Digital Voltmeters

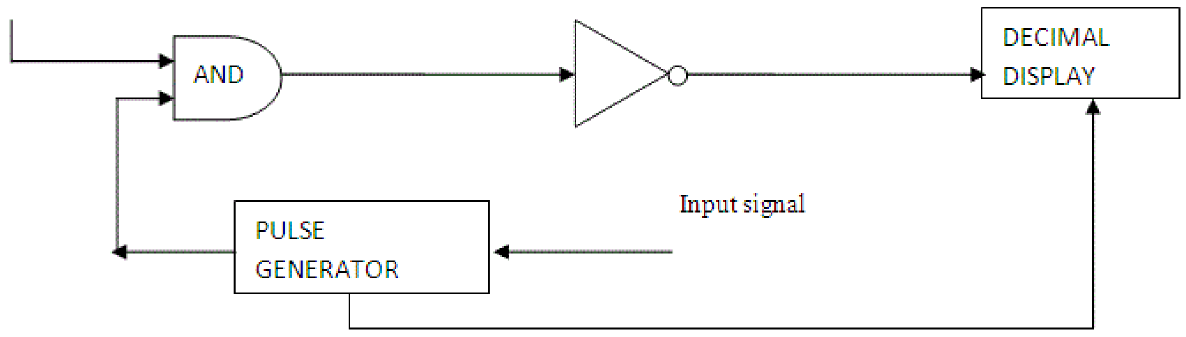
Working Principle of Digital Voltmeter

Voltmeter is an electrical measuring instrument used to measure potential difference between two points. The voltage to be measured may be AC or DC. Two types of voltmeters are available for the purpose of voltage measurement i.e. analog and digital. Analog voltmeters generally contain a dial with a needle moving over it according to the measure and hence displaying the value of the same. With time analog voltmeters are replaced by digital voltmeters due to the same advantages associated with digital systems. Although digital voltmeters do not fully replace analog voltmeters, still there are many places where analog voltmeters are preferred over digital voltmeters. Digital voltmeters display the value of AC or DC voltage being measured directly as discrete numerical instead of a pointer deflection on a continuous scale as in analog instruments.

A digital voltmeter (DVM) displays the value of a.c. or d.c voltage being measured directly as discrete numerals in the decimal number system. Numerical readout of DVMs is advantageous since it eliminates observational errors committed by operators. The errors on account of parallax and approximations are entirely eliminated. The use of digital voltmeters increases the speed with which readings can be taken. Also, the output of digital voltmeters can be fed to memory devices for storage and future computations.

A digital voltmeter is a versatile and accurate voltmeter which has many laboratory applications. On account of developments in the integrated circuit (IC) technology, it has been possible to reduce the size, power requirements and cost of digital voltmeters. In fact, for the same accuracy, a digital voltmeter now is less costly than its analog counterpart. The decrease in the size of DVMs on account of the use of ICs, the portability of the instruments has increased.

Circuit or Block diagram of Digital Voltmeters:



From the above block diagram, the voltage to be measured is given to the input signal present in the circuit diagram. And next to this signal is processed onto the pulse generator which generates a train of rectangular pulses by using both analog and digital techniques.

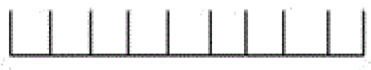
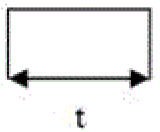
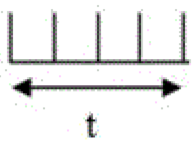
The digital circuitry present inside the pulse generator will control the width and frequency while analog circuitry will control the amplitude, rise time and fall time of the pulse generator. When AND gate is fed with train pulse and rectangular pulse, it will give train pulses with the same duration of that of the rectangular pulse.

Explanation of various blocks:

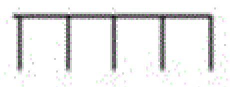
Input signal: It is basically the signal i.e. voltage to be measured.

Pulse generator: Actually it is a voltage source. It uses digital, analog or both techniques to generate a rectangular pulse. The width and frequency of the rectangular pulse is controlled by the digital circuitry inside the generator while amplitude and rise and fall time is controlled by analog circuitry.

AND gate: It gives high output only when both the inputs are high. When a train pulse is fed to it along with rectangular pulse, it provides us an output having train pulses with duration as same as the rectangular pulse from the pulse generator.

	Train pulse
	Rectangular pulse
	Output of AND gate

NOT gate: It inverts the output of AND gate.

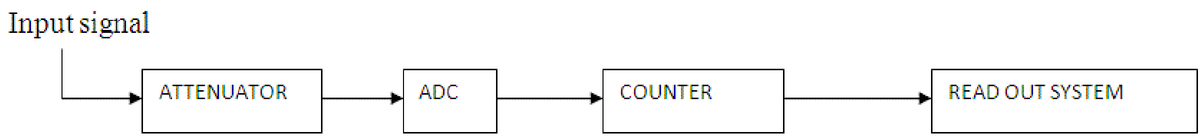
	Output of NOT gate

Decimal Display: It counts the numbers of impulses and hence the duration and display the value of voltage on LED or LCD display after calibrating it.

Working of a digital voltmeter as follows:

- Unknown voltage signal is fed to the pulse generator which generates a pulse whose width is proportional to the input signal.
- Output of pulse generator is fed to one leg of the AND gate.
- The input signal to the other leg of the AND gate is a train of pulses.
- Output of AND gate is positive triggered train of duration same as the width of the pulse generated by the pulse generator.
- This positive triggered train is fed to the inverter which converts it into a negative triggered train.
- Output of the inverter is fed to a counter which counts the number of triggers in the duration which is proportional to the input signal i.e. voltage under measurement.
- Thus, counter can be calibrated to indicate voltage in volts directly.

The working of digital voltmeter that it is nothing but an analog to digital converter which converts an analog signal into a train of pulses, the number of which is proportional to the input signal. So a **digital voltmeter** can be made by using any one of the A/D conversion methods.



On the basis of A/D conversion method used digital voltmeters can be classified as:

(i) Ramp type digital voltmeter

(ii) Integrating type digital voltmeter

(iii) Potentiometric type digital voltmeter

(iv) Successive approximation type digital voltmeter

(v) Continuous balance type digital voltmeter

Now-a-days **digital voltmeters** are also replaced by digital millimeters due to its multitasking feature i.e. it can be used for measuring current, voltage and resistance. But still there are some fields where separated digital voltmeters are being used.

WATTMETER

Dynamometer type wattmeter:

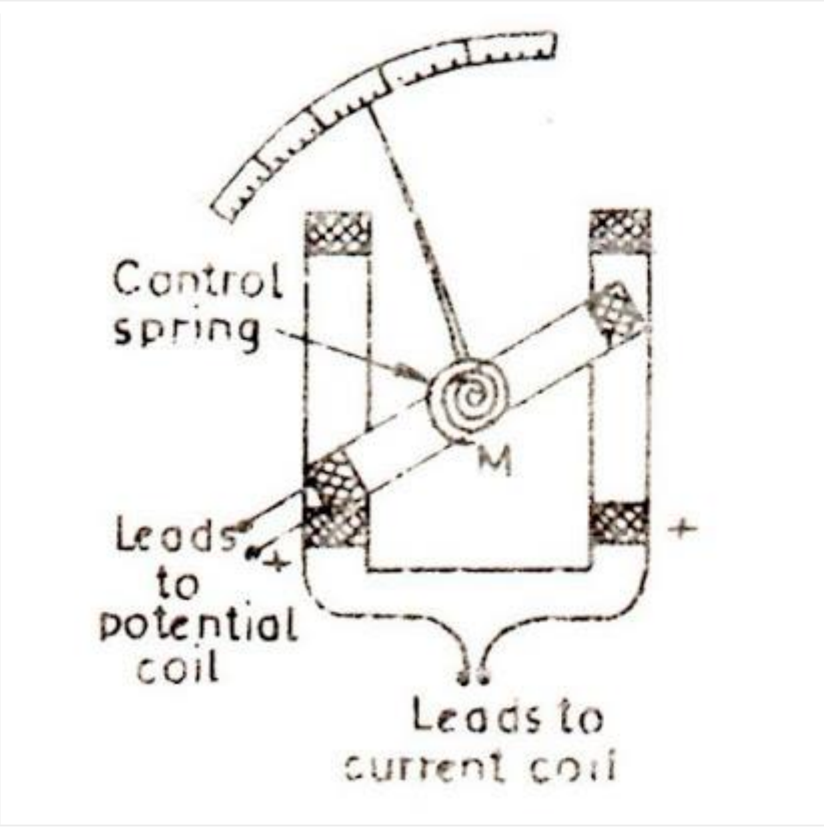
A dynamometer type wattmeter is most commonly employed for measurement of power in a.c as well as d.c circuits.

3.1Principle of Dynamometer type wattmeter:

It is based on the principle that mechanical force exists between two current carrying conductors.

3.2Construction of Dynamometer type wattmeter:

It essentially consists of two coils, namely fixed coil and moving coil. The fixed coil is split into two equal parts which are placed close together and parallel to each other. The moving coil is pivoted between the two fixed coils and is placed on the spindle to which the pointer is attached.
the fixed coils are connected in series with the load and carry the circuit current. It is, therefore called current coil. The moving coil is connected across the load and carries current proportional to the voltage. It is therefore called potential coil. Generally, a high resistance is connected in series with potential coil to limit the current through it.
The controlling torque is provided by springs which also serve the additional purpose of leading current into and out of the moving coil. Air friction damping is employed in such instruments.



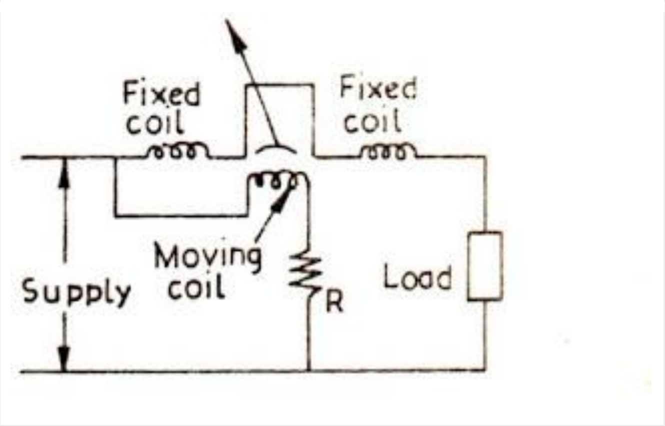
Dynamometer type wattmeter

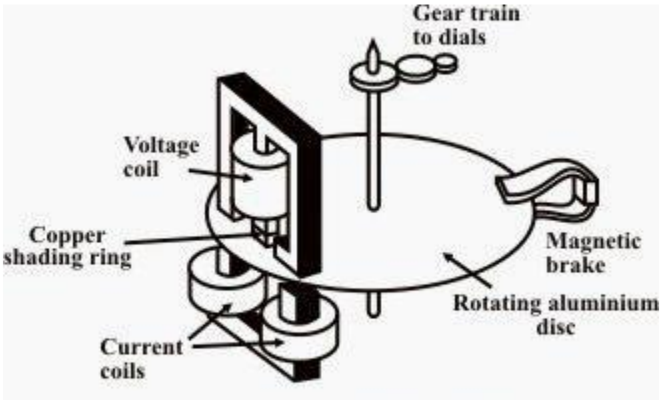
3.3Working of Dynamometer type wattmeter:

When power is to be measured in a circuit, the instrument is suitably connected in the circuit. The current coil is connected in series with load so that it carries the circuit current. The potential coil is connected across the load so that it carries current proportional to the voltage.

