Lab-Volt®

Solar/Wind Energy Training System

Energy Fundamentals

Job Sheets - Student

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Solar/Wind Energy Training System

Energy Fundamentals

Job Sheets—Student

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86514-20

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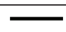
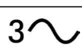
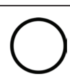
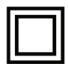
Safety Symbols

The following safety symbols may be used in this manual and on the Lab-Volt equipment:

Symbol	Description
DANGER	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
WARNING	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
CAUTION	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger sign*, indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger
	Caution, lifting hazard
	Caution, hand entanglement hazard
	Direct current
	Alternating current
	Both direct and alternating current
	Three-phase alternating current
	Earth (ground) terminal
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)

Symbol	Description
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

Foreword

The Lab-Volt Solar/Wind Energy Training System, Model 46120, is a modular program that covers the history, fundamentals, installation, operation, maintenance, and servicing of alternative energy systems.

The curriculum is divided into the following topics:

- Energy Fundamentals
- Trainer Familiarization and Safety
- Solar Module
- Wind Turbine
- Solar/Wind Systems
- Going Green

Table of Contents

Introduction

The topics covered in this manual are presented in the form of Job Sheets. The Job Sheets include a description of the objectives, a list of equipment required, a list of safety procedures, and a list of steps required to attain the objectives.

The topics are introduced in an Information Job Sheet. However, to obtain detailed information about the covered topic, you should refer to your textbook or ask your instructor to guide your learning process.

Safety Considerations

Make sure you are wearing appropriate protective equipment when performing the jobs.
You should never perform a job if you have any reason to think that a manipulation could be dangerous for you or your teammates.

Reference Textbooks

Refer to the textbooks titled *Photovoltaic Systems* written by Jim Dunlop and *Wind Power* written by Paul Gipe.

System of Units

Most of the components in the Solar/Wind Energy Training System use the Imperial system of units. For this reason the Imperial system of units was preferred in the manual.

Some formulas and calculations are also presented using SI units.

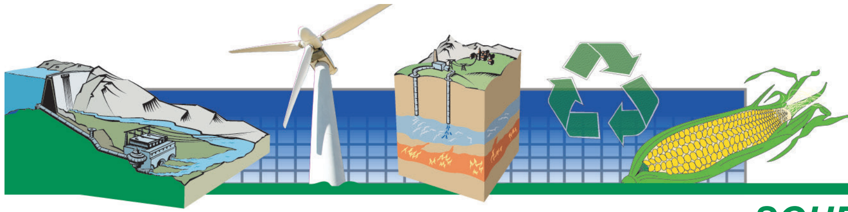
Refer to the *Unit Conversion Table* in Appendix B if necessary.

Appendices

The appendices included in the manual are:

Appendix A: *Equipment Utilization Chart*, shows in which Job Sheet(s) the equipment is used.

Appendix B: *Unit Conversion Table*, shows the conversion factors to apply to convert Imperial units to SI units and vice versa.



SOURCES OF ENERGY

Energy is defined simply as the ability to do work. There are six basic forms of energy: chemical, electrical, mechanical, nuclear, radiant, and thermal. Electrical energy is *conducted* electromagnetic energy such as electricity, and radiant energy is *radiated* electromagnetic energy such as radio waves, light, and gamma rays.

Energy Forms

Chemical—energy stored in the bonds of atoms and molecules.

Electrical—energy of moving electrons or ions.

Mechanical—energy stored in objects and the movement of objects.

Nuclear—energy stored in the nucleus of an atom.

Radiant—energy that moves in waves, or as particles (photons).

Thermal—energy of moving molecules within a substance (heat).

Each of these energy forms can be classified into one of two types: potential or kinetic.

Energy Types

Kinetic energy is defined as the energy of motion. **Potential** energy is frequently described as stored energy. Potential energy is passively stored and ready to be released, such as in a loaded crossbow or spear gun (Figure 1-1). Kinetic energy is actively moving, such as in an arrow during flight or a spear traveling under water.

Figure 1-1. Compound Crossbow and Bolt.

SOURCES OF ENERGY

Energy Sources

There are at least eleven common sources of energy that we use to provide electrical power to appliances, households, local communities, towns, cities, states, and even entire countries.

