Physics 06-01 Temperature and Thermal Expansion *Name:* _____

Common temp scales

- Celsius (centigrade)
  - Water freezes at _____°C, Water boils at _____°C
- Fahrenheit
  - Water freezes at _____°F, Water boils at _____°F

$$T_C = \frac{5}{9}(T_F - 32)$$

- Kelvin (K)
  - 0 K = _____ zero
  - _____ K = 0°C (water freezing), _____ K = 100°C (water boiling)

$$T_K = T_C + 273.15$$

Convert 30°C to °F and K

- Heat always flows from _____ object to _____ object until thermal _____

Zeroth Law of Thermodynamics

If A and B are in _____, and B and C are in _____, then A and C are in _____

Table 13.2 Thermal Expansion Coefficients at 20°C [1]

Material	Coefficient of linear expansion $\alpha(1/°C)$	Coefficient of $\beta(1/°C)$
Solids		
Aluminum	25×10^{-6}	75×10^{-6}
Brass	19×10^{-6}	56×10^{-6}
Copper	17×10^{-6}	51×10^{-6}
Gold	14×10^{-6}	42×10^{-6}
Iron or Steel	12×10^{-6}	35×10^{-6}
Invar (Nickel-iron alloy)	0.9×10^{-6}	2.7×10^{-6}
Lead	29×10^{-6}	87×10^{-6}
Silver	18×10^{-6}	54×10^{-6}
Glass (ordinary)	9×10^{-6}	27×10^{-6}
Glass (Pyrex®)	3×10^{-6}	9×10^{-6}
Quartz	0.4×10^{-6}	1×10^{-6}
Concrete, Brick	$\sim12\times10^{-6}$	$\sim36\times10^{-6}$
Marble (average)	2.5×10^{-6}	7.5×10^{-6}
Liquids		
Ether		1650×10^{-6}
Ethyl alcohol		1100×10^{-6}
Petrol		950×10^{-6}
Glycerin		500×10^{-6}
Mercury		180×10^{-6}
Water		210×10^{-6}
Gases		
Air and most other gases at atmospheric pressure		3400×10^{-6}

Thermal Expansion

- Linear Expansion
  - Expansion in 1-dimension as _____ changes

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

A steel bridge is 2 km long. If the temperature when it was built was 21°C (70°F), what length expansion joints are needed to prevent buckling at 43°C (110°F)?

- Bimetallic Strip
  - Made from _____ strips of _____ that have different _____ of linear expansion
  - One side _____ more than the other causing the strip to _____
  - Used in automatic _____ in appliances and _____
- Area thermal expansion

$$\Delta A = 2\alpha A \Delta T$$

- Volume thermal expansion

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

  - β = coefficient of volume expansion, usually is about _____

Why do fluids in the car usually have a reservoir tank (radiator, brake fluid, power steering fluid, oil)?

Physics 06-01 Temperature and Thermal Expansion *Name: _____*

Water

- Water is _____
- The volume of water _____ from 0°C to 4°C
- Then water _____ from 4°C and up
- Water is the _____ (least expanded) at 4°C
- As the weather gets cold, the lake water cools and sinks because it becomes more dense pushing the warmer water up
- After all the water is _____, the _____ starts to freeze
- Because the 0°C water is _____ dense than the 4°C water, it _____
- The ice _____ and provides insulation for the _____ water underneath so it does not freeze

Homework

1. The first international standard of length was a metal bar kept at the International Bureau of Weights and Measures. One meter of length was defined to be the distance between two fine lines engraved near the ends of the bar. Why was it important that the bar be kept at a constant temperature?
2. For added strength, many highways and buildings are constructed with reinforced concrete (concrete that is reinforced with embedded steel rods). The coefficient of linear expansion for concrete is the same as that for steel. Why is this important that these two coefficients be the same?
3. When a cold alcohol thermometer is placed in a hot liquid, the column of alcohol goes down slightly before going up. Explain why.
4. Water expands significantly when it freezes: a volume increase of about 9% occurs. As a result of this expansion and because of the formation and growth of crystals as water freezes, anywhere from 10% to 30% of biological cells are burst when animal or plant material is frozen. Discuss the implications of this cell damage for the prospect of preserving human bodies by freezing so that they can be thawed at some future date when it is hoped that all diseases are curable.
5. One method of getting a tight fit, say of a metal peg in a hole in a metal block, is to manufacture the peg slightly larger than the hole. The peg is then inserted when at a different temperature than the block. Should the block be hotter or colder than the peg during insertion? Explain your answer.
6. Does it really help to run hot water over a tight metal lid on a glass jar before trying to open it? Explain your answer.
7. What is the Celsius temperature of a person with a 98.6 °F body temperature? (RW) **37.0 °C**
8. Frost damage to most plants occurs at temperatures of 28.0°F or lower. What is this temperature on the Kelvin scale? (OpenStax 13.2) **271.0 K**
9. A tungsten light bulb filament may operate at 2900 K. What is its Fahrenheit temperature? What is this on the Celsius scale? (OpenStax 13.4) **2600 °C, 4800 °F**
10. The surface temperature of the Sun is about 5750 K. What is this temperature on the Fahrenheit scale? (OpenStax 13.5) **9890 °F**
11. The height of the Washington Monument is measured to be 170 m on a day when the temperature is 35.0°C. What will its height be on a day when the temperature falls to –10.0°C? Although the monument is made of limestone, assume that its thermal coefficient of expansion is the same as marble's ($\alpha = 2.5 \times 10^{-6}$). (OpenStax 13.9) **169.98 m**
12. How much taller does the Eiffel Tower become at the end of a day when the temperature has increased by 15°C? Its original height is 321 m and you can assume it is made of steel ($\alpha = 12 \times 10^{-6}$). (OpenStax 13.10) **0.058 m**
13. How large an expansion gap should be left between steel railroad rails if they may reach a maximum temperature 35.0°C greater than when they were laid? Their original length is 10.0 m. ($\alpha = 12 \times 10^{-6}$) (OpenStax 13.12) **0.0042 m**
14. Most automobiles have a coolant reservoir to catch radiator fluid that may overflow when the engine is hot. A radiator is made of copper ($\beta = 51 \times 10^{-6}$) and is filled to its 16.0-L capacity when at 10.0°C. What volume of radiator fluid will overflow when the radiator and fluid reach their 95.0°C operating temperature, given that the fluid's volume coefficient of expansion is $\beta = 400 \times 10^{-6}$ / °C ? Note that this coefficient is approximate, because most car radiators have operating temperatures of greater than 95.0°C. (OpenStax 13.18) **0.475 L**
15. A commonly used method of fastening one part to another part is called "shrink fitting." A steel rod ($\alpha = 12 \times 10^{-6}, \beta = 35 \times 10^{-6}$) has a diameter of 2.0026 cm, and a flat plate contains a hole whose diameter is 2.0000 cm. The rod is cooled so that if just fits into the hole. When the rod warms up, the enormous thermal stress exerted by the plate hold the rod securely to the plate. By how many Celsius degrees should the rod be cooled? (Cutnell 12.13) **110 °C**