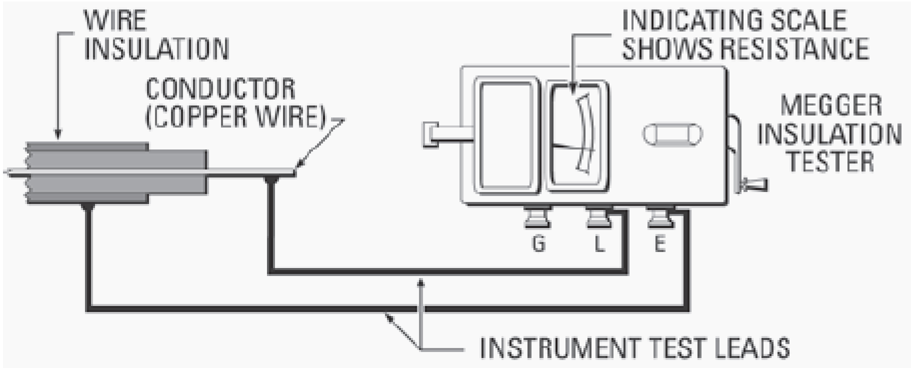
Due to the current in the coils, mechanical force exists between them. The result is that the moving coil, moves the pointer over the scale. The pointer comes to rest at a position where deflecting torque is equal to the controlling torque.

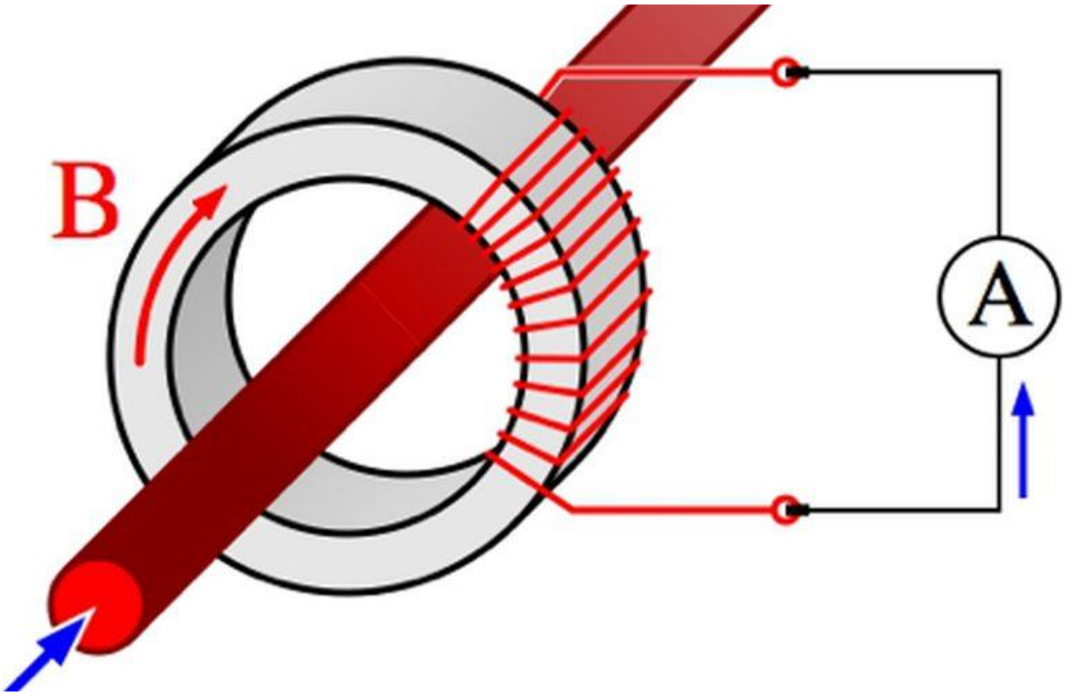
Reversing the current, reverses the field due to fixed coil as well as the current in the moving coil so that the direction of the deflection torque remains unchanged. Therefore, such instruments can be used for the measurement of a.c as well as d.c power.

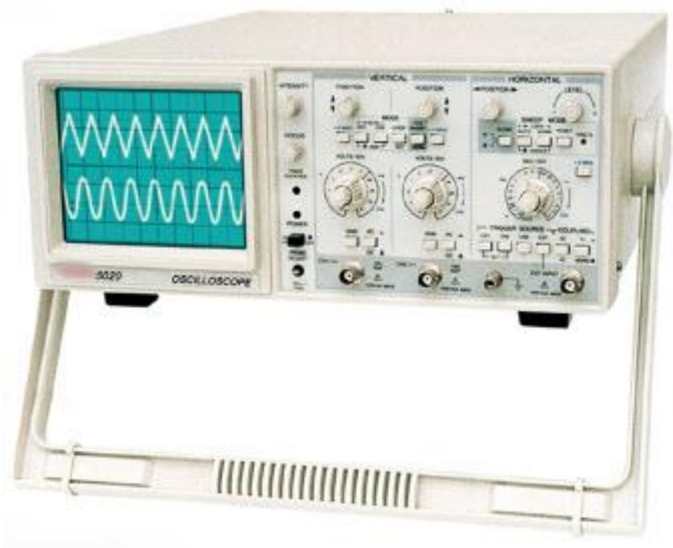




Watt-hour meter.


WIRE
INSULATION
CONDUCTOR
(COPPER WIRE)
INDICATING SCALE
SHOWS RESISTANCE
MEGGER
INSULATION
TESTER
G
L
E
INSTRUMENT TEST LEADS


B
A


VERTICAL
HORIZONTAL
OSCILLOSCOPE


LCR Meter
.0090
948.8
BK PRECISION

UNIT-9

MEASURMENT OF TEMPRATURE

9.1 THERMOMETER

*A **thermometer** is a device that measures temperature or a temperature gradient. A thermometer has two important elements: (1) a temperature sensor (e.g. the bulb of a mercury-in-glass thermometer or the digital sensor in an infrared thermometer) in which some change occurs with a change in temperature; and (2) some means of converting this change into a numerical value (e.g. the visible scale that is marked on a mercury-in-glass thermometer or the digital readout on an infrared model). Thermometers are widely used in technology and industry to monitor processes, in meteorology, in medicine, and in scientific research.*

MCQ

Q.1 Dynamometer wattmeter can measure power in a

a-single phase a.c circuit b-a.c or d.c circuit c- d.c circuit

Q.2 Speed of disc of an energy meter is kept low at full loadto reduce

a-eddy current b- friction error c-self braking torque d-all of these

Q-3 Where terminal of a meggar are open it will read

a-Zero b-infinity c-100 ohms d-1kohm

SHORT ANSWER QUESTION

Q.1 Generated test voltage in a meggar is 500/100v , why?

Q.2 For a unity power factor prove that w1=w2

Q-3 Define and classify transducer.

LONG ANSWER QUESTION

Q.1 What a strain gauge? Describe its working.

Q.2 Explain working of LVDT.

Q.3 What is a thermocouple?

Q.4 Describe construction and working of a meggar.

Q.5 Describe construction and working of an earth tester.

Q.6 Describe construction and working of a synchroscpe.

Principles and types of analog and digital ammeters and voltmeters

Electrical voltage and current are two important quantities in an electrical network.

The voltage is the effort variable without which no current is available. It is measured across an electrical circuit element or branch of a circuit. The device that measures the voltage is the voltmeter.

The current is the flow variable that represents net motion of the charged particles (electrons in solids, ions in a liquid) in a given direction.

The product of the two yields the instantaneous electrical power. The ratio of the voltage to the current is the impedance.

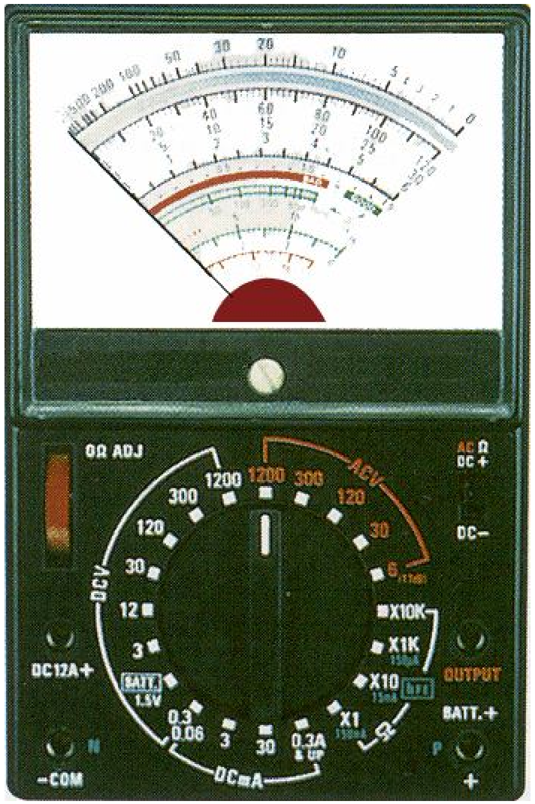
The current is measured by an ammeter (also called an ampermeter). Ammeters are connected in series with the load to measure the current in the load.

Eventually, the ammeters require breaking the current loop to place it into the circuit.

The voltmeter connection is rather easy since it is connected without disturbing the circuit layout. Voltmeter are connected in parallel with the load to measure the voltage a cross the load

Moving-Coil Meter

- Two Types of Multimeters



VOM
(analog)

DMM
(digital)

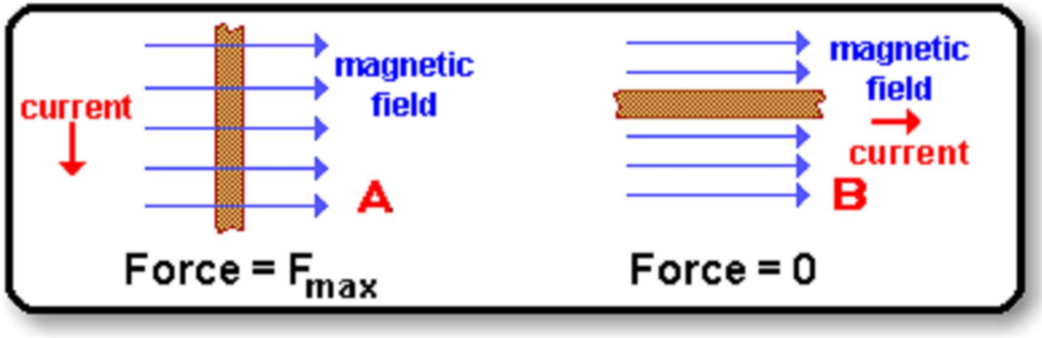
Types of Meters

- **Analog meter**:
  - Uses a moving pointer and a printed scale to indicate values of voltage, current, or resistance.
- **Volt-Ohm-Milliammeter** (VOM):
  - Allows all three kinds of measurements on a single scale or readout.
- **Digital multimeter**:
  - Uses a numerical readout to indicate the measured value of voltage, current or resistance.