Renewable energy sources are continually replenished by the sun's radiant energy and are an important resource for clean (non-polluting) energy conservation. These energy sources, such as solar and wind, are also known as **sustainable** energy sources, which do not cause long-term damage to our environment.

Non-renewable energy sources cannot be naturally replenished over a person's lifetime. These energy sources, such as fossil fuels, are also known as **non-sustainable** energy sources. They also produce many pollutants.

Common Energy Sources

- Bioenergy
- Coal
- Fuel cells (part of bioenergy)
- Geothermal
- Hydropower
- Natural gas
- Nuclear
- Ocean (part of hydropower)
- Oil
- Solar
- Wind

Figure 1-2. Sunlight.

Either directly or indirectly, all of these energy sources receive their energy from the Earth's sun. For example, wind is created by uneven heating of the planet. As warm air rises, nearby cooler air moves in, beneath the warmer air.

Most energy sources begin as potential energy. Hydropower, solar energy, and wind energy sources begin as kinetic energy. Some sources of energy may begin as one or the other, depending upon the form of fuel used. For example, geothermal energy may use the heat stored within the earth – this is potential energy. However, geothermal energy may use underground steam – this is kinetic energy.

Energy Conversion

Various forms of energy can be converted to other forms of energy. The following is a summary of some of those processes.

The following energy sources begin in chemical form:

Bioenergy	
Conversion Process	Biogas is burned to heat, power engines, and generate electricity (by steam turbine), and chemical reactions of biomass can create electricity (similar to a battery)
Fuel Examples	Biomass and biogas fuels: ethanol (from plants such as corn) and methane (from animal waste) gases
Byproducts	None normally; but in some cases, can produce carbon dioxide
Coal	
Conversion Process	Burned to heat and generate electricity (by steam turbine)
Fuel Examples	Fossil fuels: anthracite, bituminous, and lignite coals
Byproducts	Carbon dioxide, sulfur dioxide, and nitrogen oxides
Fuel Cells (part of bioenergy)	
Conversion Process	A thin membrane separates the hydrogen molecules' electrons from protons to create electricity during electrolysis
Fuel Examples	Biomass fuel creates hydrogen gas (by electrolysis of organic compounds and water, which requires a primary energy source) and oxygen is used from surrounding air
Byproducts	Water and heat - no harmful byproducts
Natural Gas	
Conversion Process	Burned to heat, cook, and generate electricity (by steam turbine)
Fuel Examples	Fossil fuels: methane, propane, and butane gases
Byproducts	Carbon dioxide
Oil	
Conversion Process	Burned to heat, power engines, and generate electricity (by steam turbine)
Fuel Examples	Fossil fuel: crude oil is refined into gasoline, heating oil, diesel oil, jet fuel, asphalt, and petrochemicals that are used to produce plastics, fertilizers, and paints
Byproducts	Hydrocarbons

Table 1-1. Energy Sources in Chemical Form.

SOURCES OF ENERGY

The following energy sources begin in mechanical form:

Hydropower	
Conversion Process	Drives a turbine generator to produce electricity
Fuel Examples	Moving water (traditionally from dammed rivers)
Byproducts	None
Wind	
Conversion Process	Drives a turbine generator to produce electricity
Fuel Examples	Moving air
Byproducts	None

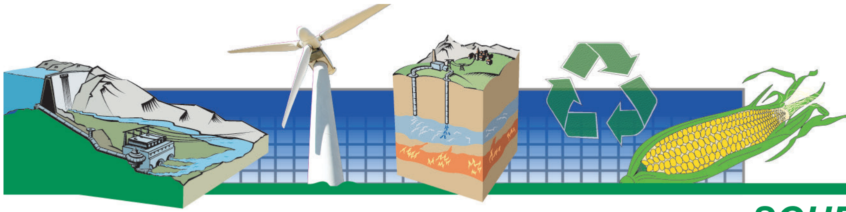
Table 1-2. Energy Sources in Mechanical Form.

