Measurements and Instrumentation [SBE206A] (Fall 2018)
Tutorial 1

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Cheat Sheet

Length

$1\mathrm{m} = 3.2808\mathrm{ft}$
$1\mathrm{km} = 0.621\mathrm{mi}$

Volume

$1\mathrm{L} = 0.001\mathrm{m}^3$
$1\mathrm{L} = 61.02\mathrm{in.}^3$

Mass

$1\mathrm{kg} = 2.2046\mathrm{lbm}$
$1\mathrm{kg} = 0.068522\mathrm{slug}$

Force

$1\mathrm{N} = 0.2248\mathrm{lbf}$

Work/Energy

$1\mathrm{kJ} = 737.562\mathrm{ft} \cdot \mathrm{lbf}$
$1\mathrm{kJ} = 0.947817\mathrm{Btu}$

Pressure/Stress

$1\mathrm{atm} = 14.696\mathrm{psi}$
$1\mathrm{atm} = 101325\mathrm{Pa}$
$1\mathrm{atm} = 407.189\mathrm{in.H_2O}$
$1\mathrm{atm} = 760.00\mathrm{mmHg}$
$1\mathrm{atm} = 1\mathrm{bar}$

Density

$1\mathrm{slug/ft}^3 = 512.38\mathrm{kg/m}^3$

Temperature

$\mathrm{K} = \mathrm{C} + 273.15$
$\mathrm{K} = (5/9)\mathrm{F} + 255.38$
$\mathrm{K} = (5/9)\mathrm{R}$
$\mathrm{F} = (9/5)\mathrm{C} + 32.0$
$\mathrm{F} = \mathrm{R} - 459.69$

Scales

$\mathrm{yotta(Y)} = 10^{24}$
$\mathrm{zeta(Z)} = 10^{21}$
$\mathrm{exa(E)} = 10^{18}$
$\mathrm{peta(P)} = 10^{15}$
$\mathrm{tera(T)} = 10^{12}$
$\mathrm{giga(G)} = 10^{9}$
$\mathrm{mega(M)} = 10^{6}$
$\mathrm{kilo(k)} = 10^{3}$
$\mathrm{hecto(h)} = 10^{2}$
$\mathrm{deka(da)} = 10^{1}$
$\mathrm{deci(d)} = 10^{-1}$
$\mathrm{centi(c)} = 10^{-2}$
$\mathrm{milli(m)} = 10^{-3}$
$\mathrm{micro}(\mu) = 10^{-6}$
$\mathrm{nano(n)} = 10^{-9}$
$\mathrm{pico(p)} = 10^{-12}$
$\mathrm{femto(f)} = 10^{-15}$
$\mathrm{atto(a)} = 10^{-18}$
$\mathrm{zepto(z)} = 10^{-21}$
$\mathrm{yocto(y)} = 10^{-24}$

Physical Units

Patrick F. Dunn Sol. 2.4 **1. Exercise**

Which of the following is not equivalent to the SI unit of energy?

1. $\mathrm{kg \cdot m^2/s^2}$
2. $\mathrm{Pa \cdot m^2}$
3. $\mathrm{N \cdot m}$
4. $\mathrm{W \cdot s}$

1. Solution

$\mathrm{Pa \cdot m^2}$
$\mathrm{Pa = N/m^2}$, which implies that $\mathrm{Pa \cdot m^2 = N}$. A newton is a unit of force, not of energy.

Patrick F. Dunn Sol. 2.7 **2. Exercise**

An astronaut weighs 164 pounds on Earth (assume that Technical English is spoken). What is the astronauts weight (in the appropriate SI unit and with the correct number of significant figures) on the surface of Mars where the gravitational acceleration is 12.2 feet per second squared?

2. Solution

276 N
If weight is known in one gravitational field, then the weight of the same mass in another gravitational field can be determined simply by multiplying by the ratio of gravitational accelerations. So, multiply the weight by 12.2/32.174 to the weight on Mars. Then multiply by 4.448 N/lbf.

Patrick F. Dunn Sol. 2.8

3. Exercise

An astronaut weighs 162 pounds on Earth (assume that Technical En- glish is spoken). What is the astronauts mass (expressed in the appropriate SI unit and with the correct number of significant figures) on the surface of Mars, where the gravitational acceleration is 12.2 feet per second squared?

3. Solution

73.5 kg
There are three significant figures. To determine the mass, first convert the weight to mass by dividing by 32.174 to get slugs. Then use the conversion 14.594 kg = 1 slug.

Patrick F. Dunn Sol. 2.10

4. Exercise

A robotic manipulator weighs 393 lbf (Technical English) on Earth. What is the weight of the probe on the moons surface in newtons (to the nearest tenth of a newton) if the lunar gravitational acceleration is 1/6 of that on Earth?

4. Solution

291 N
To arrive at the probe weight on the moon, multiply the weight on earth by 1/6. Convert to newtons by multiplying by 4.448 N/lbf.

Patrick F. Dunn Sol. 2.11

5. Exercise

How much work is required to raise a 50 g ball 23 in. vertically upward? Express your answer in units of ft-lbf to the nearest one-thousandth of a ft-lbf.

