CHAPTER 2

DC and AC Meters (part2)

STRUCTURE FOR CHAP

PART 1 (DC)

- Introduction to DC meters
- D' Arsonval meter movement
- DC ammeter
- DC voltmeter
- DC ohmmeter

PART 2 (AC)

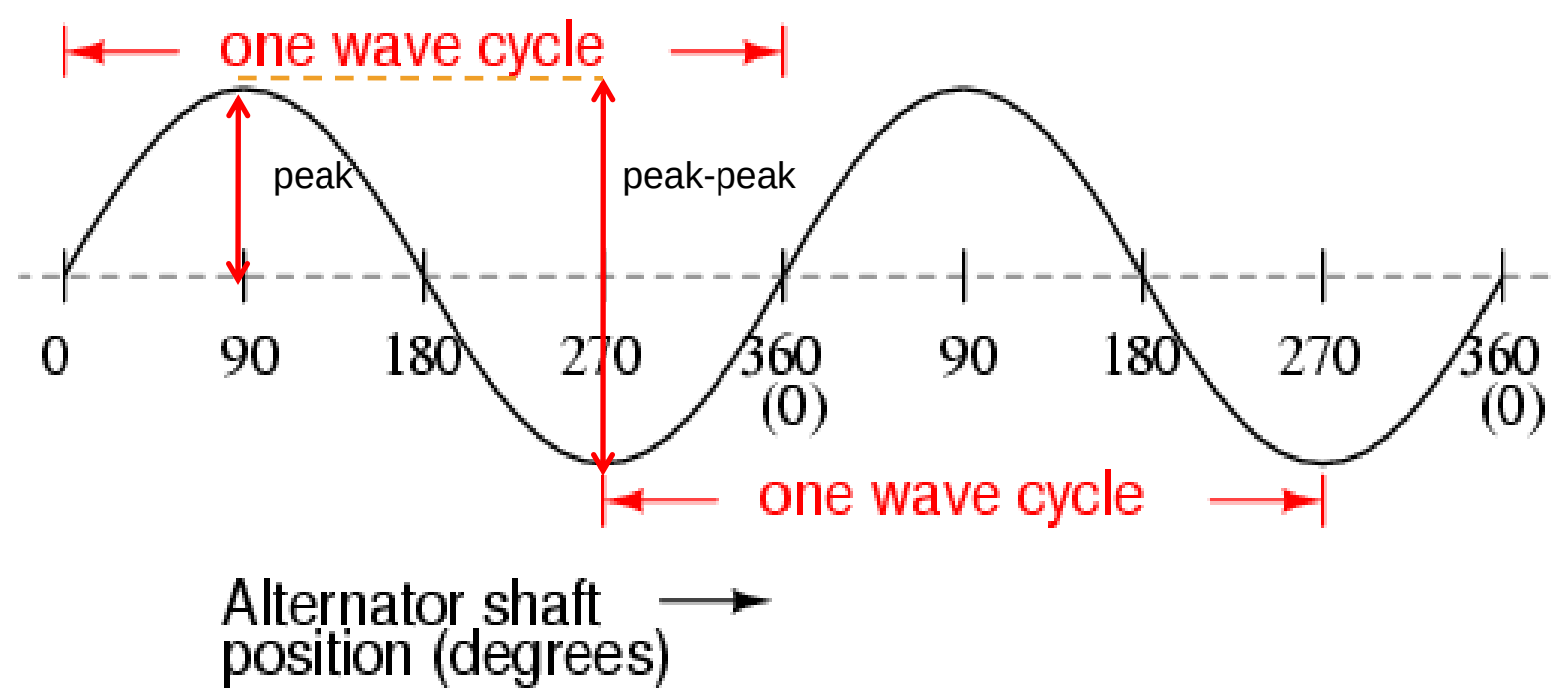
- Introduction to AC meters
- D' Arsonval meter movement (half-wave rectification)
- D' Arsonval meter movement (full-wave rectification)
- Loading effects of AC meter

PART 2 – AC METERS (INTRO..)