The following energy sources may begin in several forms:

Geothermal	
Energy Form	Thermal or mechanical
Conversion Process	Drives a turbine generator to produce electricity
Fuel Examples	Earth-heated underground water and steam
Byproducts	Small amounts of harmful substances may be released into the atmosphere
Nuclear	
Energy Form	Nuclear (thermal and radiant)
Conversion Process	Neutron friction produces heat that is controlled in a nuclear reactor to generate electricity (by steam turbine)
Fuel Examples	Nuclear fission (atom splitting) of uranium, plutonium, or thorium
Byproducts	Radioactive waste
Ocean (part of hydropower)	
Energy Form	Mechanical and thermal
Conversion Process	Energy from water movement is converted to electricity by special generators; deep/shallow temperature differences drive a heat engine to generate electricity (by steam turbine)
Fuel Examples	Tidal, wave, and ocean current energy; also, ocean thermal energy conversion (OTEC)
Byproducts	No harmful byproducts; but OTEC can produce fresh water, and provide cool air

Solar	
Energy Form	Radiant and thermal
Conversion Process	PV solar cells create electricity, and solar collectors heat air and water
Fuel Examples	Abundant full-spectrum light from the sun
Byproducts	None

Table 1-3. Energy Sources in Several Forms.



SOURCES OF ENERGY

OBJECTIVES

In this job, you will become familiar with some common energy sources that we use to electrically power areas of our planet. You will identify several energy sources that we use for daily work, and determine which examples of energy are renewable and which examples are non-renewable. You will also identify the form and type of each energy source.

PROCEDURE

☐ 1. Complete the following table:

Energy Source	Renewable or Non-renewable	Potential or Kinetic	Initial Form(s) Before Conversion
Bioenergy			
Coal			
Geothermal			
Hydropower			
Natural Gas			
Nuclear			
Oil			
Solar			
Wind			

☐ 2. What is the predominant source of energy in your community?

____

____

☐ 3. Why is this the predominant energy source?

____

____

☐ 4. What would be the best choice of alternative or renewable energy for your community?

____

____

☐ 5. Why do you believe this is the best choice?

____

____

Name: ______________________________________ Date: ________________

Instructor approval: ____

While **energy** is defined simply as the ability to do work, **power** is the measured rate for energy to do work. The unit of measure for power is the **watt** (**W**). A common unit for measuring total power used during a period of time is the **watt-hour** (**Wh**), or simply watts (W) times hours (h).

1 Wh = 1 W x 1 h

For large amounts of power, the **kilowatt** (**kW**) and the **kilowatt-hour** (**kWh**) is used.

1 kW = 1,000 W
1 kWh = 1,000 Wh

For example, if a 100-watt light bulb consumes power for 1 month (4 weeks, 28 days, or 672 hours), the total consumed power is 67.2 kWh.

100 W x 672 h = 67,200 Wh / 1,000 = 67.2 kWh

The **joule** (**J**) is the unit of measurement for energy as defined by the International System of Units (SI). Although energy is not directly measurable, energy conversion is measurable, for example the transfer of heat or mass, or the work being done.

kinetic energy (joules) = $0.5 \times m \times V^2$
where:
m = mass (kg) (1 kg = 2.2 pounds)
V = velocity (meters/second) (meter = 3.281 feet = 39.37 inches)

One joule (J) is the amount of work done to produce the power of one watt (W) continuously for one **second** (**s**), and is equal to one **watt-second** (**Ws**).

1 J = 1 Ws = 1W x 1s
1 Wh = 3,600 J

1 kWh = 3,600,000 J

Energy Conversion

The **conservation of energy** law states that the total amount of energy in an isolated system remains constant. In other words, in a closed system, energy cannot be created or destroyed, it can only change form.

Energy gets converted into different forms throughout our everyday lives. While energy passes through a system or object, the energy form at its input can become a different form of energy at its output during the transfer process.

Figure 2-1 shows some typical conversions that take place between various forms of energy. In Figure 2-1, a wind turbine captures some of the kinetic energy from the wind, and the generator shaft rotates. The generator converts this mechanical energy into electrical energy. This is discussed in greater detail later in the course. Finally, an electric lamp emits light as radiant energy.

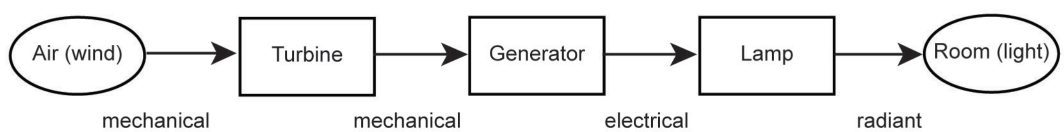


Figure 2-1. Examples of Energy Conversion.

