DC Circuits

Basic Concepts

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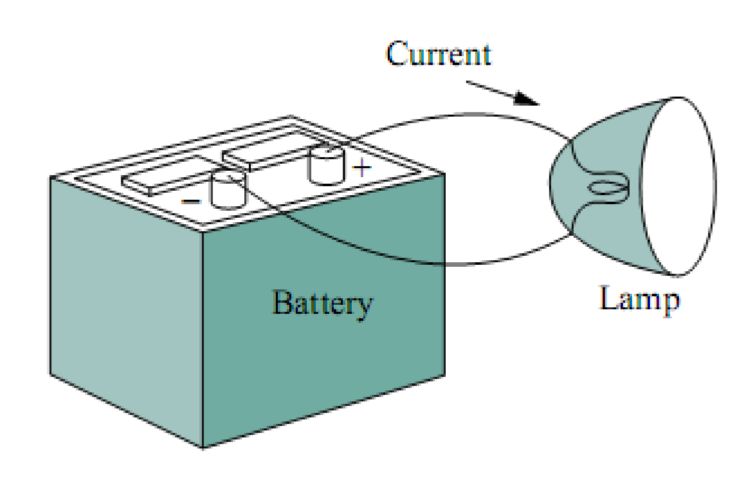
Alessandro Antonio Volta (1745-1827), an Italian physicist, invented the electric battery which provided the first continuous flow of electricity and the capacitor.

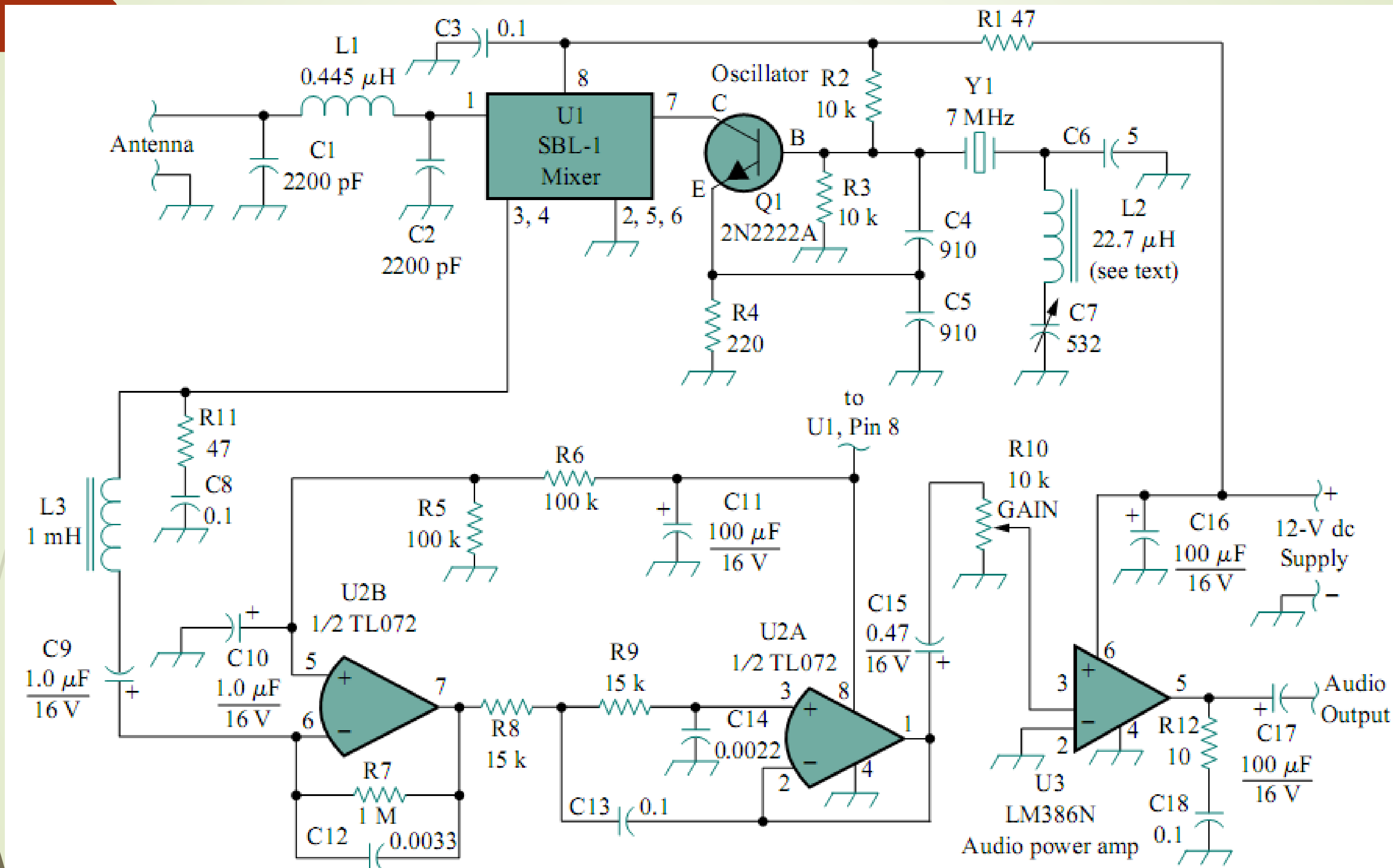
Andre-Marie Ampere (1775-1836), a French mathematician and physicist, laid the foundation of electrodynamics. He defined the electric current and developed a way to measure it in the1820s.