- Several types of meter movements maybe used to measure AC current or voltage.
- The five principle meter movements used in ac instruments are listed in Table below:

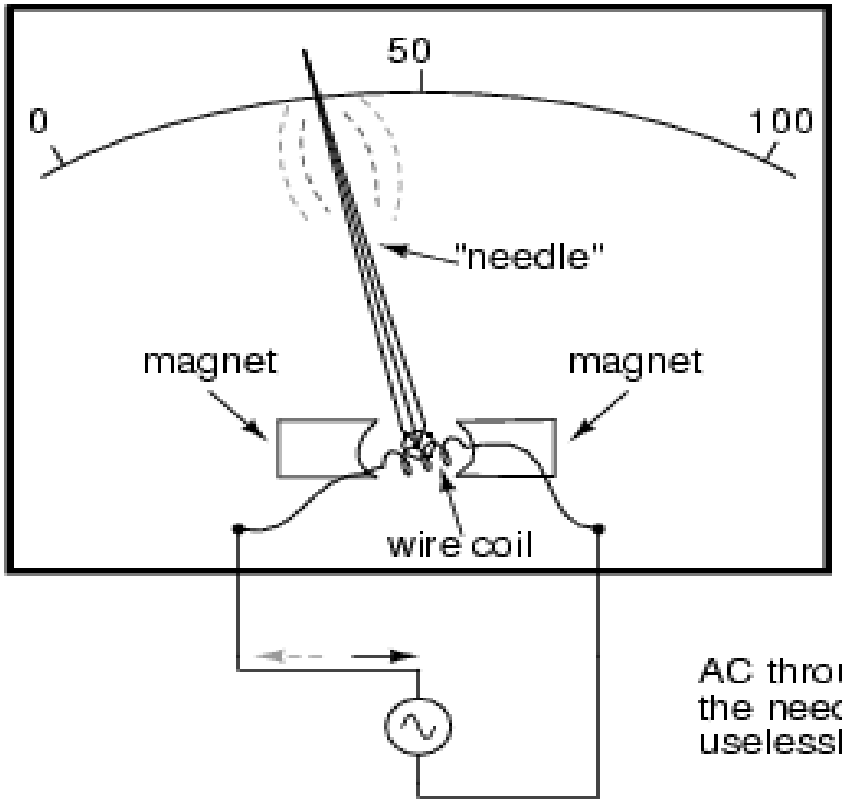
No	Meter Movement	DC Use	AC Use	Applications
1	Electro-dynamometer	YES	YES	Standard meter,Wattmeter, etc..
2	Iron-Vane	YES	YES	Indicator applications, etc…
3	Electro-static	YES	YES	High voltage measurement.
4	Thermocouple	YES	YES	Radio freq measurement
5	D'Arsonval	YES	YES-w/ rectifiers	Voltage, currents, resistance, etc…

SINE WAVEFORM



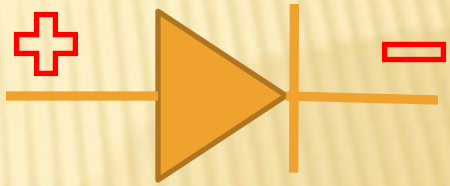
IF THE DMM IS CONNECTED TO AC SOURCE?

D'Arsonval electromechanical meter movement



AC through this movement will cause the needle to flutter back and forth uselessly.

HOW TO MODIFY THE DMM TO BE AS AC METERS?

