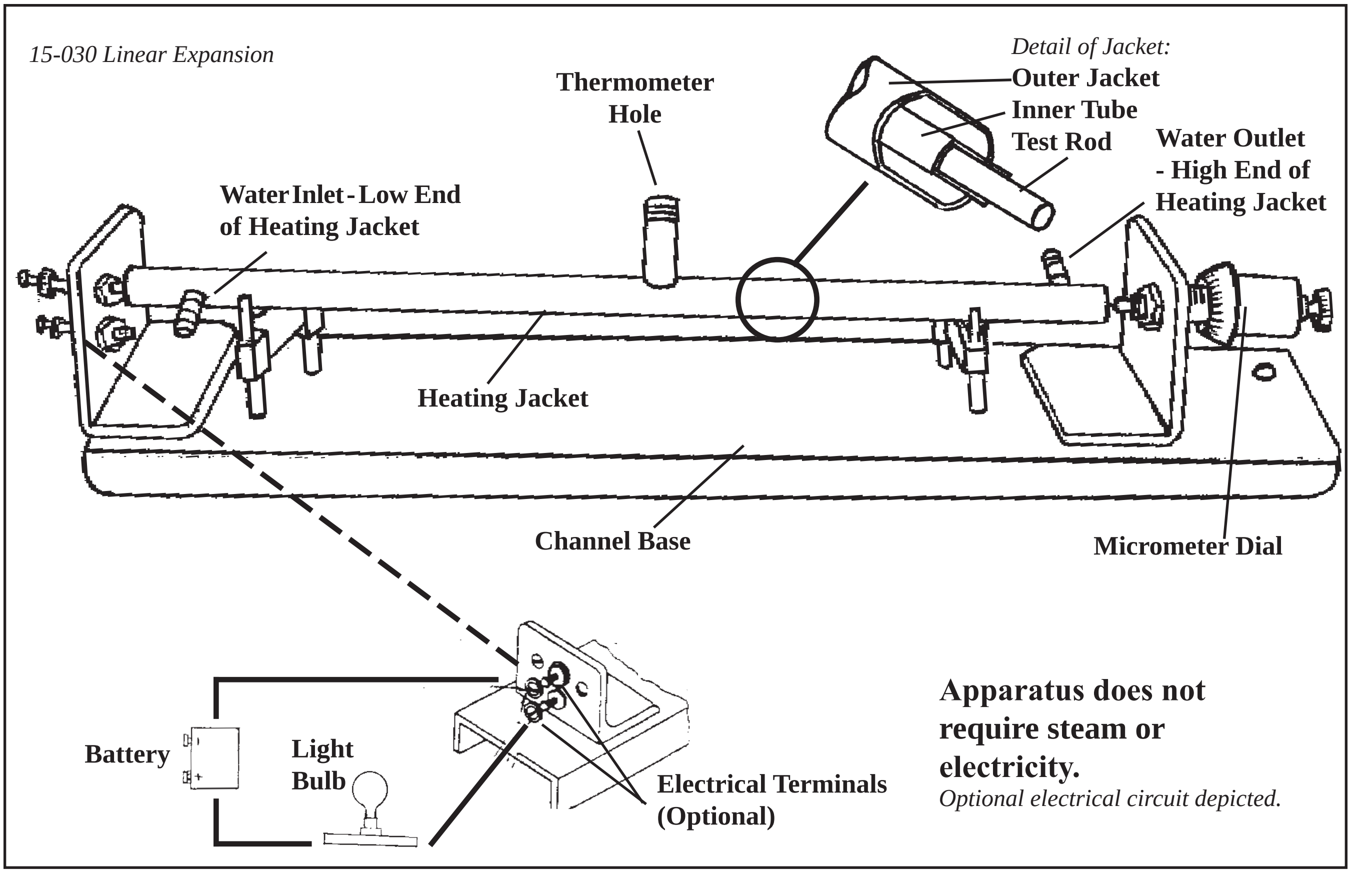
May be ordered from your distributor or from manufacturer **Science First.**

15-040 Aluminum Rod
15-041 Brass Rod
15-042 Copper Rod
15-044 Iron Rod

All rods 60 cm long, 6.3 mm diameter

29-3300 Dial Indicator

Calculation Area



Apparatus does not require steam or electricity.
Optional electrical circuit depicted.

Calculation Area

Sample Problems

Problem 1

Objective: find the Coefficient of Linear Expansion for a brass rod and use the result to estimate the expansion of a rod which is twice as long and has been heated to the same temperature.

Procedure: Measure length of brass rod to nearest inch. Place rod into heating jacket. Make sure micrometer screw is not touching rod.

Fill jacket with water approximately room temperature.

Wait 60 seconds. Take temperature reading and turn micrometer dial until it touches the rod.