See more examples in Figures 2-2 and 2-3.

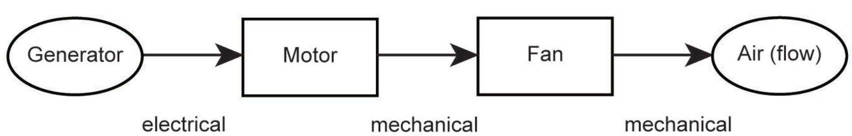


Figure 2-2. Examples of Energy Conversion (Man-made).

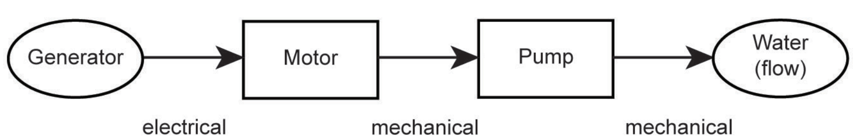


Figure 2-3. Examples of Energy Conversion (Man-made).

Energy conversion occurs naturally, as well. See Figure 2-4 for some examples found in nature. The sun's radiant energy produces thermal energy from the earth's land mass. This thermal energy causes air masses to move, creating wind. The wind's friction on the surface of water can create waves within the body of water.

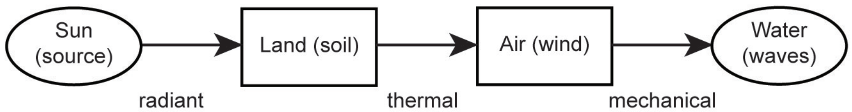


Figure 2-4. Examples of Natural Energy Conversion.

See another example in Figure 2-5.

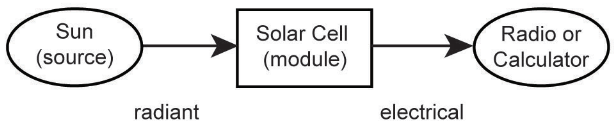
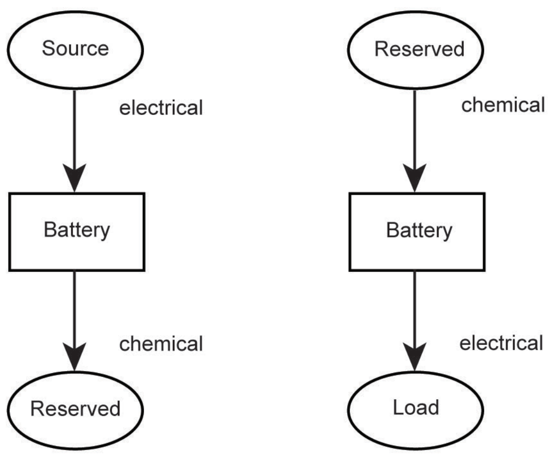


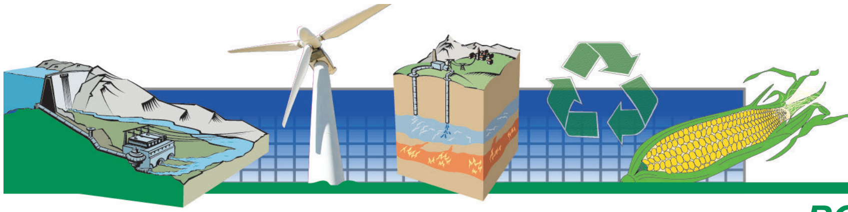
Figure 2-5. Examples of Energy Conversion.

Often, energy can be converted in both directions, as shown in Figures 2-6 and 2-7. A rechargeable battery can store potential energy for later use.



Figures 2-6 and 2-7. Examples of Energy Conversion (Bi-directional).

Solar and wind energy technologies are being used today to produce electric power. Developing a basic understanding of energy conversion is an important fundamental aspect of alternative energy technology.



Job Sheet 2

POWER AND WORK

OBJECTIVES

In this job, you will become familiar with some common energy terms and the conversion process between different energy forms.