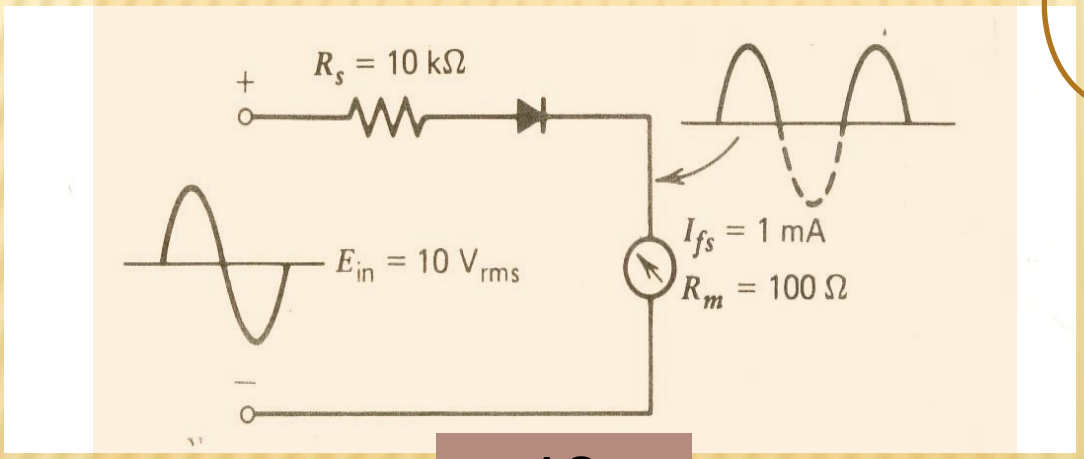


Needs for rectification

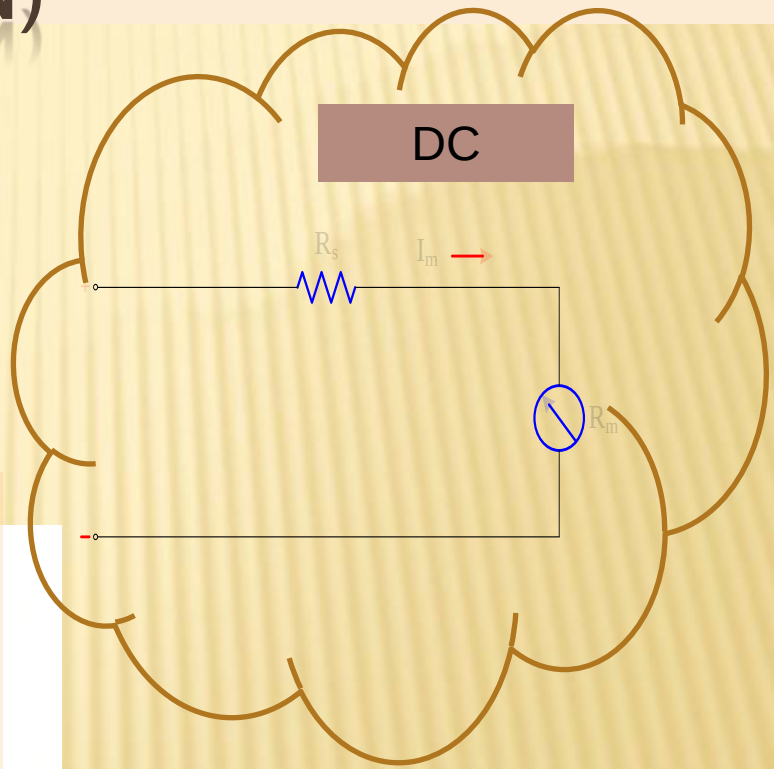
- Convert AC source to DC source
- Most common rectification device is diode (a nonlinear device)
- Two types of rectifier circuits:
  - Half-Wave rectifier circuit
  - Full-Wave rectifier circuit

D' ARSONVAL METER MOVEMENT (HALF-WAVE RECTIFICATION)

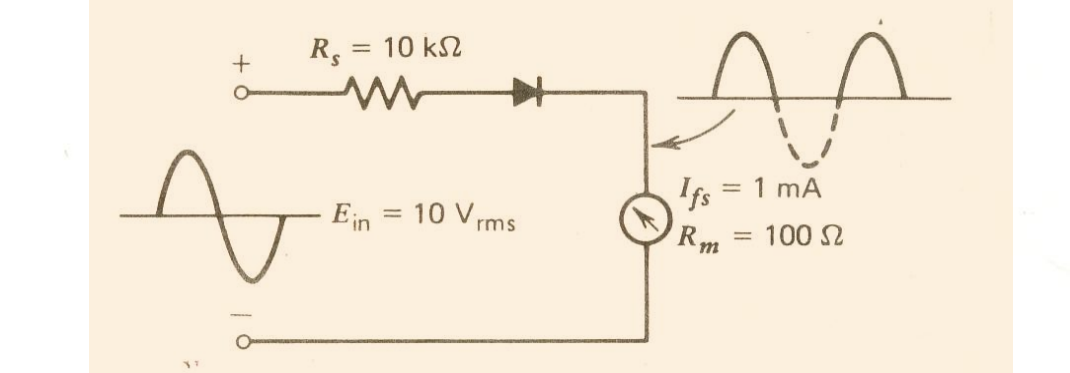
suppose we replace the 10-Vdc with 10Vrms…



AC



DMM (HALF-WAVE RECTIFICATION) CONT'D



Peak Value,

$$E_p = E_{rms} x\sqrt{2} = 1.414 E_{rms}$$

Average value, or DC value

$$E_{ave} = E_{dc} = \frac{E_p}{\pi} = 0.318 \;\; E_p = 0.45 E_{rms}$$

DMM (HALF-WAVE RECTIFICATION) CONT'D

- Diode = Produces half sine wave across load resistor
- * DC/Ave. Voltage → The dc meter will only respond to the average value of ac sine wave.