Introduction

Electric circuit theory and electromagnetic theory are the two fundamental the theories upon which all branches of electrical engineering are built. Many branches ofelectrical engineering, such as power, electricmachines, control, electronics, communications, and instrumentation, are based on electric circuit theory.

An electric circuit is an interconnection of electrical elements.





C3 0.1
R1 47
L1
0.445 μH
Antenna
C1
2200 pF
C2
2200 pF
U1
SBL-1
Mixer
1
7
8
3, 4
2, 5, 6
Oscillator
C
B
E
Q1
2N2222A
R2
10 k
R3
10 k
R4
220
Y1
7 MHz
C6
5
C4
910
C5
910
L2
22.7 μH
(see text)
C7
532
R11
47
C8
0.1
L3
1 mH
to
U1, Pin 8
R6
100 k
R5
100 k
C11
100 μF
16 V
R10
10 k
GAIN
C16
100 μF
16 V
12-V dc
Supply
U2B
1/2 TL072
C10
1.0 μF
16 V
C9
1.0 μF
16 V
R9
15 k
R8
15 k
U2A
1/2 TL072
C15
0.47
16 V
C14
0.0022
R7
1 M
C12
0.0033
C13
0.1
U3
LM386N
Audio power amp
R12
10
C17
100 μF
16 V
C18
0.1
Audio
Output

Systems of Units

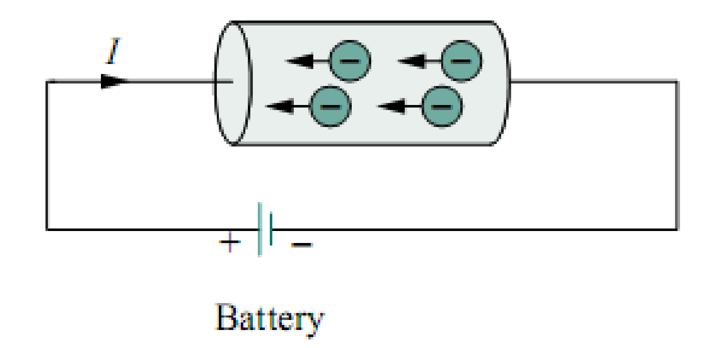
Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Charge and Current

Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

Electric current is the time rate of change of charge, measured in amperes (A).