Moving-Coil Meter

- Direct Current Meters
  - Direct current in a moving-coil meter deflects the pointer in proportion to the amount of current.
  - A current meter must be connected in series with the part of the circuit where the current is to be measured.
  - A dc current meter must be connected with the correct polarity.

Moving-Coil Meter: principle of operation



$$F = Bli\sin\phi$$

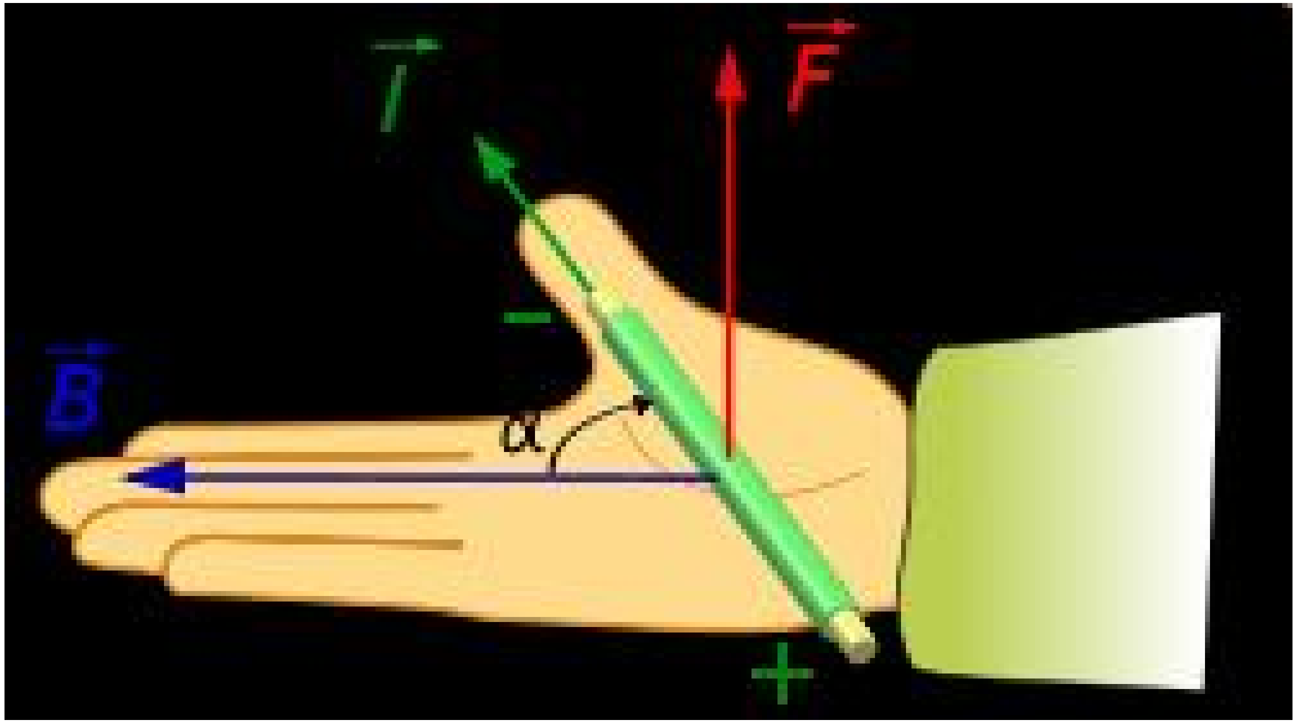
Where, B is magnetic flux density

i the current passing through the wire

Φ the angle between B and I

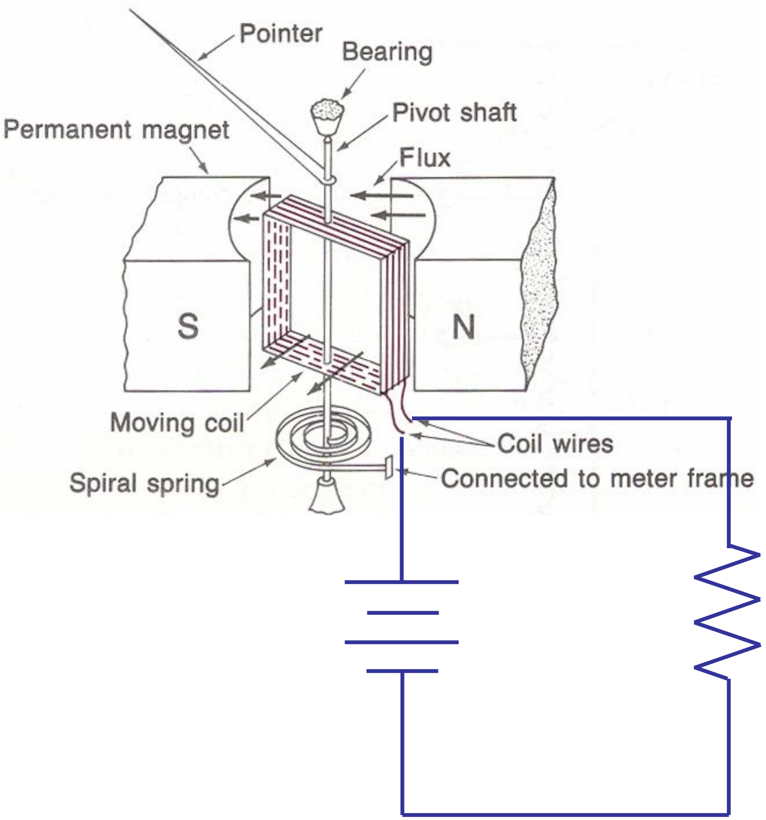
l is the length of the conductor

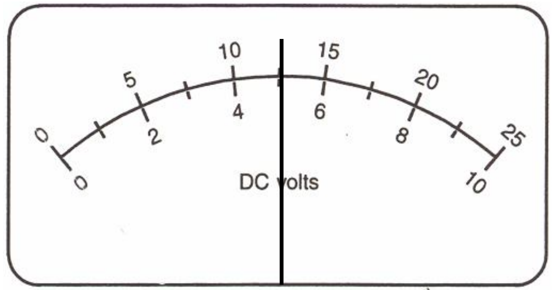
Right-hand rule for a current-carrying wire in a magnetic field B



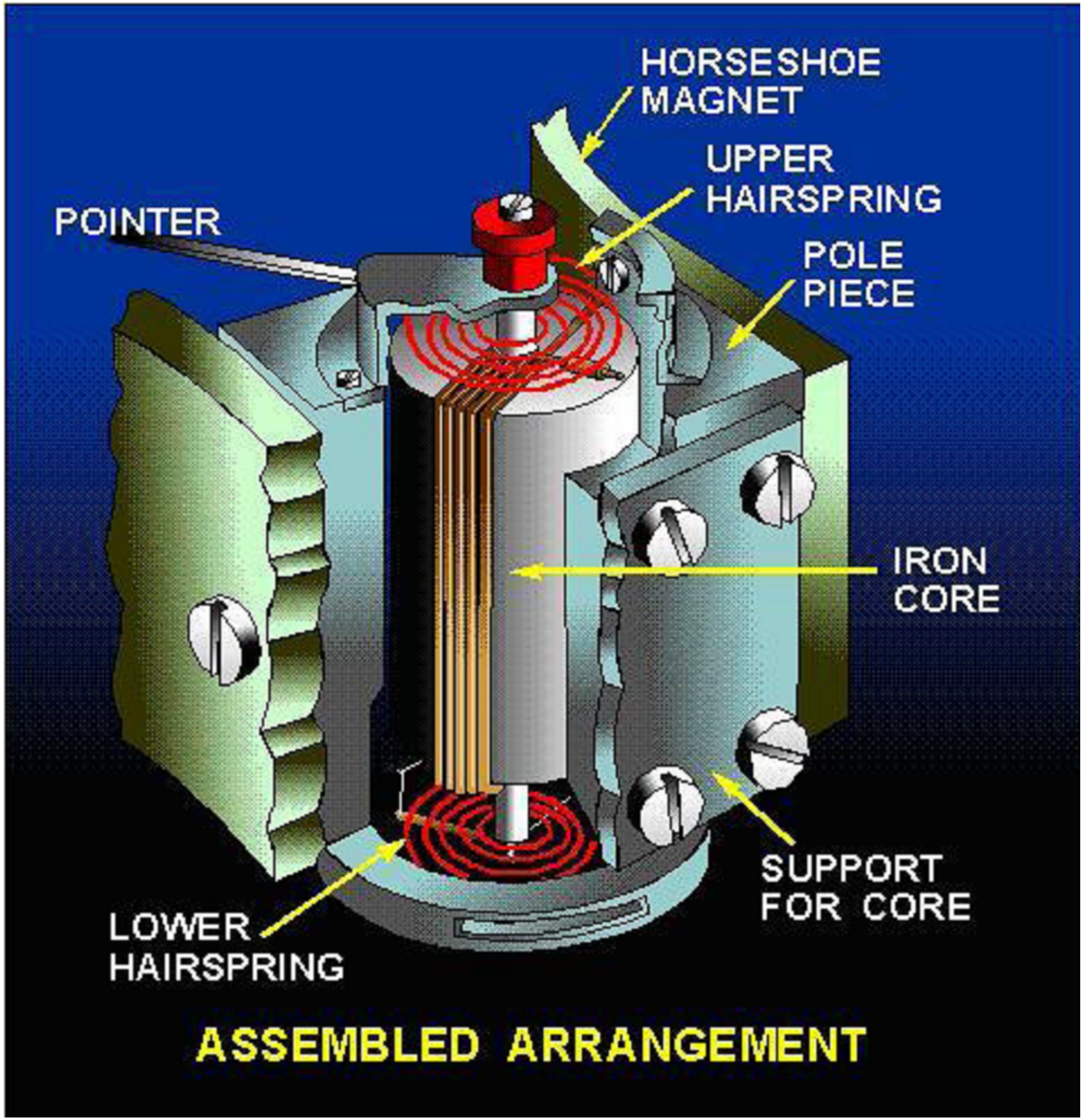
Moving-Coil Meter

Analog instruments use a moving coil meter movement.





Current flow in the coil moves the pointer up-scale.