Simple example:

- If we were to measure 10V DC, the meter will deflect which indicate 10V
- However, if we were to measure 10 V rms, the meter will deflect which indicate only 4.5V
- DC voltmeter = 4.5V (Meter read dc/average voltage only)
- Ac voltmeter is not sensitive as a dc voltmeter
- Approximately 45% as sensitive as a dc voltmeter

DMM (HALF-WAVE RECTIFICATION) CONT'D

$$S_{ac} = 0.45 S_{dc}$$

$$R_T = R_s + R_m = \frac{E_{DC}}{I_{DC}}$$

$$R_s = \frac{E_{DC}}{I_{DC/\,fs}} - R_m = \frac{0.45 E_{rms}}{I_{dc/\,fs}} - R_m$$

where $S = 1/I_{dc}\ (\Omega/V)$

Therefore,

$R_s = S \times 0.45\ E_{rms} - R_m$

In general, multiplier resistor (R_s)

$R_s = (S \times Range) - R_m$

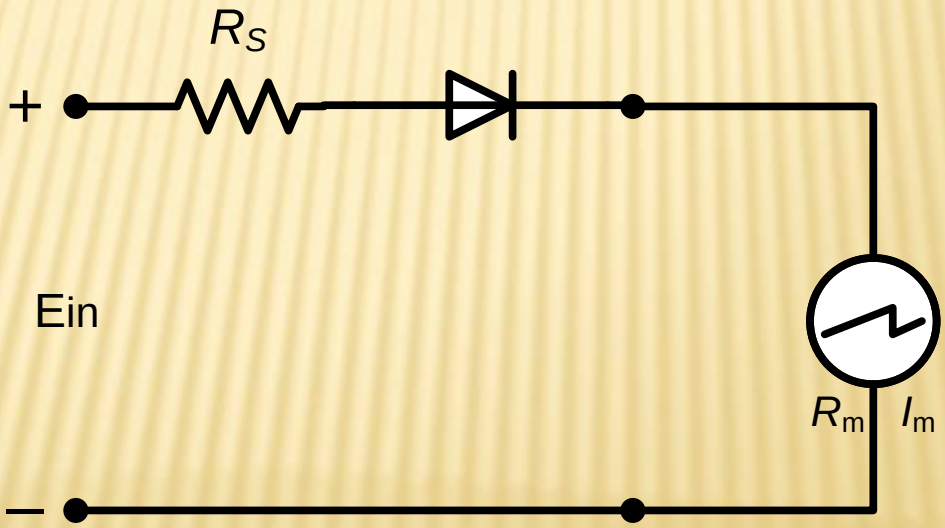
for DC: $R_s = (S_{dc} \times Range_{dc}) - R_m$

for AC: $R_s = (S_{ac} \times Range_{ac}) - R_m$

EXAMPLE 1

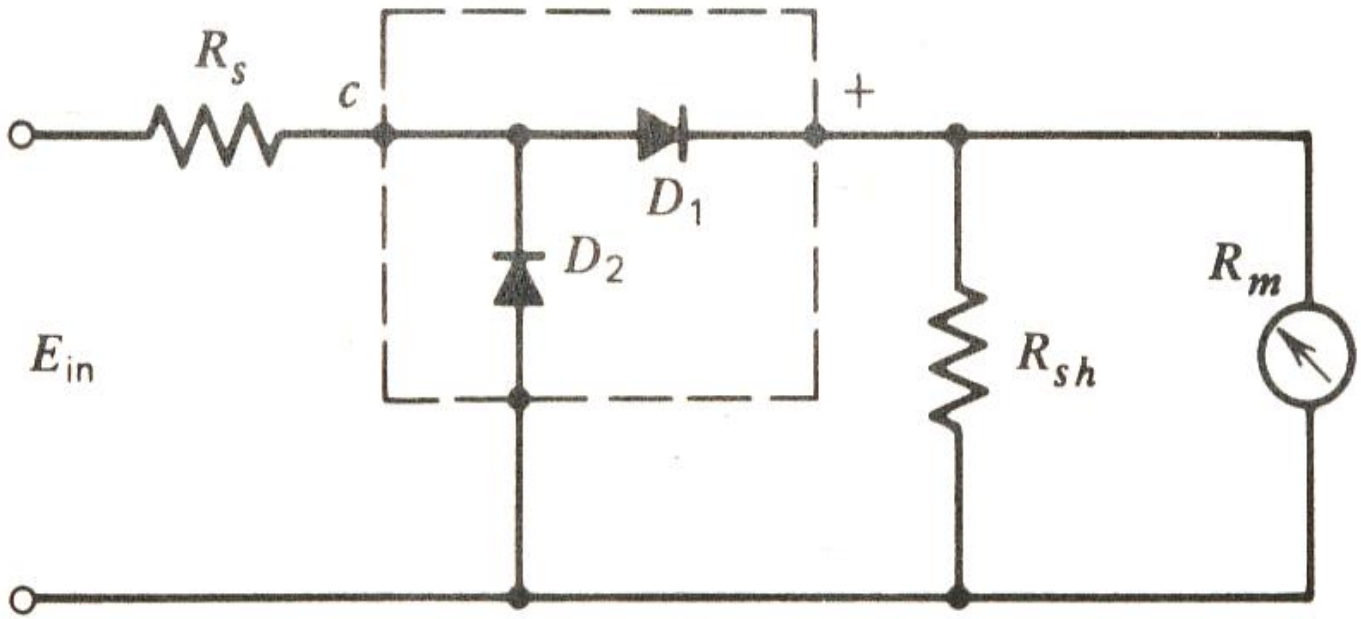
Compute the value of R_s for a 10-V_{rms} AC range on the voltmeter shown in Figure 1.