PROCEDURE

Complete Table

☐ 1. What are the input and output forms of energy for the examples provided in Table 2-1?

Energy Form Input	System or Object	Energy Form Output
Radiant	**Desert sand**	
	Infrared LED lamp	Radiant
Electrical	**Heating pad**	
	Bicycle generator	Electrical
Electrical	**Clock motor**	
	Photo detector (photodiode or phototransistor)	Electrical
Mechanical	**Automobile brakes**	
	Hydrogen fuel cell	Electrical
Chemical	**Campfire**	
	Plant photosynthesis	Chemical
Electrical	**Power transformer**	
	Garden greenhouse	Thermal
Thermal	**Thermocouple, thermopile (TEM), peltier junction**	

Table 2-1. Energy Conversion Examples.

NOTE: *The answers in black are provided for you. Simply fill in the blanks.*

Calculate Answers

□ 2. If a 75W indoor light bulb is left on continuously for 2 days (48 hours), how much power is consumed in total Wh?

Power consumed (Wh):______

□ 3. For the same situation, how much power is consumed in total kWh?

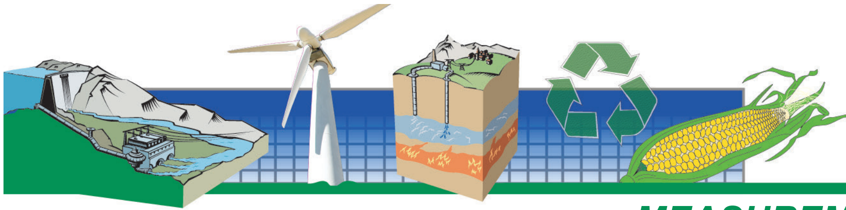
Power consumed (kWh):______

□ 4. If the lamp was a 150W outdoor flood light, left on for 2 days (48 hours), how much power is consumed in total kWh?

Power consumed (kWh):______

Name: ____ Date: _________________

Instructor approval: ____



Electrical **voltage** contains potential energy, just as air and water pressures contain potential energy. Electrical **current** contains kinetic energy, as do air and water currents. Electrons can flow in a wire just as air can flow in a hose or water can flow in a pipe. However, an energy source must be present to provide a voltage and the circuit path must be complete (closed) in order for current to flow. The rate at which current flows is rated in amperes (A) and voltage is rated in volts (V). The opposition to electrical current flow is called **resistance** and it is rated in ohms (Ω). As discussed earlier, **power** is the rate for energy to do work and it is rated in watts (W).

Ohm's Law states the following relationships between **voltage** (**V**), **current** (**A**), **resistance** (**Ω**), and **power** (**W**).

Voltage equals current times resistance:

$V = A \times \Omega$

$A = V / \Omega$

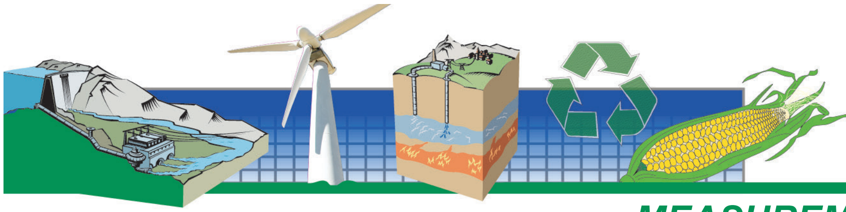
$\Omega = V / A$

Power equals current times voltage:

$W = A \times V$

$A = W / V$

$V = W / A$



OBJECTIVES

In this job, you will become familiar with common electrical measurement units, equations, and calculations. You will calculate answers by using some simple electrical equations.

PROCEDURE

Calculate Answers

☐ 1. If you measured 12Vdc across a 4-ohm resistive load, how much DC current is drawn?

Current drawn:_____

☐ 2. If you measured 5A of current at the output of a 12Vdc generator, how much power is generated?

Power generated:_____

☐ 3. For the same conditions, connected to a single load, how much power is the load dissipating?

Power dissipated:_____

☐ 4. For the same conditions, if the load is resistive (non-inductive), what is the load resistor value?

Load resistor value:_____

☐ 5. If the 5A load was powered for a full day (24 hours), how much power is consumed in total Wh?

Power consumed (Wh):_____

☐ 6. For the same situation, how much power is consumed in total kWh?