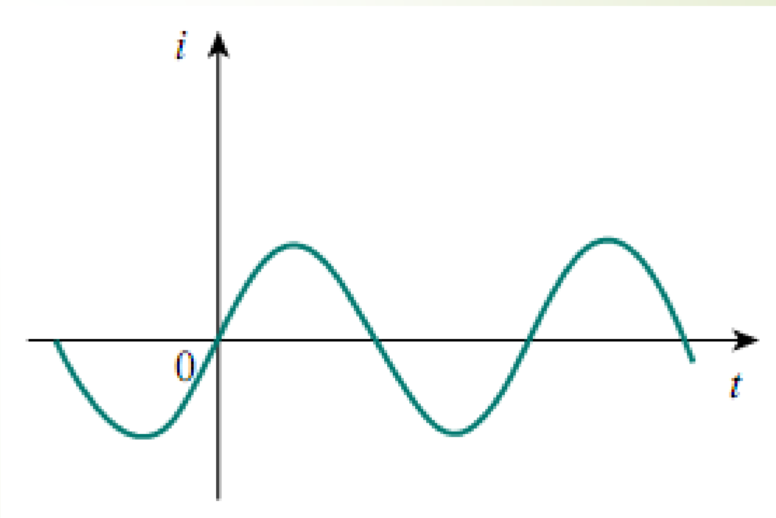
$$i = \frac{dq}{dt}$$

$$q = \int_{t_0}^{t} i \, dt$$

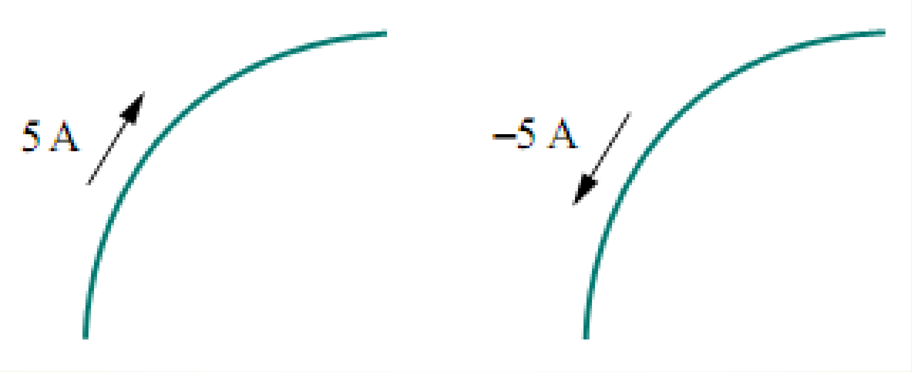
1 ampere = 1 coulomb/second

A direct current (dc) is a current that remains constant with time.

An alternating current (ac) is a current that varies sinusoidally with time.



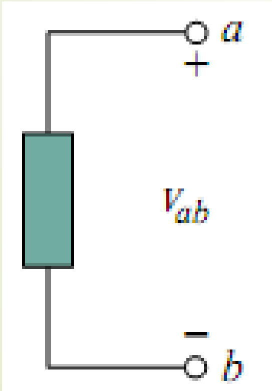
Once we define current as the movement of charge, we expect current to have an associated direction of flow. The direction of current flow is conventionally taken as the direction of positive charge movement.