5. Solution

0.211 ft-lbf
Work is force times distance. Mass and distance are given. Force is mass times acceleration. So, the answer is
$\mathrm{mass(g)} \times \frac{1\mathrm{kg}}{1000\mathrm{g}} \times 9.806650\mathrm{m/s^2} \times \mathrm{distance(in.)} \times \frac{1\mathrm{ft}}{12\mathrm{in.}} \times \frac{1\mathrm{m}}{3.2808\mathrm{ft}} \times \frac{0.737562\mathrm{ft-lbf}}{\mathrm{N{\cdot}m}}$

Significant Figures

Rationale

- The number of significant figures *is the number of digits between and including the least and* the most significant digits.
- The leftmost nonzero digit is called *the most significant digit*; the rightmost nonzero digit, *the least significant digit*.
- If there is a decimal point in the number, then the rightmost digit is *the least significant digit* even if it is a zero.
- These rules imply that the following numbers have five significant figures:
  - 1.0000
  - 2734.2
  - 53 267.
  - 428 970
  - 10 101
  - 0.008 976 0

Round-off

1. To round off a number, the number first is truncated to its desired length. Then the excess digits are expressed as a decimal fraction.
2. If it is greater than $1/2$, we round up the least significant digit by one; if it is less than $1/2$, it is left alone. If the fraction equals $1/2$, the least significant digit is rounded up by one only if that digit is odd (Patrick F. Dunn).
3. Do not round-off intermediate results. Only the final results to be rounded-off.
4. The number of significant figures in a computed result equals the minimum number of significant figures in any number used in the computation.

Scientific Notation

- What happens when no decimal point is present, a zero is the rightmost digit and it is significant? This situation is ambiguous and can be avoided by expressing the number in scientific notation, where 428970 becomes 4.28970×10^5 .
- All of the digits present in scientific notation are significant.

6. Exercise

Round off the following numbers to three significant figures: 23421, 16.024, 273.61, 5.6850×10^3 , and 5.6750×10^3 .

6. Solution

The answers are 23400, 16.0, 274, 5.68×10^3 , and 5.68×10^3 . Note that 16.024 when rounded off to three significant figures is 16.0, where the 0 is significant because it is to the right of the decimal point. Also note that the last two numbers when rounded off to three significant figures become the same. This is because of our rule for round-off when the truncated fraction equals $1/2$.

7. Exercise

How many significant figures does the number 001 001.0110 have?

7. Solution

8. The left-most 2 zeros are not significant. However, the right-most zero is significant because of the presence of a decimal point.

8. Exercise

Determine in the appropriate SI units the value with the correct number of significant figures of the work done by a 1.460×10^6 lbf force over a 2.3476 m

8. Solution

There are four significant figures for the force and five for the distance. Because work is the product of force and distance (assuming that the force is applied along the direction of motion), work will have four significant figures. The SI unit of work is the joule, where $J = N \cdot m$. Now 1.460×10^6 lbf equals $6.495 \times 10^6 N$. So, the work is $1.525 \times 10^6 J$ or $1.525 MJ$.

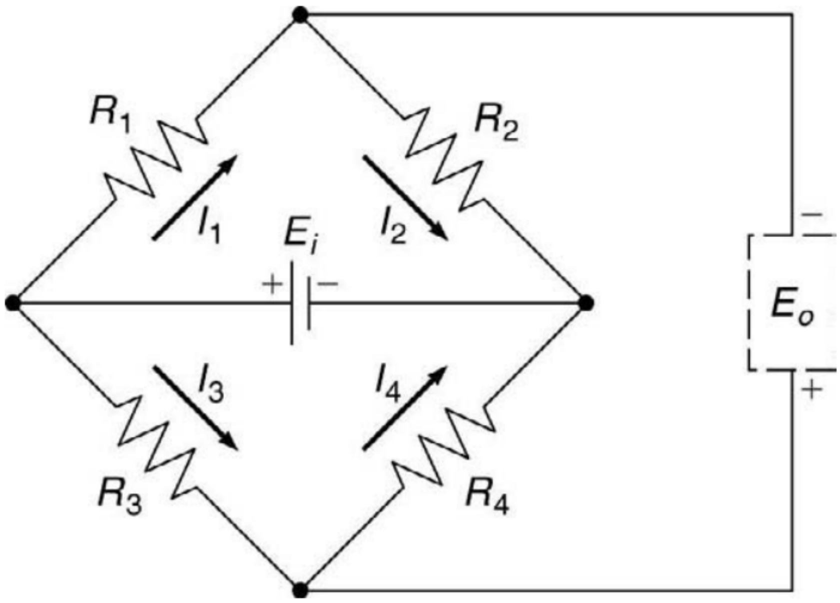

Figure 1: A wheatstone bridge.

Warming-up Circuits

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9. Exercise

Referring to Figure 1, prove the following equation

$$\mathrm{E_0 = E_i \left[\frac{R_1}{R_1 + R_2} - \frac{R_3}{R_3 + R_4}\right]} \tag{1}$$

Also, derive the balanced equation

$$\mathrm{\frac{R_1}{R_2} = \frac{R_3}{R_4}} \tag{2}$$

9. Solution

10. Exercise

Referring to Figure 1, if $\mathrm{R}_1 = 1\Omega$, $\mathrm{R}_2 = 3\Omega$, and $\mathrm{R}_3 = 2\Omega$, determine (a) the value of R_4 such that the Wheatstone bridge is balanced, and (b) the bridges output voltage under this condition.

10. Solution

Equation 2 specifies the relationship between resistances when the bridge is balanced. Thus, $R_4 = \frac{R_2 R_3}{R_1} = 3 \times 2/1 = 6\Omega$. Because the bridge is balanced, its output voltage is zero. This can be verified by substituting the four resistance values into Equation 1.