HORSESHOE MAGNET
UPPER HAIRSPRING
POINTER
POLE PIECE
IRON CORE
SUPPORT FOR CORE
LOWER HAIRSPRING
ASSEMBLED ARRANGEMENT

Moving-Coil Meter: principle of operation

The length of each side of the coil is perpendicular to the magnetic field, that is Φ=0

$$F = 2LBi$$

for n turn coil

$$F = 2LNBi$$

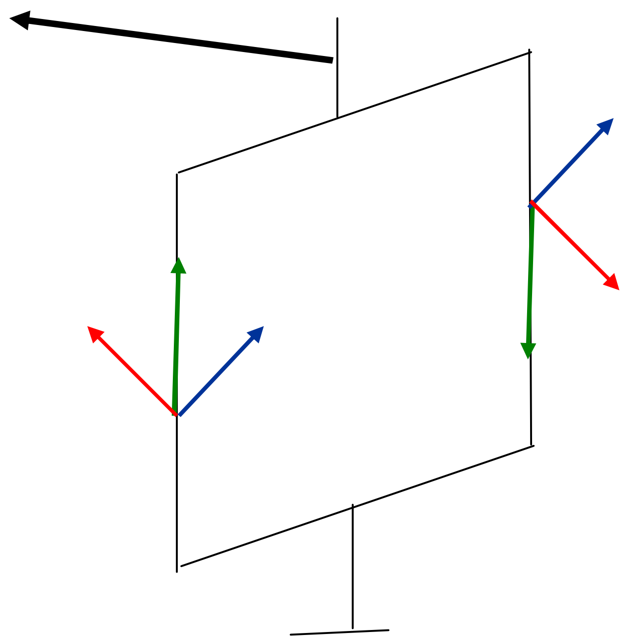
the torque generated by passing the current through the N turns(Tm)

$$Tm = F \times h / 2$$

where h is the width of the coil

$$Tm = 2LNBi \times h / 2$$
$$= LhNBi = ANBi$$

Note: L* h = area



B: flux density

I : Current

F : Force

Moving-Coil Meter: principle of operation

- The deflection torque causes the moving system to move from zero position when the instrument is connected to the circuit to measure the given electrical quantity.

The Torque is given by,

$$\mathbf{T = BiNA}$$

where

T = Torque in unit Newton meter(N.m)

B = Flux density in unit Tesla(T) or wb/m^2

i = Current through coil in unit Ampere (A)

N = Numbers of coil

A = Area (length x wide), m^2

Moving-Coil Meter: principle of operation

At equilibrium (at balance)

$$Tm = Ts$$

Where Ts is the spring torque and Ts

$$Ts = K\theta$$

Moving-Coil Meter: principle of operation

At equilibrium (at balance)

$$BNAi = K\theta$$

$$\theta = \frac{BNA}{k} i$$

the sensitivity S,

$$S = \frac{\partial \theta}{\partial I} = \frac{BNA}{k}$$

which is constant for a specific equipment provided that B is constant

Example

- A moving coil has following parameters: Area A= 2 cm^2, N=90 turns, B= 0.2 Tesla, coil resistance = 50Ω, current I= 1 *mA*. Calculate The electromagnetic torque (Tm) established:

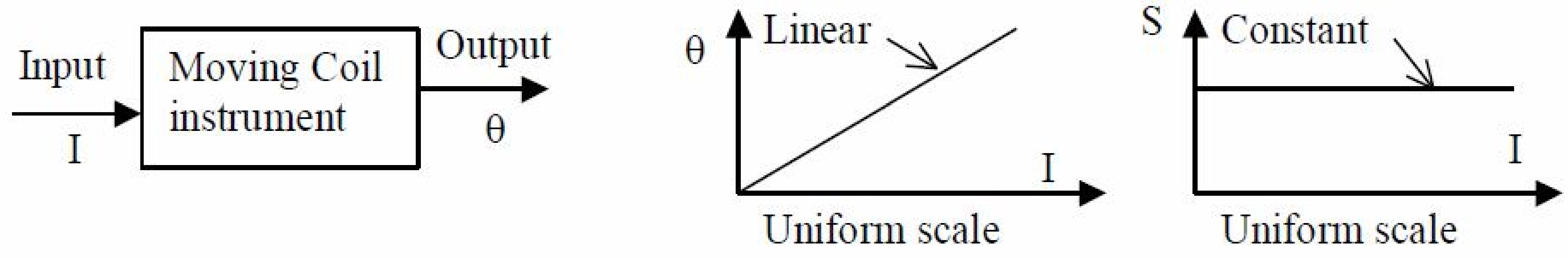
$$T_M = NBAI = 90 \times 0.2 \times 2 \times 10^{-4} \times 10^{-3}$$
$$= 3.6 \times 10^{-6} \text{ N.m}$$

- Assume that the electromagnetic torque of the coil is compensated by a spring torque and the spring constant k = 3.6×10^{-8} N-m/degrees. Find the angle of deflection of the coil at equilibrium.

Example

- $\theta = T_M / k = 100\,°$

Model of a moving coil instrument



The moving coil instrument can be considered as a transducer that converts the electrical current to angular displacement. The linear relation between θ and *I* indicate that we have a linear (uniform) scale.

Example

- A moving coil instrument has the following data: number of turns of the coil = 100, width of the coil = 2 cm, length of the coil = 3 cm, flux density in the air gap = 0.1 Tesla. Calculate the deflection torque when carrying a current of 10 mA. Also calculate the deflection (angle) if the control spring constant is 20×10^{-7} N-m/degree.

- Solution
- A = 6 cm2 , therefore, $T_M = NBAI$
- $T_M = 60\times10^{-6}$ N-m

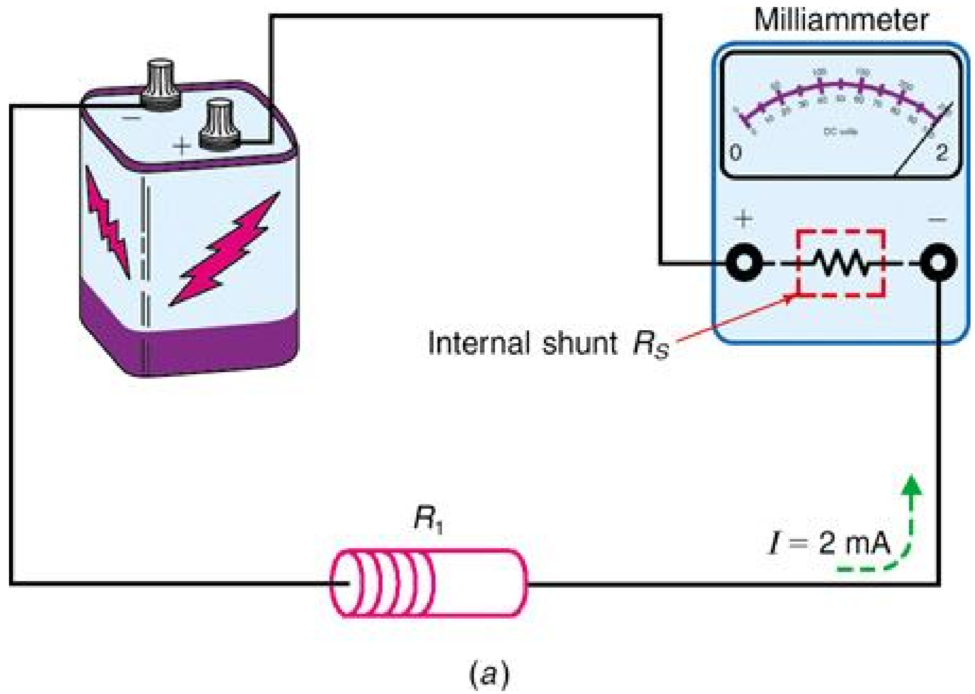
$\theta = T_{EM} / k = 30$

Meter Shunts

- Meter Shunts
  - **Meter shunts** are low-value precision resistors that are connected in parallel with the meter movement.
  - Meter shunts bypass a portion of the current around the meter movement. This process extends the range of currents that can be read with the same meter movement.

Meter Shunts

- Using Shunts to Increase Ammeter Range

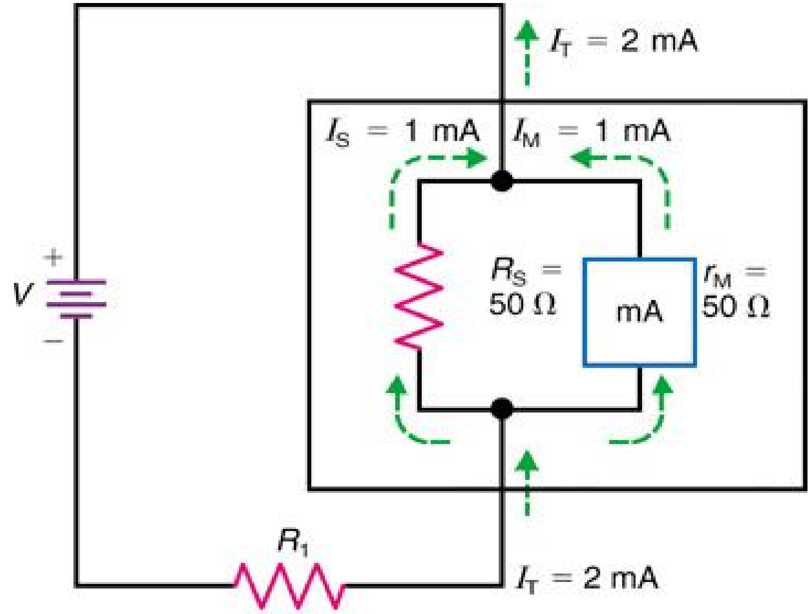


Example of meter shunt R_S in bypassing current around the movement to extend range from 1 to 2 mA. (*a*) Wiring diagram.

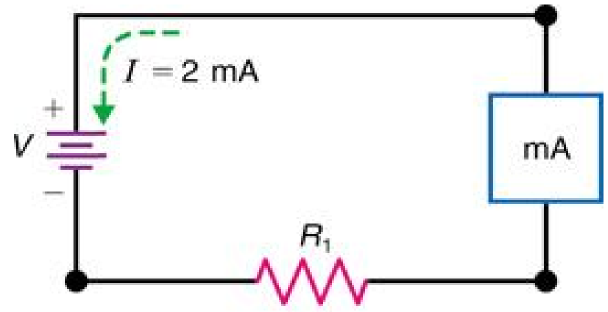
Meter Shunts

$V_M = I_M \times r_M$ $\quad I_S = I_T - I_M$ $\quad R_S = \dfrac{V_M}{I_S}$

$V_M = 50\text{mV}$ $\quad I_S = 1\text{ mA}$ $\quad R_S = 50\ \Omega$



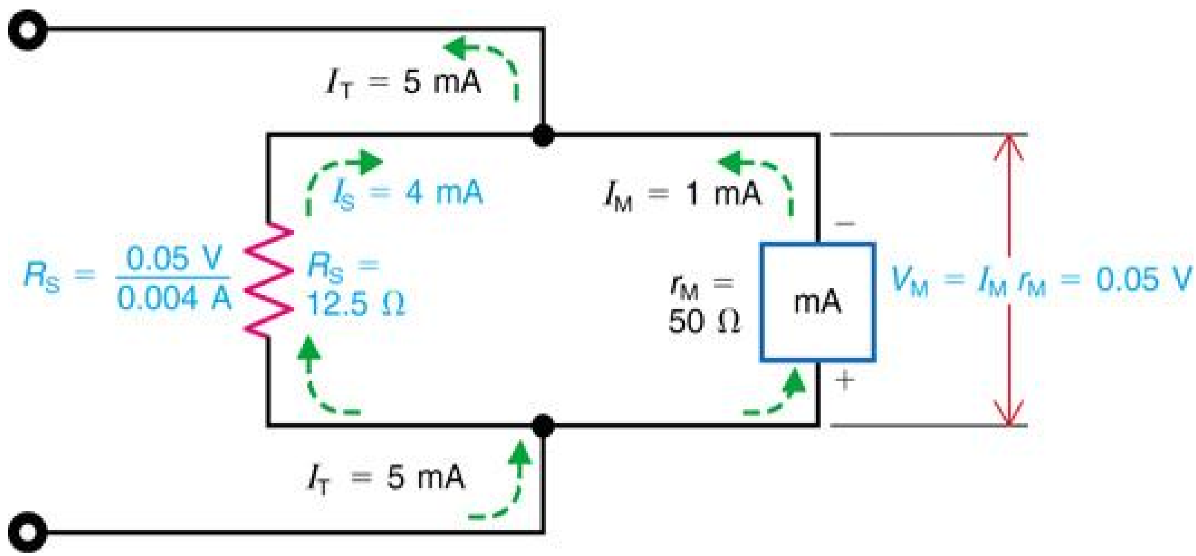
(b)



(c)

(*b*) Schematic diagram showing effect of shunt. With $R_S = r_M$ the current range is doubled. (*c*) Circuit with 2-mA meter to read the current.