Voltage

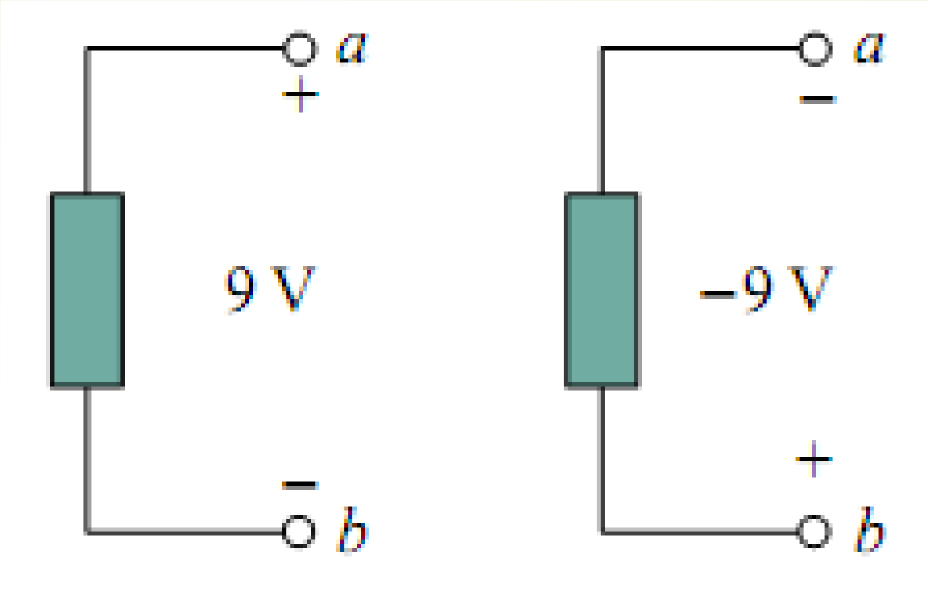
To move the electron in a conductor in a particular direction requires some work or energy transfer. This work is performed by an external electromotive force (emf). This emf is also known as *voltage* or *potential difference*.

Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).



$$v_{ab} = \frac{dw}{dq}$$

1 volt = 1 joule/coulomb = 1 newton meter/coulomb



Current and voltage are the two basic variables in electric circuits.
The common term *signal* is used for an electric quantity such as a current or a voltage when it is used for conveying information.

Power and Energy

Although current and voltage are the two basic variables in an electric circuit, they are not sufficient by themselves. For practical purposes, we need to know how much *power* an electric device can handle.

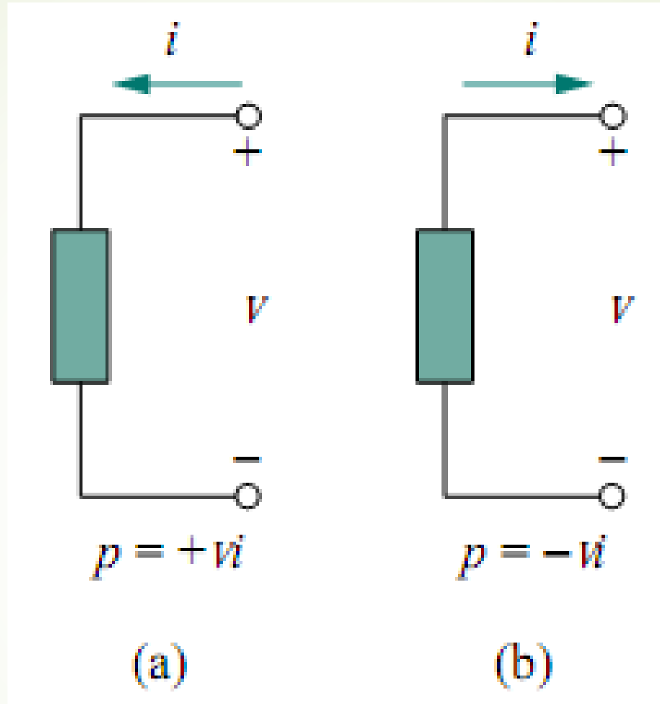
Power is the time rate of expending or absorbing energy, measured in watts (W).

$$\boxed{p = \frac{dw}{dt}}$$

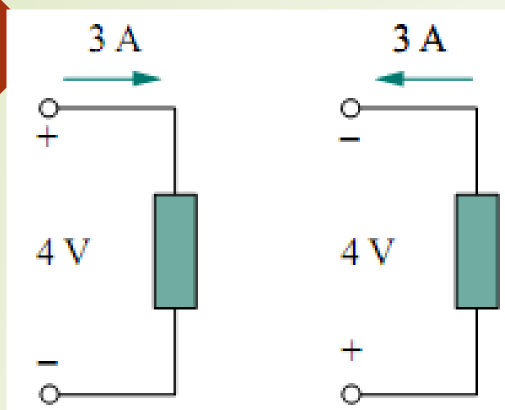
$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = vi$$