Given that E_{in}= 10V_{rms}, I_{fs}= 1mA, R_m=300Ω.

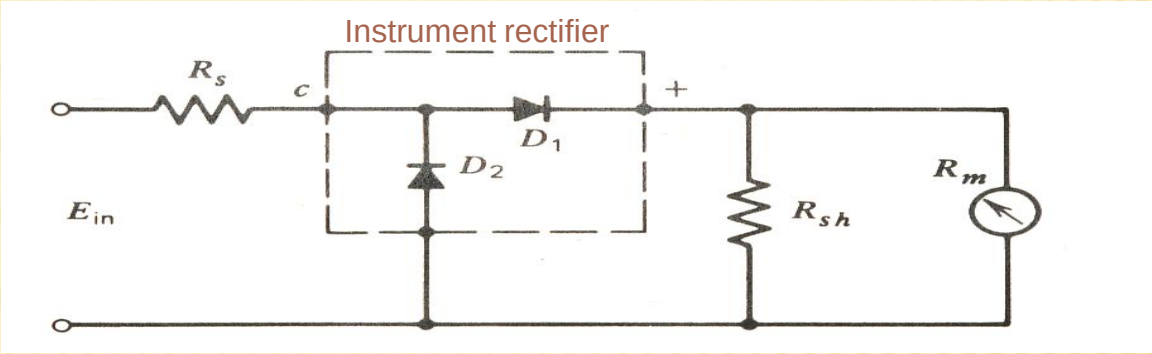


COMMERCIAL AC VOLTMETERS

Instrument rectifier



COMMERCIAL AC VOLTMETERS (CONT'D)



R_{sh} :

- increase current flow through D_1 during the +ve ½ cycle
- diode will be operating in linear region
- improve linearity of AC meter during measurement of low voltage, but further reduces the ac sensitivity

D_2 :

- +ve ½ cycle = no effect (Reverse-bias)
- -ve ½ cycle = provides an alternate path for reverse biased leakage current that would normally flow through meter movement and D_1.

EXAMPLE 2

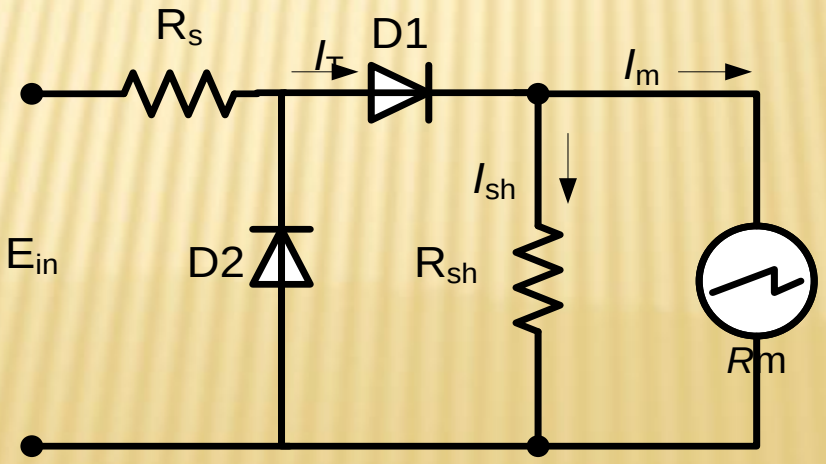
In the ½ wave rectifier shown below, D1 and D2 have an average forward resistance of 50Ω and are assumed to have an infinite resistance in reverse biased. Calculate the following:

(a) R_s value

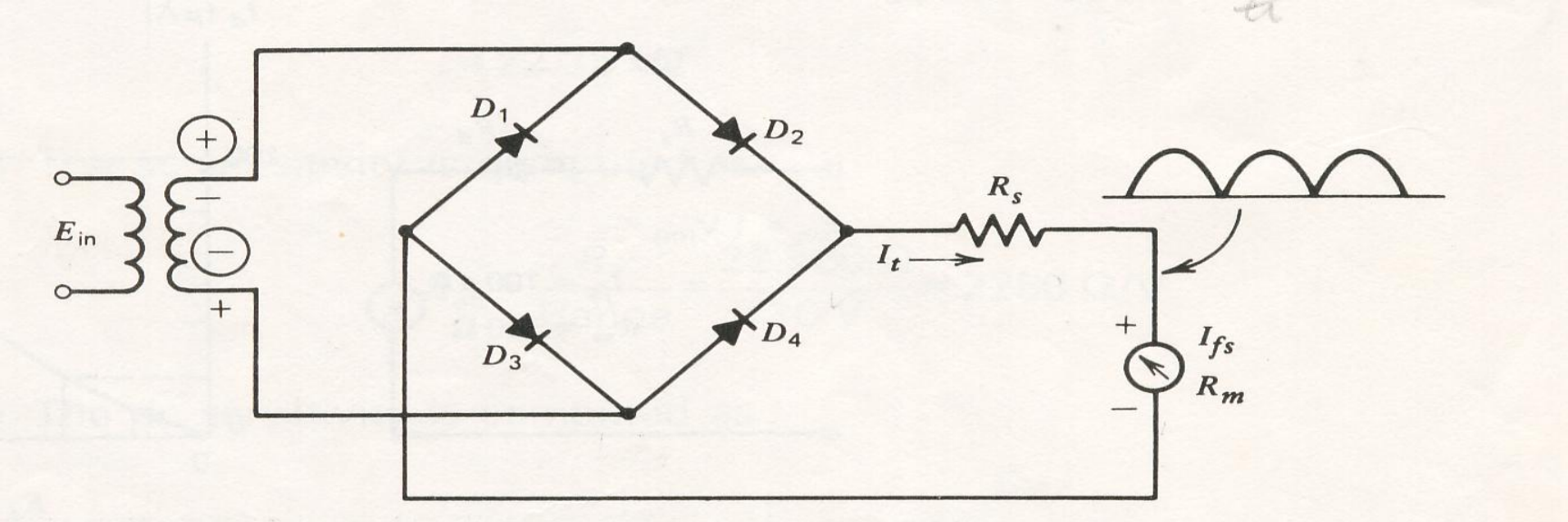
(b) S_{dc}

(c) S_{ac}

Given that E_{in} = 10-V_{rms}, R_{sh} = 200Ω, I_{fs} = 100μA, R_m = 200Ω



D' ARSONVAL METER MOVEMENT (FULL-WAVE RECTIFICATION)



- Full-wave has higher sensitivity rating
- Change the input waveform from +ve & -ve to only +ve

DMM FULL-WAVE RECTIFICATION (CONT'D)