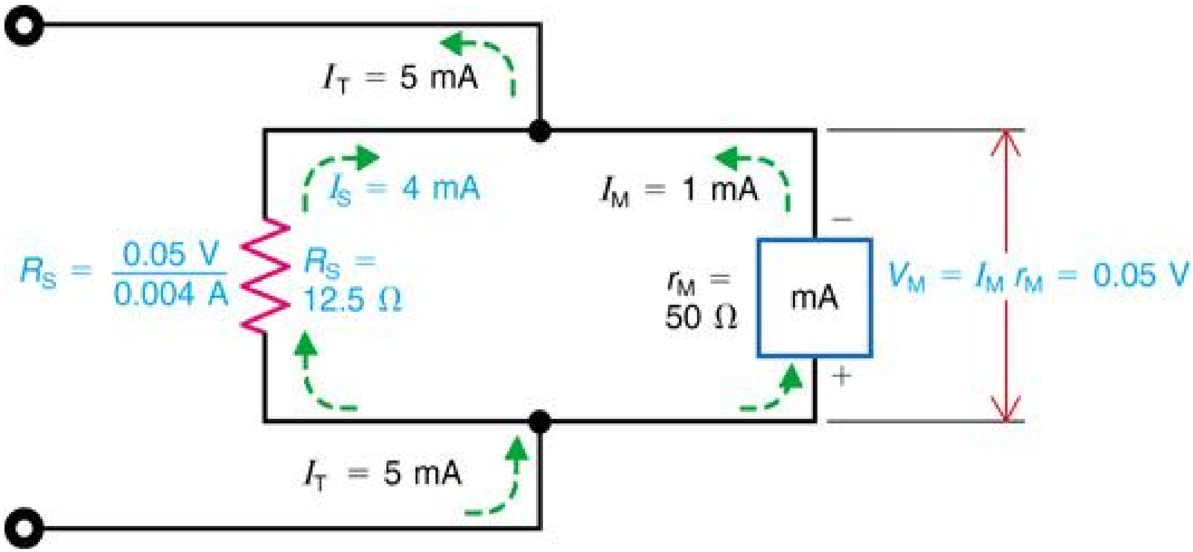
Meter Shunts



V_M = 0.001 x 50 = **0.05V or 50 mV**

Calculating the resistance of a meter shunt. R_S is equal to V_M/I_S.

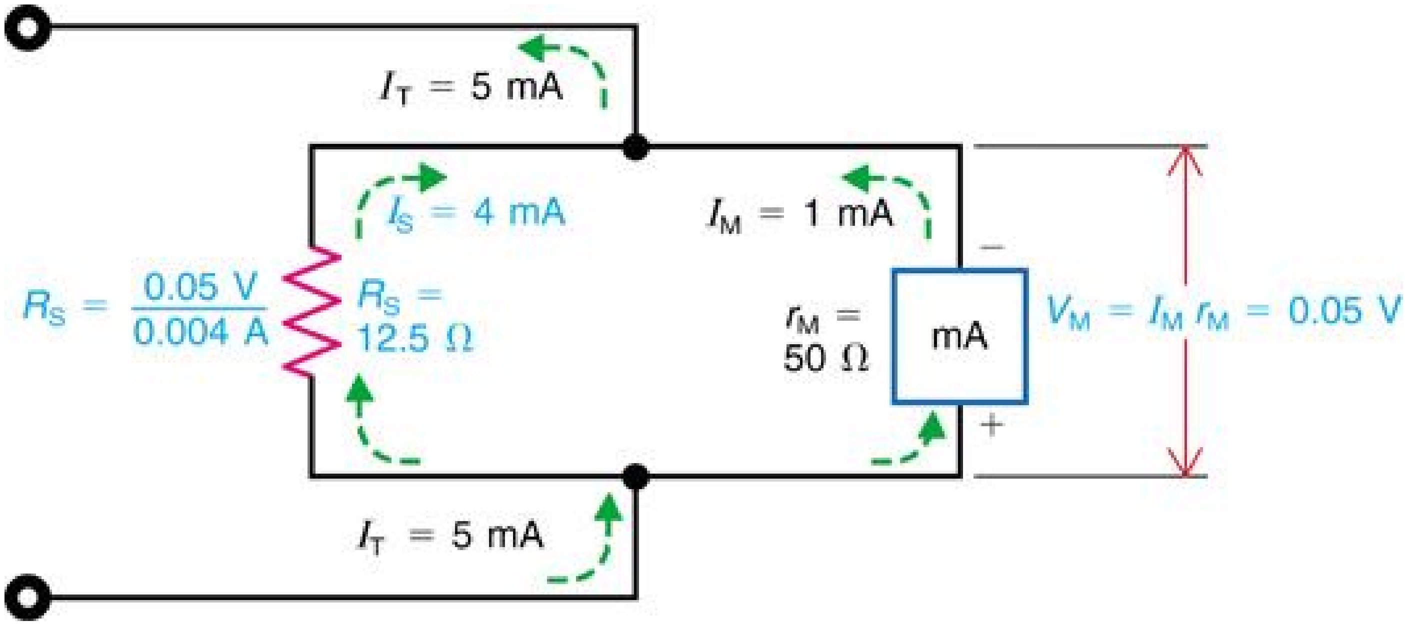
Meter Shunts



$I_S = 0.005 - 0.001 =$ **0.004 A or 4 mA**

Calculating the resistance of a meter shunt. R_S is equal to V_M/I_S.

Meter Shunts



Divide V_M by I_S to find R_S.

$R_S = 0.05/0.004 = 12.5\ \Omega$

This shunt enables the 1-mA movement to be used for an extended range from 0-5 mA.

Voltmeters

– A **voltmeter** is connected across two points to measure their difference in potential.

– A voltmeter uses a high-resistance **multiplier** in series with the meter movement.

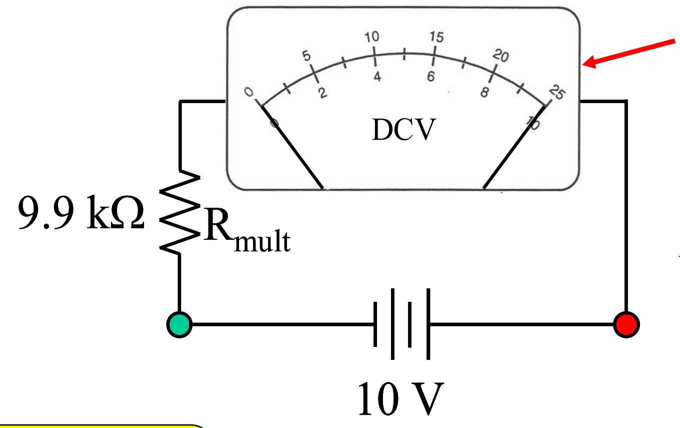
– A **dc voltmeter** must be connected with the correct polarity.

Voltmeters

A **multiplier resistor** is a large resistance in series with a moving-coil meter movement which allows the meter to measure voltages in a circuit.

Voltmeters

Using Multipliers to Increase Voltmeter Range



$V_M = I_M \times r_M = 0.1$ V

$$R_{mult} = \frac{V_{FS}}{I_M} - r_M$$

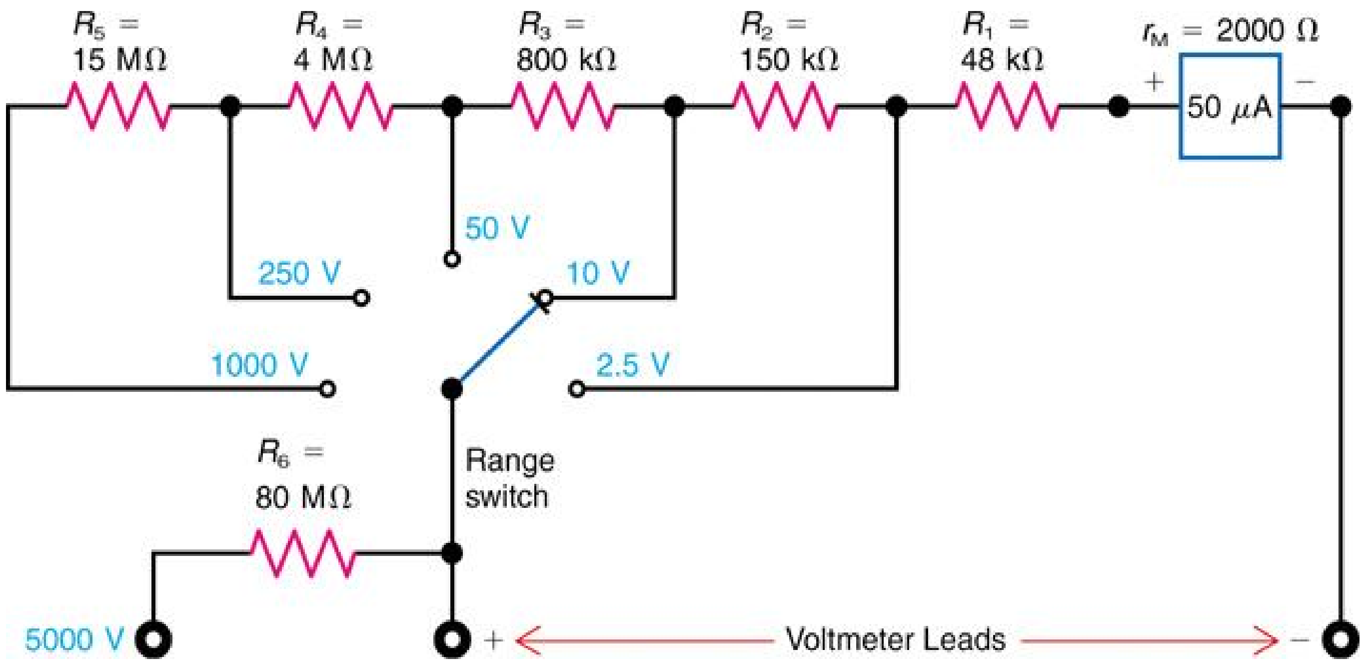
$$\text{Sensitivity} = \frac{r_M}{V_M} = 1000\ \Omega \text{ per volt}$$

For a 25 V range, change R_{mult} to 24.9 kΩ.