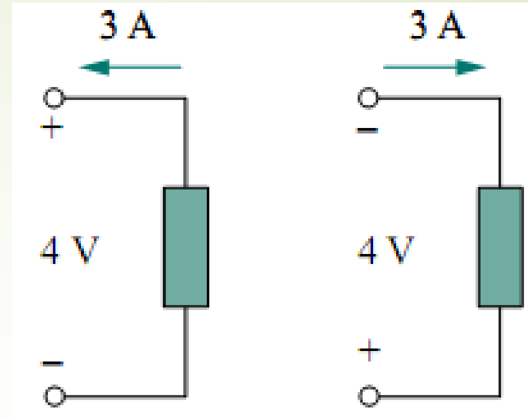
$$\boxed{p = vi}$$

Reference polarities for power using the passive sign convention.



Passive sign convention is satisfied when the current enters through the positive terminal of an element and $p = +vi$. If the current enters through the negative terminal, $p = -vi$.





Absorbing power of 12 W

Supplying power of 12 W

The law of *conservation of energy* must be obeyed in any electric circuit. For this reason, the algebraic sum of power in a circuit, at any instant of time, must be zero:

$$\boxed{\sum p = 0}$$

The energy absorbed or supplied by an element is

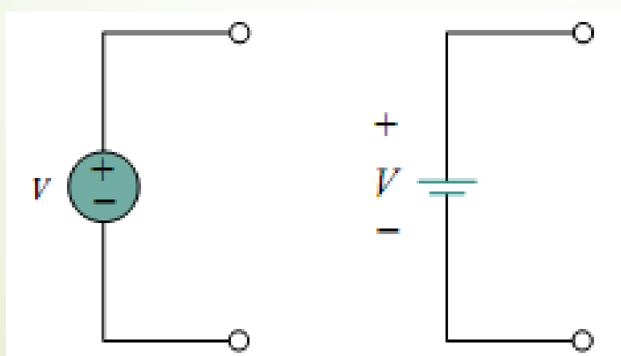
$$w = \int_{t_0}^{t} p \, dt = \int_{t_0}^{t} vi \, dt$$

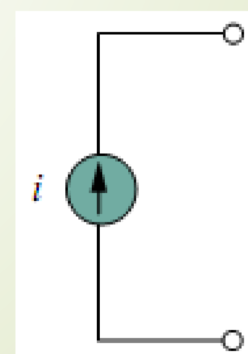
Energy is the capacity to do work, measured in joules (J).

Circuit Elements

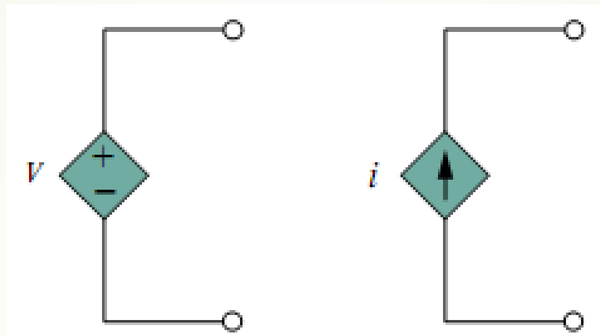
There are two types of elements found in electric circuits: *passive* elements and *active* elements. An active element is capable of generating energy while a passive element is not. Examples of passive elements are resistors, capacitors, and inductors. Typical active elements include generators and batteries.

An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit variables.





An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.