Record $\mathbf{t_1}$ and $\mathbf{L_o}$

***Note: If initial temperature of rod is know, the preceding steps can be eliminated. In this case** L_o = 60 cm and **t_1** = initial temperature.*

Drain water and turn micrometer dial until there is a small gap between rod and screw.

Fill jacket with warm to hot water. Wait 60 seconds.

Turn dial until contact is made.

Record $\mathbf{L_H}$ and $\mathbf{t_2}$.

Calculations

For calculation purposes, let:

t_1 = 19° C
t_2 = 29° C
L_0 = 60 cm
L_H = .0258
L_L = .0150
$\triangle L$ = $L_H - L_0$ (expansion)
= .0258 - .0150
= .0108 cm
$\triangle t$ = $t_2 - t_1$ (temperature change)
= 29° C - 19° C
= 10° C

$$\alpha = \frac{\triangle L}{L_0 \times \triangle t} = \frac{.0108 \text{ cm}}{(60\text{cm}) \times 10}$$
= .000018

Results: α = .00018

Since the coefficient remains the same for any brass rod, all that changes in the above calculations for a rod 120 cm long is L_0.

Solving for L_H:

$L_H = a (L_0 \times \Delta t) + L_0$

$L_H = (.000018)(120\text{ cm} \times 10^0) + 120\text{ cm}$

$L_H = 120.0216\text{ cm}$

$L = L_H - L_0 = .0216$

The new rod should expand by 0.0216cm.

Problem 2:

Objective: determine the solid from the following experiment.

Procedure:

Given: a rod 60 cm in length. Its initial temperature is 18° C.

Place the rod in the heating jacket and fill jacket with water 30° C. Allow approximately 60 seconds for the rod to expand.

Record L_H.

Calculate α.

Review the table on Page 1 to see which solid has an expansion coefficient similar to the one you have obtained.

Calculations:

For demonstration purposes, assume $L_H = 0.0355$ and $L_L = .0235$

$\Delta t = 30 - 18 = 12°\text{ C}$

$\Delta L = .0355 - .0235 = .0120\text{ cm}$

$\alpha = \dfrac{\Delta L}{L_0 \times \Delta t} = \dfrac{.0120\text{ cm}}{(60\text{ cm}) \times 12} = .0000166$

Results:

Since you know from the Table on Page 1 that **copper** has an expansion coefficient of .000017, you can conclude that this rod is probably made of copper.

Problem 3:

Objective: To estimate expansion of an aluminum rod and compare results with actual expansion calculated experimentally.

Procedure: You must first calculate the expected expansion. Since the rod is aluminum, from the Table you see that a = .000022.

You are given a rod length of 60 cm at an initial temperature 20° C.

Calculate ΔL if you heat the rod to 35°. Record L_L.

Insert the rod into the heating jacket and fill jacket with 35° C water. Wait 60 seconds.

Turn micrometer dial until contact is made and record L_H.

Calculations:

In the experiment $\Delta L = .0210$

Expected $(\Delta L) = \alpha \times L_0 \times t$

$= .000022 \times 60\text{ cm} \times (35-20)$

$= .0198\text{ cm}$

Actual $(\Delta L) = L_H - L_L$

$= .0305 - .0115$

$= .0210\text{ cm}$

Results:

Experimental $(\Delta L) = .0198\text{ cm}$

Actual $(\Delta L) = .0210$

Possible reasons for error:

(1) You did not heat rod long enough and 35° was never reached

(2) The dial was still turned after contact was met.

Corresponding ideas:

- What would happen if the rod is not made of a **pure** metal?
- **Why** is it necessary to know the coefficient of expansion? When would it be desirable to have a solid expand? When would it be a disadvantage?
- What are everyday examples of solids expanding or contracting due to temperature change?

Related Products:

The following products may be ordered from your distributor. For more information, contact us at 1-800-875-3214.

612-1300 Steam Generator - Safe, economical source of steam. Won't collapse even if boiled dry. With tripod, 2 stoppers, cup. *May be used with 15-030 and 15-035 Linear Expansion Apparatus.*

612-1050 Conductometer - Investigate how different metals conduct heat. 5 spokes, wax, instructions, wood handle.

612-1330 Aneroid Calorimeter - No water needed, 5 times more sensitive than traditional versions. Instructions with graphical workup.

612-1331 Resistor - For 15-120 Calorimeter. Perform electrical equivalent of heat experiment.

612-0025 Thermostat Model - Study the action of a switch. With bimetal strip, base, hardware, instructions.

15-075

15-095

Download these and other instructions from our website at [www.sciencefirst.com.](http://www.sciencefirst.com)

(Instructions to be used in conjunction with **Science First.** *products only.)*

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