Note: sensitivity *is not affected* by the multipliers.

Voltmeters

- Typical Multiple Voltmeter Circuit



A typical voltmeter circuit with multiplier resistors for different ranges.

Voltmeters

Voltmeter Resistance

- The high resistance of a voltmeter with a multiplier is essentially the value of the multiplier resistance.
- Since the multiplier is changed for each range, the voltmeter resistance changes.

Voltmeters

- Ohms-per-Volt Rating
  - Analog voltmeters are rated in terms of the ohms of resistance required for 1 V of deflection.
  - This value is called the **ohms-per-volt rating**, or the **sensitivity** of the voltmeter.
  - The ohms-per-volt rating is the same for all ranges. It is determined by the full-scale current I_M of the meter movement.
  - The voltmeter resistance R_V can be calculated by multiplying the ohms-per-volt rating and the full-scale voltage of each range.

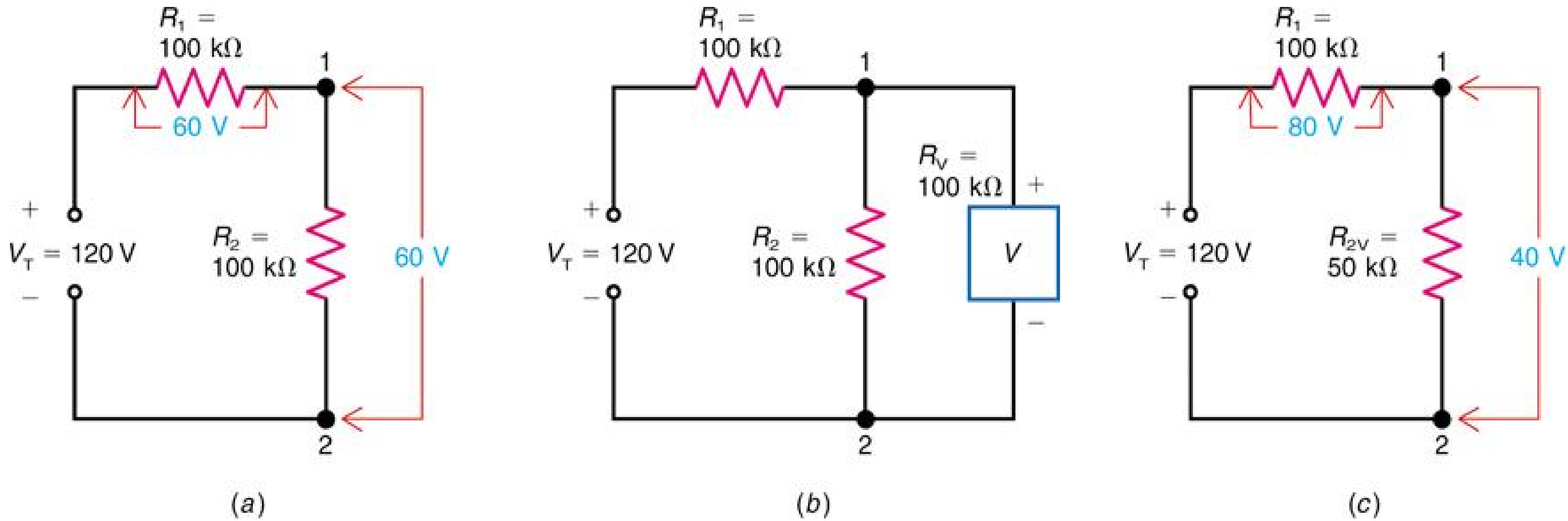
Loading Effect of a Voltmeter

– When voltmeter resistance is not high enough, connecting it across a circuit can reduce the measured voltage.

– This effect is called **loading down** the circuit, because the measured voltage decreases due to the additional load current for the meter.

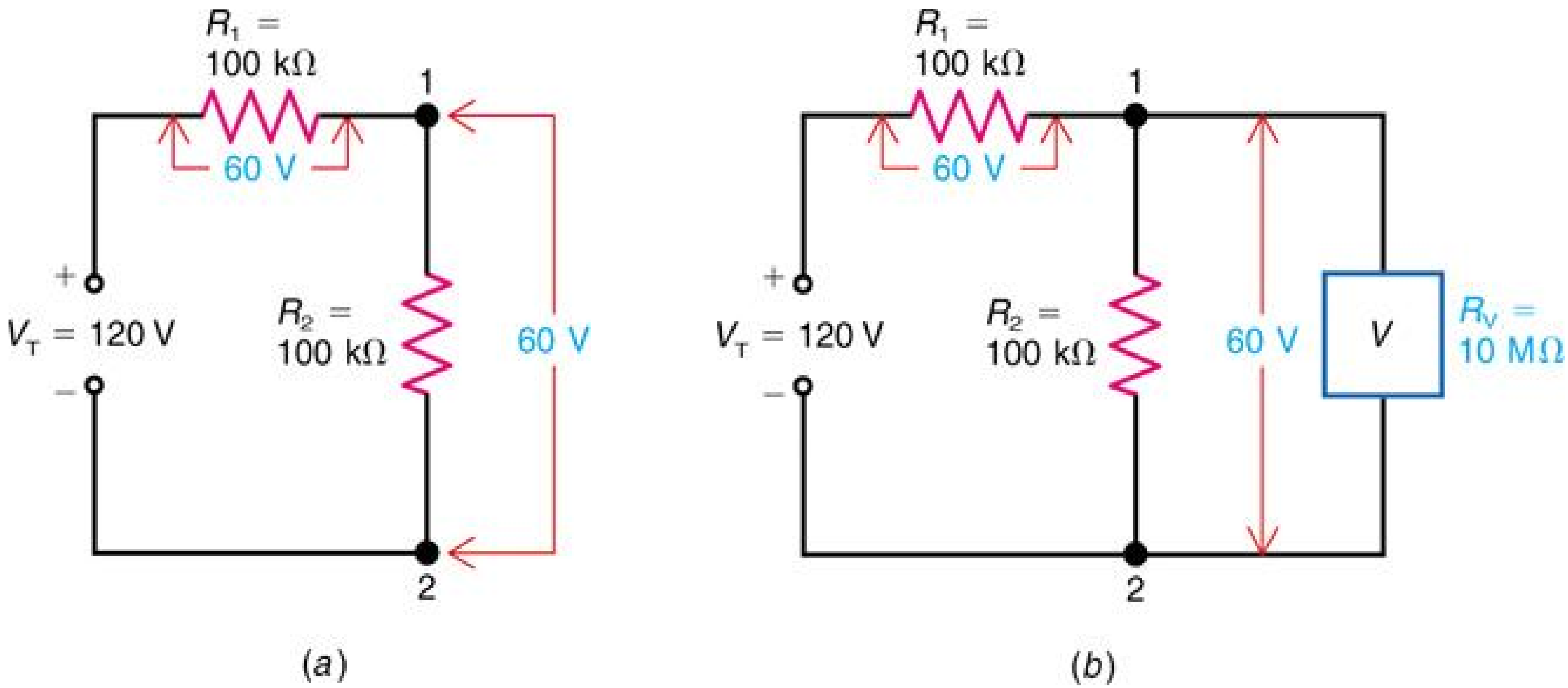
Loading Effect of a Voltmeter

– High resistance circuits are susceptible to **Voltmeter loading.**



How loading effect of the voltmeter can reduce the voltage reading. (*a*) High-resistance series circuit without voltmeter. (*b*) Connecting voltmeter across one of the series resistances. (*c*) Reduced *R* and *V* between points 1 and 2 caused by the voltmeter as a parallel branch across R_2. The R_{2V} is the equivalent of R_2 and R_V in parallel.

Loading Effect of a Voltmeter



Negligible loading effect with a high-resistance voltmeter. (*a*) High-resistance series circuit without voltmeter. (*b*) Same voltages in circuit with voltmeter connected, because R_V is so high.

Loading Effect of a Voltmeter

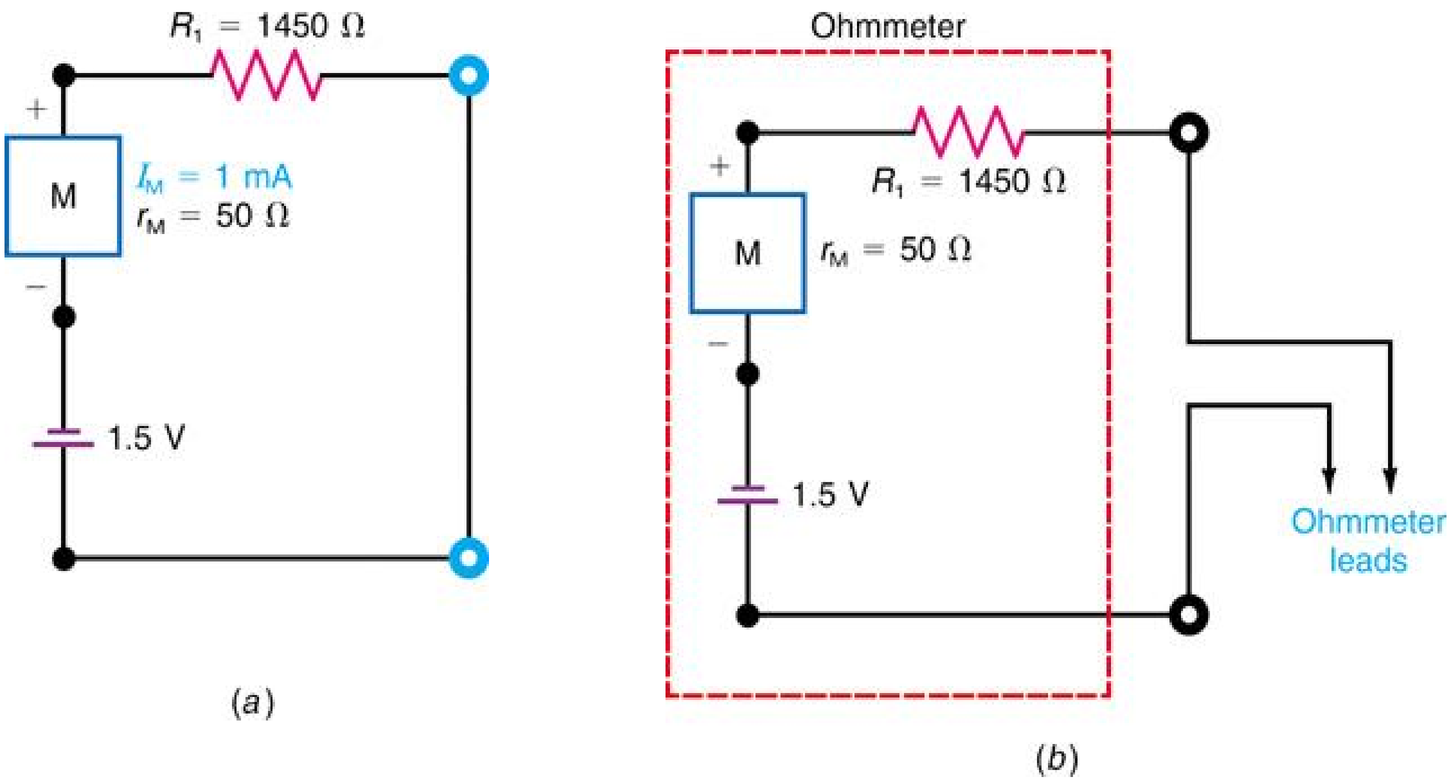
- The **loading effect** is minimized by using a voltmeter with a resistance much greater than the resistance across which the voltage is measured.
- The loading effect of a voltmeter causes too low a voltage reading because R_V is too low as a parallel resistance.
- The digital multimeter (DMM) has practically no loading effect as a voltmeter because its input is usually 10 to 20 MΩ on all ranges.
- The following formula can be used to correct for loading:

$$V = V_M + [R_1R_2/R_V(R_1 + R_2)]V_M$$

Ohmmeters

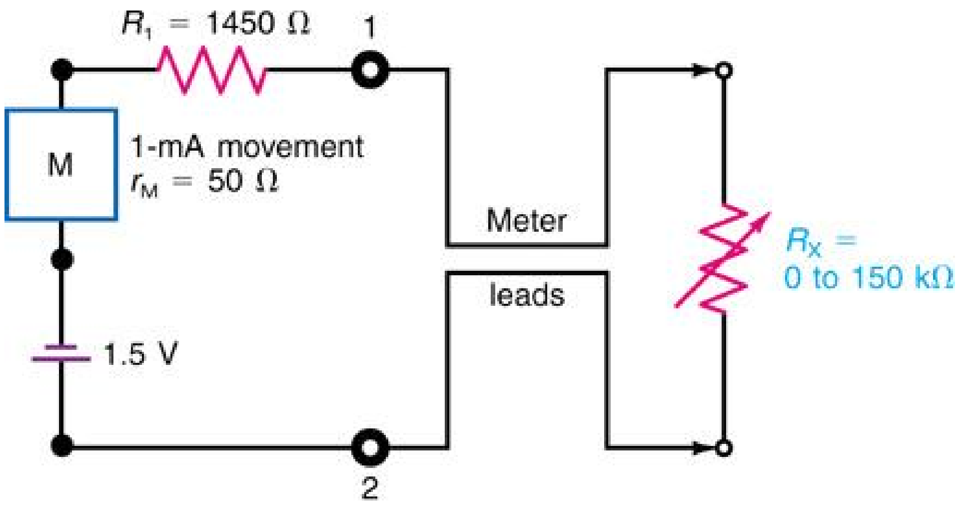
- An ohmmeter consists of an internal battery in series with the meter movement, and a current limiting resistance.
- Power in the circuit being tested is shut off.
- Current from the internal battery flows through the resistance being measured, producing a deflection that is:
  - Proportional to the current flow, and
  - Displayed on a back-off scale, with ohm values increasing to the left as the current backs off from full-scale deflection.

Ohmmeters

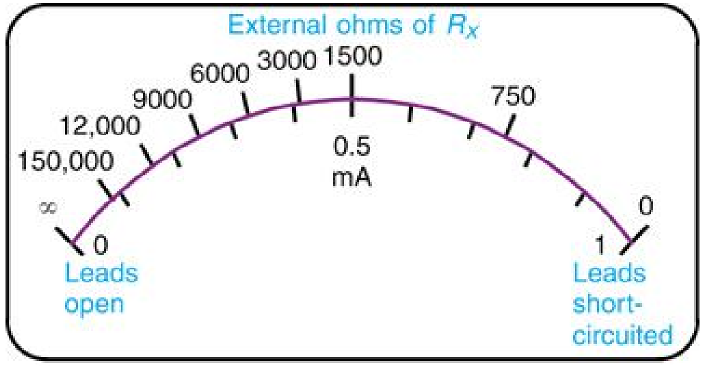


How meter movement *M* can be used as an ohmmeter with a 1.5-V battery. (*a*) Equivalent closed circuit with R_1 and the battery when ohmmeter leads are short-circuited for zero ohms of external *R.* (*b*) Internal ohmmeter circuit with test leads open, ready to measure an external resistance.

Ohmmeters



(*a*)



(*b*)

Resistance R_T is the total resistance of R_X and the ohmmeter's internal resistance. NOTE: R_X is the external resistance to be measured.

The ohmmeter's internal resistance R_i is constant at 50 + 1450, or 1500 Ω here. If R_X also equals 1500 Ω, R_T equals 3000 Ω.

The current then is 1.5 V/3000 Ω, or 0.5 mA, resulting in half-scale deflection for the 1-mA movement.

Multimeters

- **Multimeters** are also called multitesters.
- Multimeters are used to measure voltage, current, or resistance.
- Main types of multimeters are:
  - Volt-ohm-milliammeter (VOM)
  - Digital multimeter (DMM)

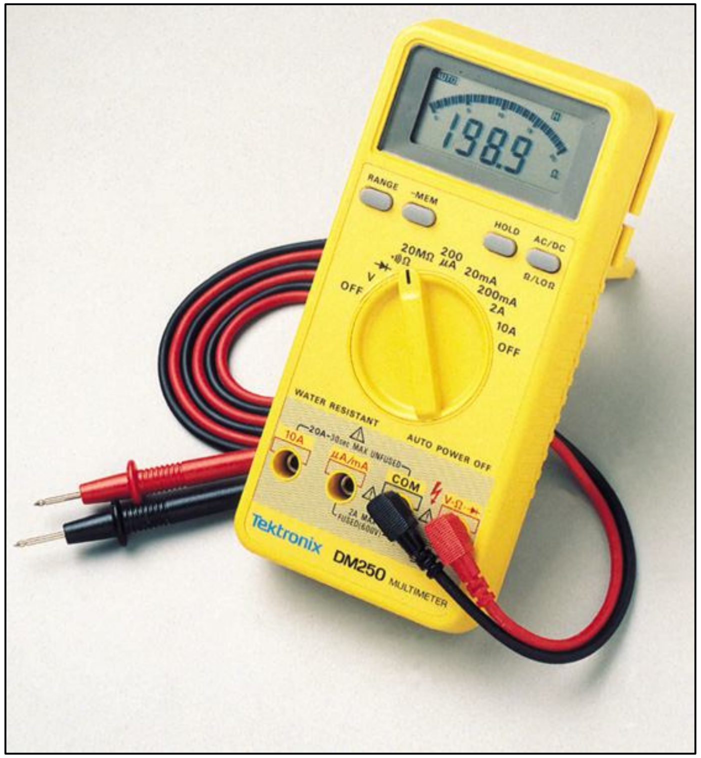
Multimeters

Comparison between VOM and DMM

VOM	DMM
Analog pointer reading	Digital readout
DC voltmeter R_V changes with range	R_V is 10 or 22 MΩ, the same on all ranges
Zero-ohms adjustment changed for each range	No zero-ohms adjustment
Ohm ranges up to R x 10,000 Ω, as a multiplying factor	Ohm ranges up to 20 MΩ; each range is the maximum

Multimeters

Analog VOM that combines a function selector and range switch.



Portable digital multimeter (DMM).

Multimeters

DMM with amp clamp accessory.

The problem of opening a circuit to measure current can be eliminated by using a probe with a clamp that fits around the current-carrying wire.

The clamp probe measures only ac, generally for the 60-Hz ac power line.

Digital Multimeters (DMMs)

- The **digital multimeter** has become a very popular test instrument.
- The digital value of the measurement is displayed automatically with decimal point, polarity, and the unit for V, A, or Ω.

Digital Multimeters (DMMs)

Typical digital multimeter (DMM).

- ❑ **Digital multimeters** are generally easier to use.

- ❑ They eliminate the human error that often occurs in reading different scales on an analog meter with a pointer.

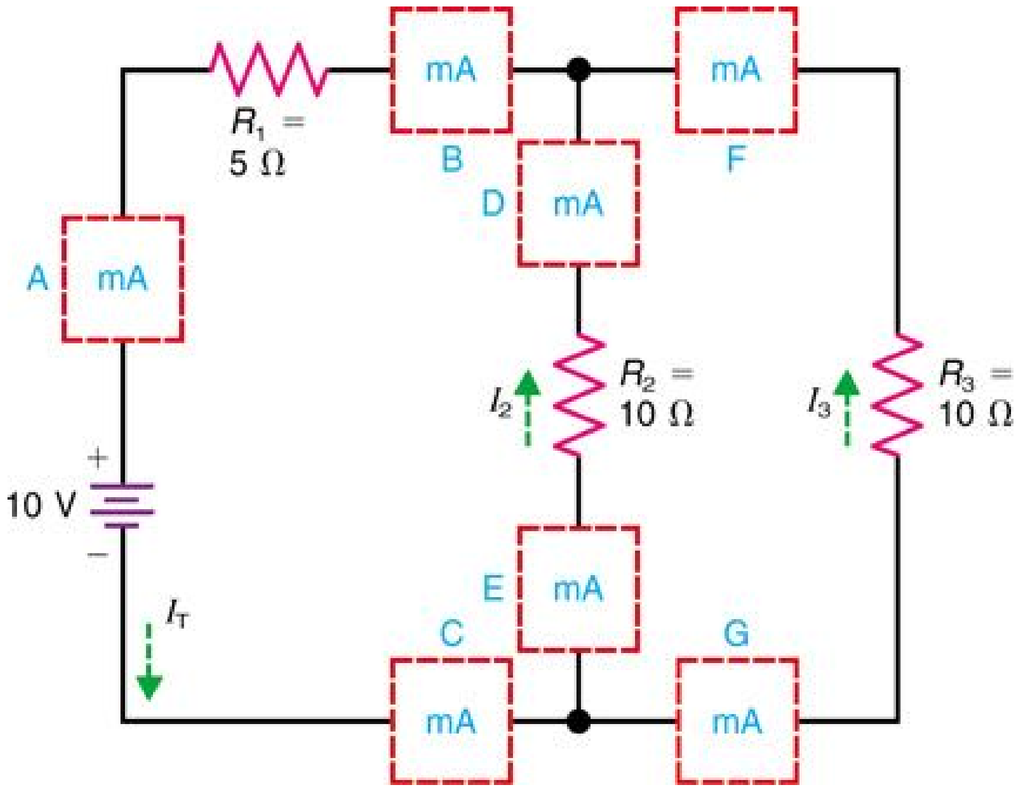
Meter Applications

- **Table 8-4** (next slide) summarizes the main points to remember when using a voltmeter, ohmmeter, or milliammeter.