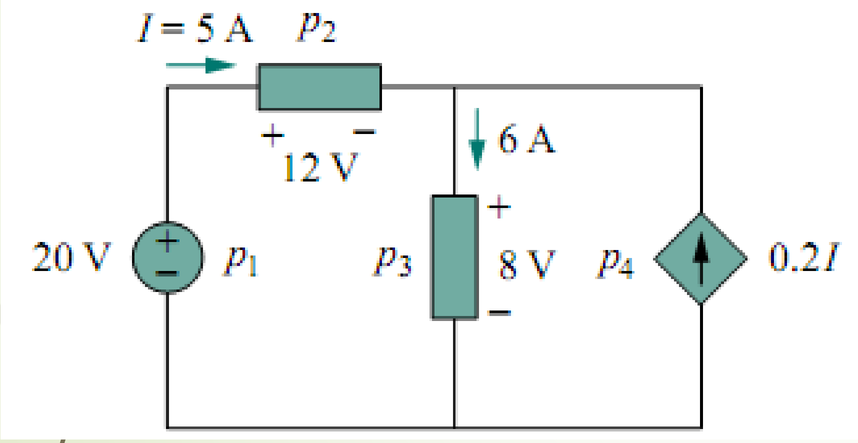
There are four types of dependent sources:

1. A voltage-controlled voltage source (VCVS).
2. A current-controlled voltage source (CCVS).
3. A voltage-controlled current source (VCCS).
4. A current-controlled current source (CCCS).

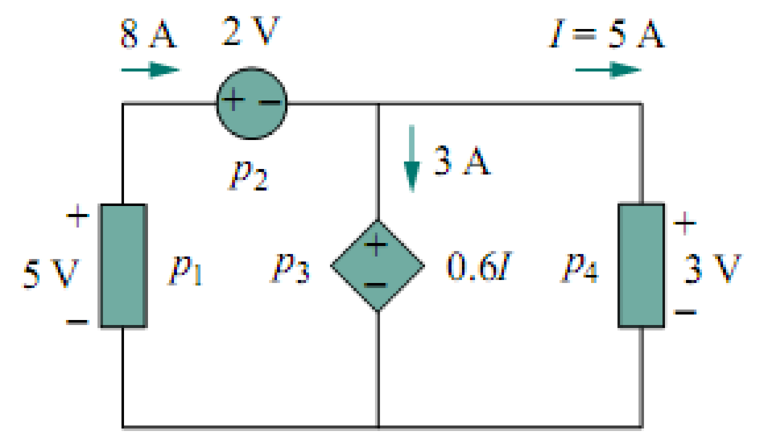
Practice Problems

Compute the power absorbed or supplied by each component of the circuits in figures below.

(1)



(2)



Selected Problems

1.14 Figure 1.25 shows a circuit with five elements. If $p_1 = -205$ W, $p_2 = 60$ W, $p_4 = 45$ W, $p_5 = 30$ W, calculate the power p_3 received or delivered by element 3.

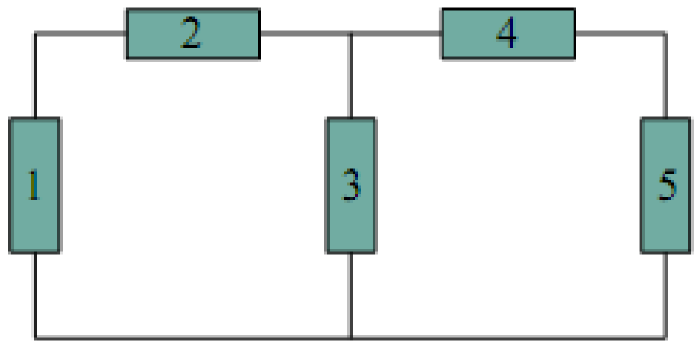


Figure 1.25 For Prob. 1.14.