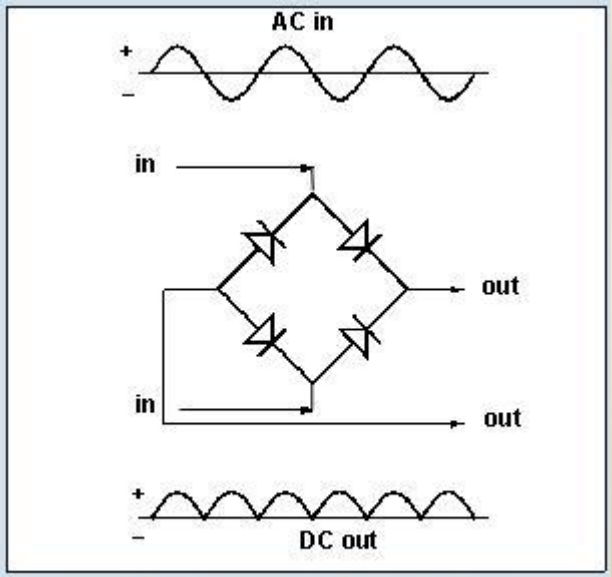
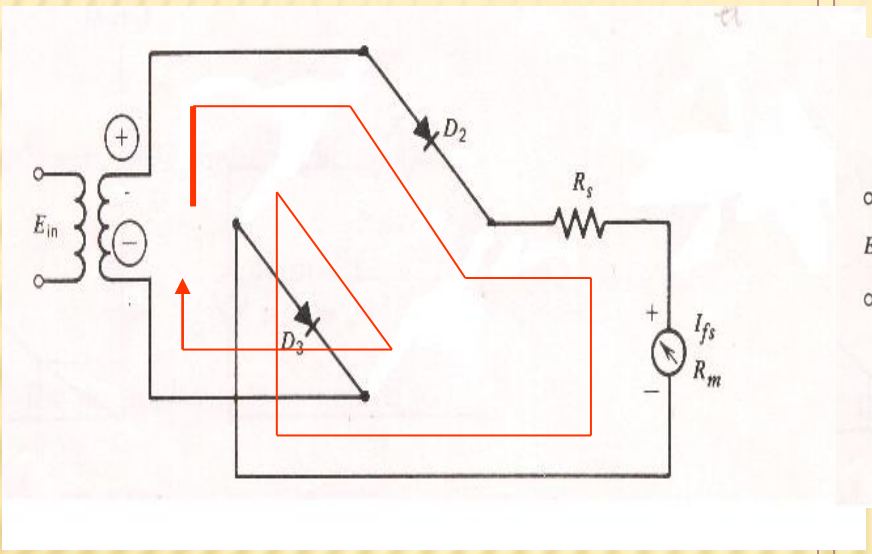


Figure 1. Full wave rectifier circuit diagram

DMM-FULL-WAVE RECTIFICATION (CONT'D)

POSITIVE CYCLE

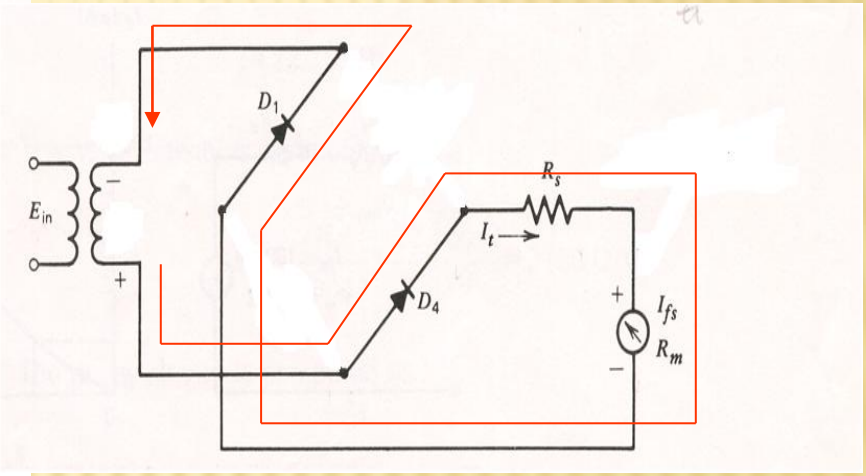


(Diode Ideal, R=0)

$E_{in} = V_{Rs} + V_{Rm}$

$V_{Rm} = E_{in} - V_{Rs}$

NEGATIVE CYCLE



(Diode Ideal, R=0)

$E_{in} = V_{Rs} + V_{Rm}$

$V_{Rm} = E_{in} - V_{Rs}$

DMM FULL-WAVE RECTIFICATION (CONT'D)

Peak Value,

$$E_p = E_{rms}\sqrt{2}$$

Average value, or DC value,

$$E_{avg} = \frac{2E_p}{\pi} = \frac{2\left(\sqrt{2}\right)E_{rms}}{\pi} = 0.9xE_{rms}$$

