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VERSION	EFFECTIVE DATE	DESCRIPTION OF REVISION(S)
001	2013 12	Module creation and release.
002	2016.11	Format update and appearance update.
003	2018.07	Refined content sequencing to Appendix 1.
003.1	2020.05	Clarified formulas for Buoyant Force (Submodule 2).
003.2	2021.05	Corrected formulas for Pendular Movement and Vibration (Submodule 2).
003.3	2022.06	Clarified number of electrons in orbital shells (Submodule 1).
003.4	2023.04	Minor appearance and format updates.
004	2024.05	Regulatory update for EASA 2023-989 compliance.
004.1	2024.08	Thermal Expansion/Contraction renamed to Volumetric Expansion and moved to 2.3 Section B.

Module was reorganized based upon the EASA 2023-989 subject criteria.
Submodule *2.1* - enhanced to Level 2
Submodule *2.2.1* - Added Nature and properties of Solids, Fluids, and Gas Matter.
Other minor adjustments and figure enhancements throughout.

RADIATION

Conduction and convection cannot wholly account for some of the phenomena associated with heat transfer.

For example, the heat one feels when sitting in front of an open fire cannot be transferred by convection because the air currents are moving toward the fire. It cannot be transferred through conduction because the conductivity of the air is very small, and the cooler currents of air moving toward the fire would more than overcome the transfer of heat outward. Therefore, there must be some way for heat to travel across space other than by conduction and convection.

The existence of another process of heat transfer is still more evident when the heat from the sun is considered. Since conduction and convection take place only through some medium, such as a gas or a liquid, heat from the sun must reach the earth by another method, since space is an almost perfect vacuum. Radiation is the name given to this third method of heat transfer.

The term "radiation" refers to the continual emission of energy from the surface of all bodies. This energy is known as radiant energy. It is in the form of electromagnetic waves, radio waves, or x-rays, which are all alike except for a difference in wave length. These waves travel at the velocity of light and are transmitted through a vacuum more easily than through air because air absorbs some of them. Most forms of energy can be traced back to the energy of sunlight. Sunlight is a form of radiant heat energy that travels through space to reach the earth. These electromagnetic heat waves are absorbed when they come in contact with nontransparent bodies. The result is that the motion of the molecules in the body is increased as indicated by an increase in the temperature of the body.

The differences between conduction, convection, and radiation may now be considered. First, although conduction and convection are extremely slow, radiation takes place at the speed of light. This fact is evident at the time of an eclipse of the sun when the shutting off of the heat from the sun takes place at the same time as the shutting off of the light. Second, radiant heat may pass through a medium without heating it. For example, the glass through which the sun's rays pass. Third, although heat transfer by conduction or convection may travel in roundabout routes, radiant heat always travels in a straight line. For example, radiation can be cut off with a screen placed between the source of heat and the body to be protected.

VOLUMETRIC EXPANSION

Thermal expansion takes place in solids, liquids, and gases when they are heated. With few exceptions, solids will expand when heated and contract when cooled. Because the molecules of solids are much closer together and are more strongly attracted to each other, the expansion of solids when heated is very slight in comparison to the expansion in liquids and gases. The expansion of fluids is discussed in the study of Boyle's law. Thermal expansion in solids must be explained in some detail because of its close relationship to aircraft metals and materials.

Because some substances expand more than others, it is necessary to measure experimentally the exact rate of expansion of each one. The amount that a unit length of any substance expands for a one degree rise in temperature is known as the coefficient of linear expansion for that substance. The coefficient of linear expansion for various materials is shown in **Figure 3-14**.

To estimate the expansion of any object, such as a steel rail, it is necessary to know three things about it: its length, the rise in temperature to which it is subjected, and its coefficient of expansion. This relationship is expressed by the equation:

$$\text{Expansion} = (\text{coefficient}) \times (\text{length}) \times (\text{rise in temp.})$$

If a steel rod measures exactly 9 ft at 21°C, what is its length at 55°C? The coefficient of expansion for steel is 11×10^{-6}.

$$\text{Expansion} = (11 \times 10^{-6}) \times (9 \text{ feet}) \times 34°$$
$$\text{Expansion} = 0.003\ 366 \text{ feet}$$

This amount, when added to the original length of the rod, makes the rod 9.003 366 ft long. Its length has only increased by $\frac{3}{1000}$ of an inch.

The increase in the length of the rod is relatively small, but if the rod were placed where it could not expand freely, there would be a tremendous force exerted due to thermal expansion. Thus, thermal expansion must be taken into consideration when designing airframes, powerplants, or related equipment.

THERMODYNAMIC LAWS

The principle of conservation of energy can be stated as: energy can be neither created or destroyed. Alternately, this can be thought of as: the total energy in an isolated system remains constant. The first law of thermodynamics is an application of the fact that energy cannot be created or destroyed. It states that the change in internal energy of a system is equal to the heat added to the system minus the work done. In other words, there is a finite amount of heat (energy) in any closed system. If it increases, it is because it was added from outside the system. If it appears to decrease such as when the temperature decreases, that energy is accounted for by the work that is done by the system.

Substance	Coefficient of Expansion Per Degree Celsius
Aluminum	25×10^{-6}
Brass or Bronze	19×10^{-6}
Brick	9×10^{-6}
Copper	17×10^{-6}
Glass (Plate)	9×10^{-6}
Glass (Pyrex)	3×10^{-6}
Ice	51×10^{-6}
Iron or Steel	11×10^{-6}
Lead	29×10^{-6}
Quartz	0.4×10^{-6}
Silver	19×10^{-6}

Figure 3-14. Coefficient of expansion for various materials.