1.15 Find the power absorbed by each of the elements in Fig. 1.26.

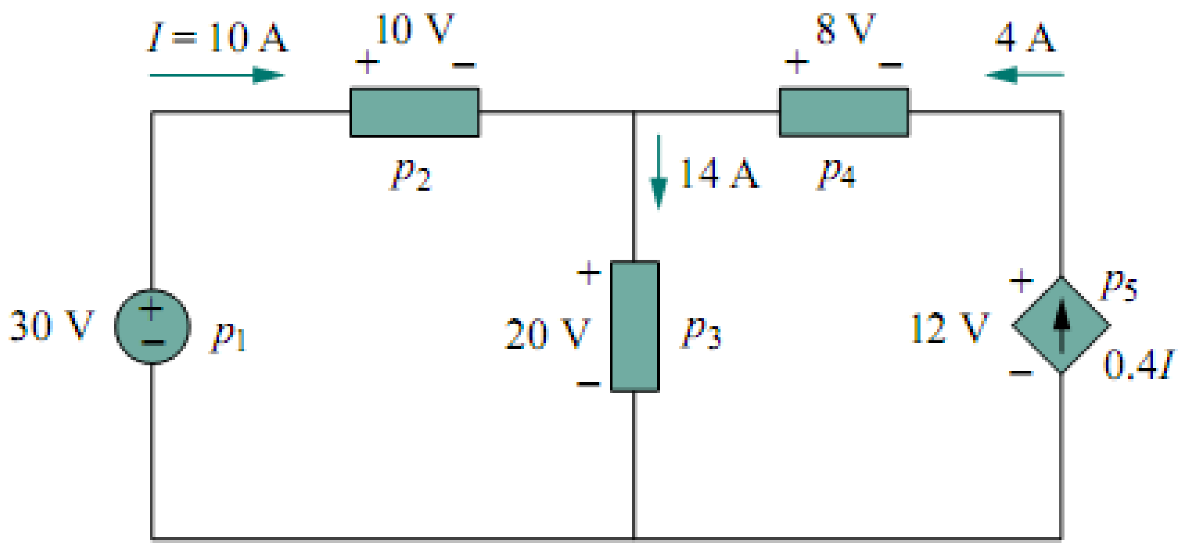


Figure 1.26 For Prob. 1.15.

1.16 Determine I_o in the circuit of Fig. 1.27.

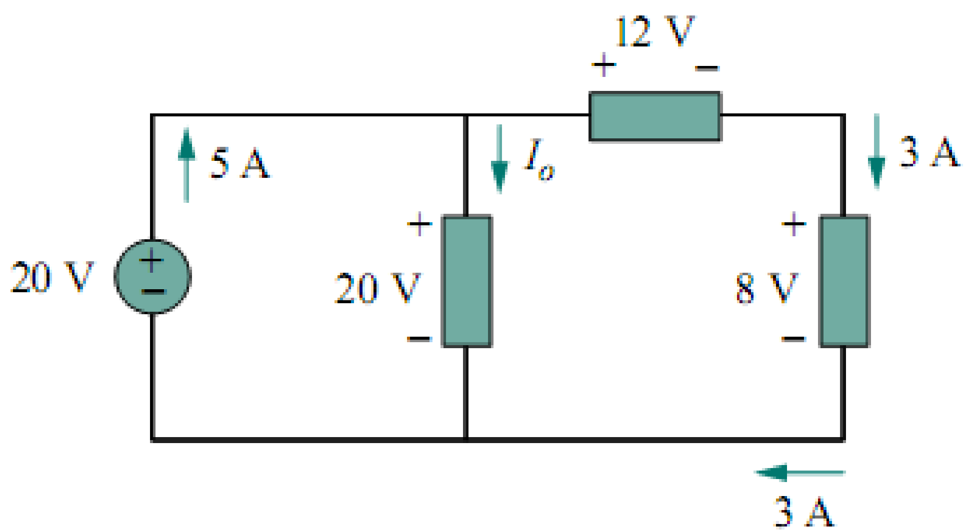


Figure 1.27 For Prob. 1.16.