Meter Applications

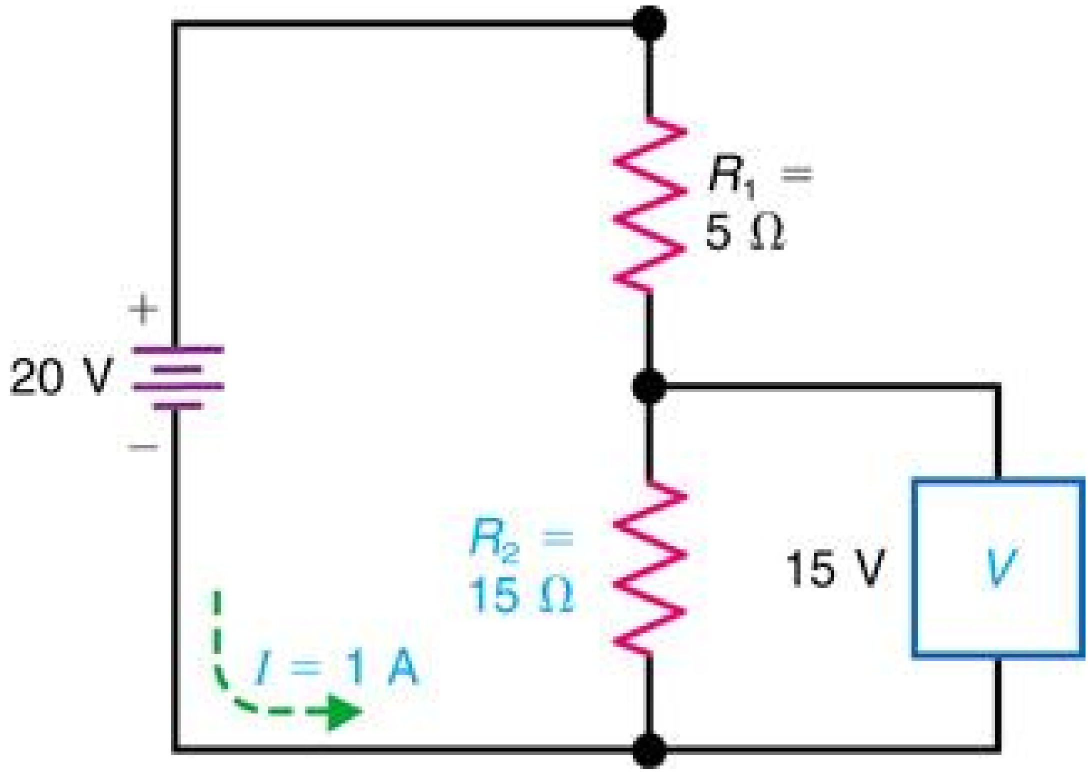
Voltmeter	Milliammeter or Ammeter	Ohmmeter
Power on in circuit	Power on in circuit	Power off in circuit
Connect in parallel	Connect in series	Connect in parallel
High internal R	Low internal R	Has internal battery
Has internal series multipliers; higher R for higher ranges	Has internal shunts; lower resistance for higher current ratings	Higher battery voltage and more sensitive meter for higher ohms ranges

Meter Applications



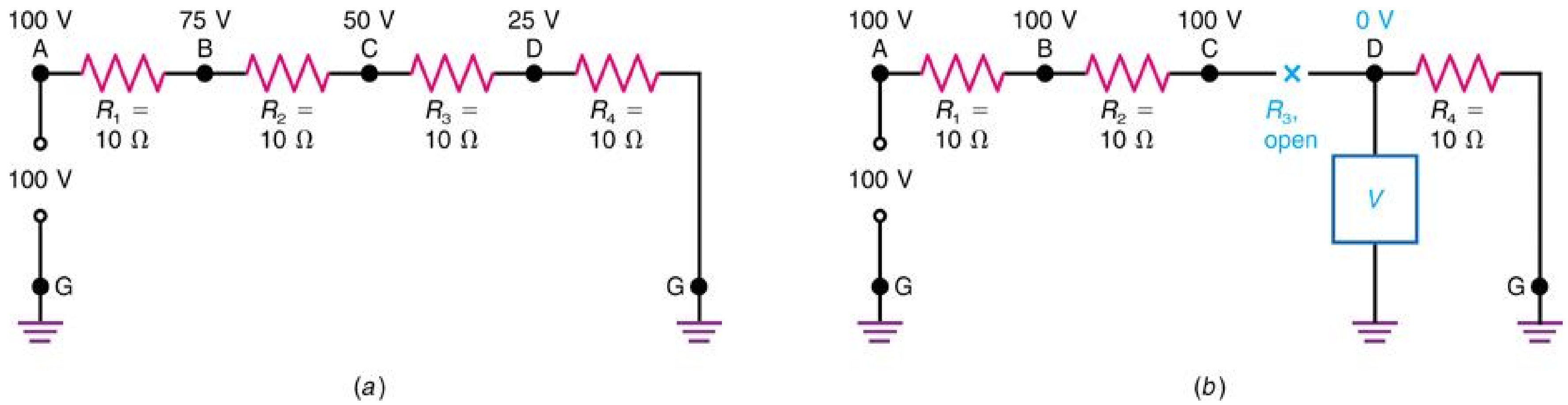
How to insert a current meter in different parts of a series-parallel circuit to read the desired current I. At point A, B, or C the meter reads I_T; at D or E the meter reads I_2; at F or G the meter reads I_3.

Meter Applications



With 15 V measured across a known *R* of 15 Ω, the *I* can be calculated as *V/R* or 15 V / 15 Ω = 1 A.

Meter Applications

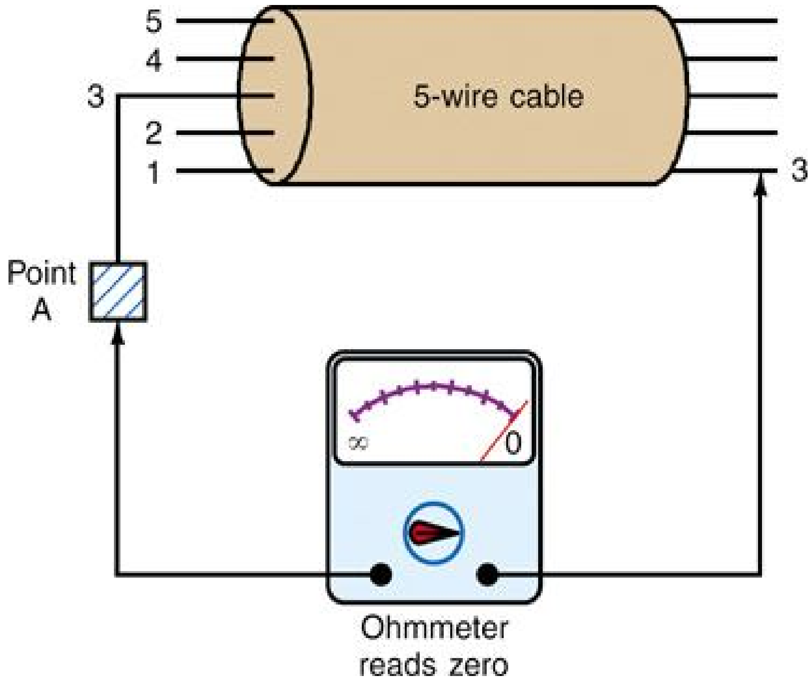


Voltage tests to localize an open circuit. (*a*) Normal circuit with voltages to chassis ground. (*b*) Reading of 0 V at point D shows R_3 is open.

Checking Continuity with the Ohmmeter

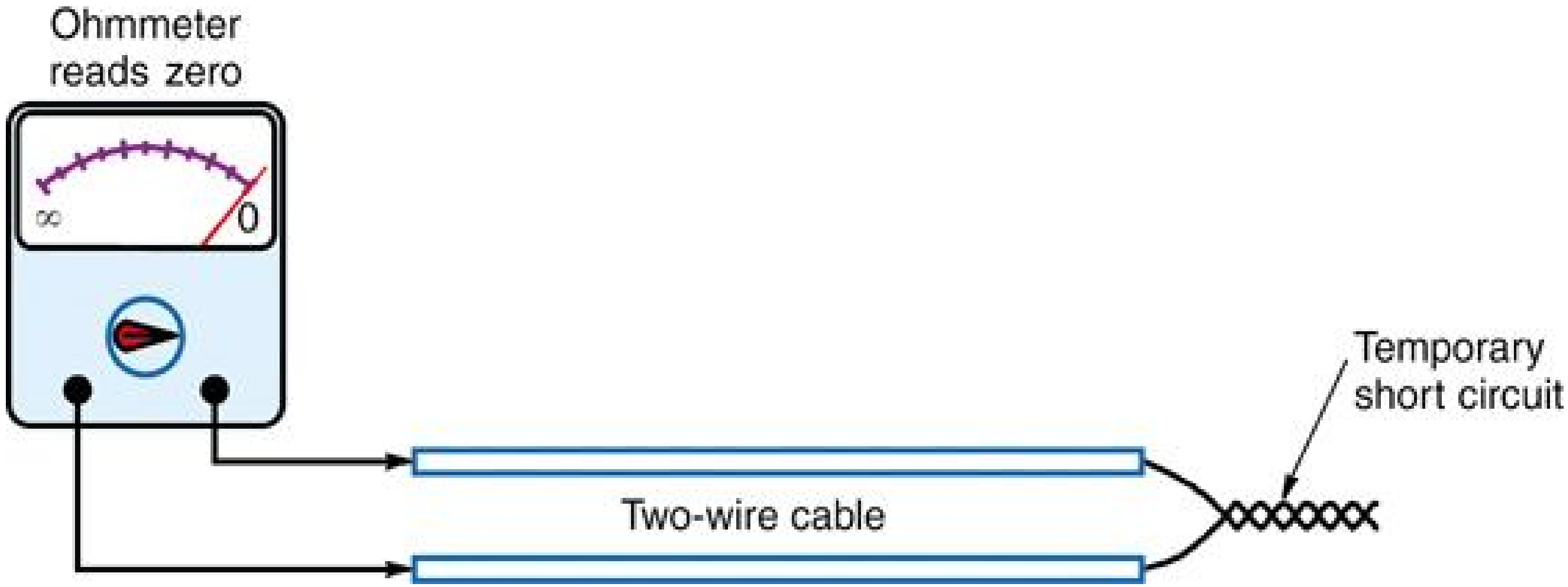
- The ohmmeter is a great tool for checking the continuity between two points.
- When checking for continuity, make sure the ohmmeter is set on the lowest ohms range.
- If continuity exists between two points, the ohmmeter will read a very low resistance such as zero ohms.
- If there is no continuity between two points, the ohmmeter will read infinite ohms.

Checking Continuity with the Ohmmeter



Continuity testing from point A to wire 3 shows this wire is connected.

Checking Continuity with the Ohmmeter



Temporary short circuit at one end of a long two-wire line to check continuity from the opposite end.