Power consumed (kWh):_____

☐ 7. With 120Vac connected to a pump motor, you measure 4A. How much power is consumed?

Power consumed (W):_____

☐ 8. With a 40W light bulb connected to the same electrical branch, how much current do you expect to measure for the lamp?

Current drawn:_____

☐ 9. What is the total power to run the motor and the lamp?

Power consumed:_____

☐ 10. If the two devices are on for a week, how much power is consumed in total kWh? (HINT: 1 week = 7 days = 168 hours)

Power consumed (kWh):_____

Name: ______________________________________ Date: _______________

Instructor approval: ____

Equipment Utilization Chart

COMPONENT NAME	PART NUMBER	JOB SHEET		
		1	2	3
Mobile workstation	46801-J0			
Photovoltaic solar module	66070-10 or 65918 (outdoor)			
Wind turbine generator	66075 or 65938 (outdoor)			
Stop switch	66066			
Solar charge controller	66065			
Diversion load controller	66056			
Dump load	66057			
Digital multimeter	6394			
Power/usage monitor	66063			
Ammeter	66052			
Watt-hour meter	p/o 66059 or 66059-A0 (UL/CSA)			
Battery bank	65917			
Power inverter (with remote)	66064			
Disconnect switch (with key)	66054H and 66054V			
Lockout/tagout module (with hasp)	66061			
AC circuit breaker box	p/o 66059 or 66059-A0 (UL/CSA)			
DC circuit breaker	66058			
AC outlet	66051-10			
DC lamp socket	66067			
AC/DC wall switch	66060			
Light socket adapter	p/o 66154			
Incandescent lamp	p/o 66154			
Fluorescent lamp	p/o 66154			
LED lamp	p/o 66154			
Power bus bar	66062			
DC power distribution panel	66053			

Appendix A

COMPONENT NAME	PART NUMBER	JOB SHEET		
		1	2	3
DC motor & controller (wind simulator)	p/o 66075 or 65909 (motor), 66153 (controller)			
AC flood lamp (sun simulator)	66151			
Battery bank junction box	66050			
Solar array junction box	66150-10			
Accessories package (lamps, fuses, leads, adapters, power strip, and battery charger)	66154			
Connection cables kit (wires)	87339			

Unit Conversion Table

SI UNITS	CONVERSION FACTOR	IMPERIAL UNITS
ACCELERATION		
centimeter per square second, cm/s^2	0.3937	inch per square second, in/s^2
meter per square second, m/s^2	3.2808	foot per square second, ft/s^2
AREA		
square millimeter, mm^2	0.00155	square inch, in^2
square centimeter, cm^2	0.1550	square inch, in^2
square meter, m^2	10.7639	square foot, ft^2
FLOW		
liter per minute, L/min	0.0351	cubic foot per minute, ft^3/min
cubic centimeter per minute, cm^3/min	0.0021	cubic foot per hour, ft^3/h
FORCE		
newton, N	0.2248	pound-force, lbf
LENGTH		
millimeter, mm	0.0394	inch, in.
centimeter, cm	0.3937	inch, in.
meter, m	39.3701	inch, in.
meter, m	3.2808	foot, ft
MASS		
gram, g	0.0353	ounce, oz
kilogram, kg	2.2046	pound, lb
POWER		
watt, W	0.00134	horsepower, hp
PRESSURE		
kilopascal, kPa	0.1450	pound force per square inch, lbf/in^2
TORQUE		
newton meter, N·m	0.7376	pound-force foot, lbf·ft
newton meter, N·m	8.8507	pound-force inch, lbf·in
VELOCITY		
centimeter per second, cm/s	0.0328	foot per second, ft/s
millimeter per second, mm/s	0.0394	inch per second, in/s
VOLUME		
cubic centimeter, cm^3	0.0610	cubic inch, in^3
cubic meter, m^3	35.3147	cubic foot, ft^3

How to use:

Imperial units = SI units × conversion factor
SI units = Imperial units ÷ conversion factor

We Value Your Opinion!

Your comments will allow us to produce better manuals and develop new systems in order to better meet the needs of our users. Please contact us by e-mail at **services@labvolt.com**

For further information, visit our website at **www.labvolt.com**