1.17 Find V_o in the circuit of Fig. 1.28.

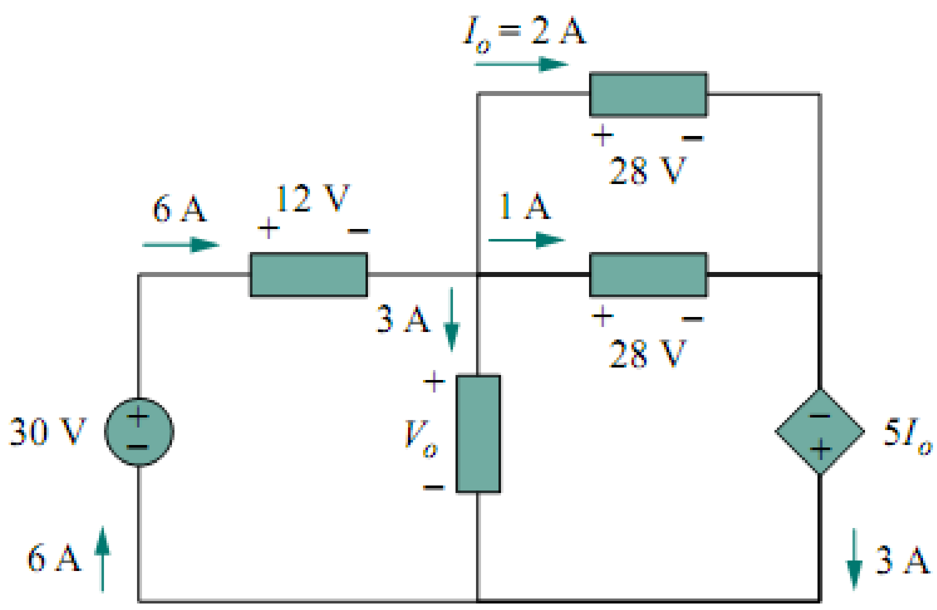


Figure 1.28 For Prob. 1.17.

1.29 The power consumption for a certain household for a day is shown in Fig. 1.29. Determine:

(a) the total energy consumed in kWh

(b) the average power per hour.

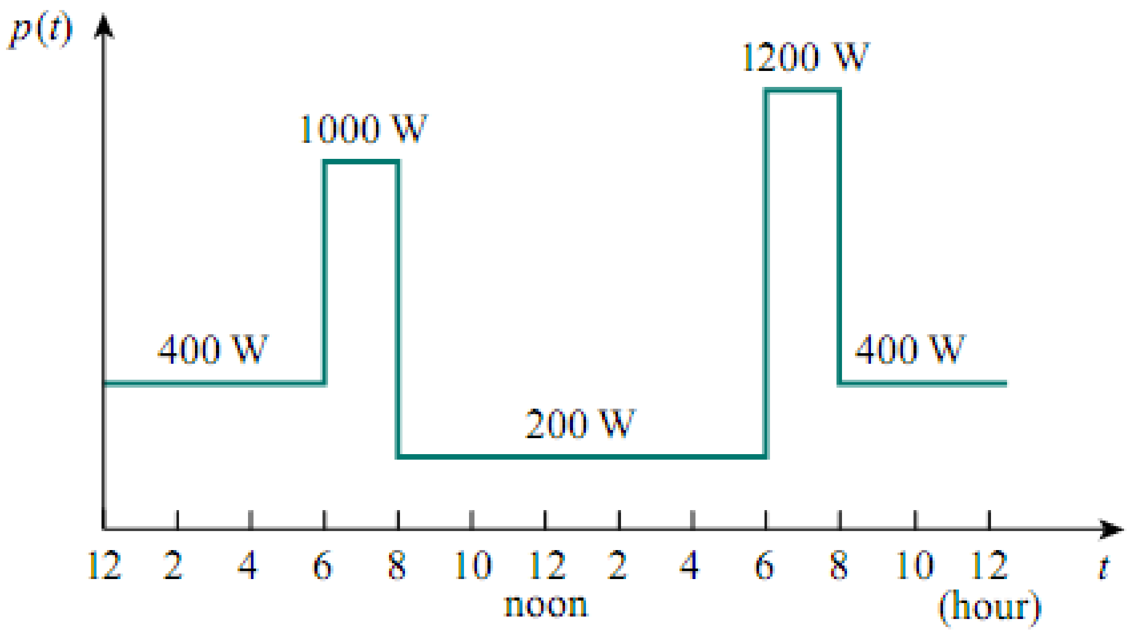


Figure 1.29 For Prob. 1.29.