AC Sensitivity,

$$S_{ac} = 0.9S_{dc}$$

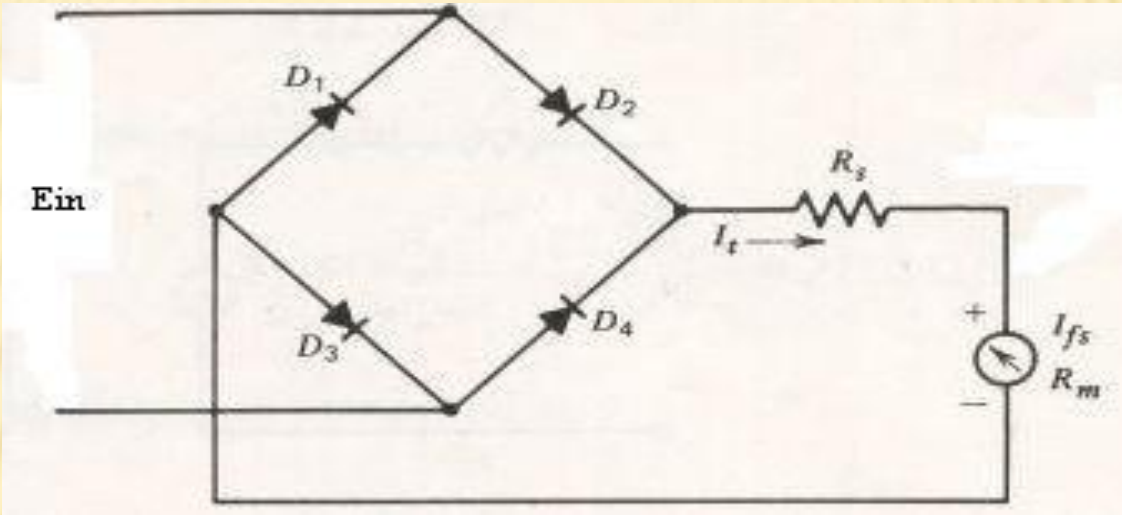
DC Sensitivity,

$$S_{dc} = \frac{R_T}{Range_{dc}} = \frac{1}{I_T}$$

Total Resistance of AC voltmeter,

$$R_T = \frac{E_{dc}}{I_T} = S_{ac} \text{ x } Range_{ac}$$

EXAMPLE 3



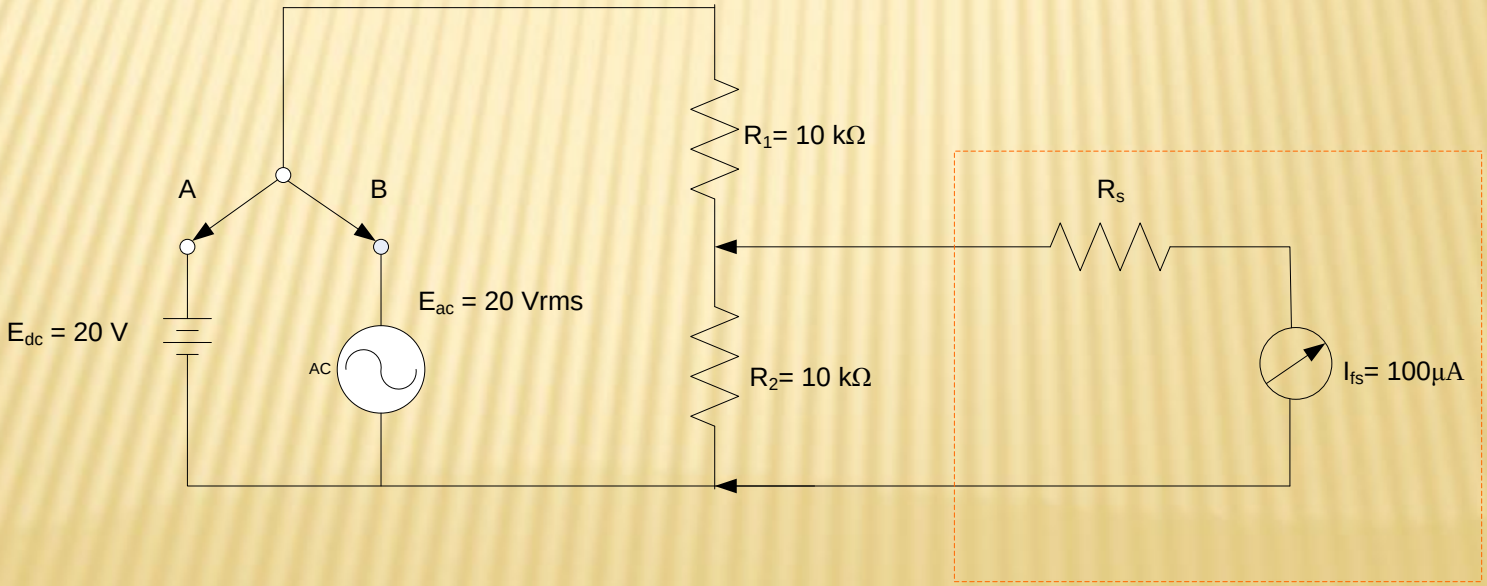
Compute the value of the multiplier resistor for a 10-V rms range on the voltmeter shown above. Let E_{in} = 10Vrms, I_{fs}=1mA, R_m=500Ω

LOADING EFFECTS OF AC METER

Sensitivity AC < Sensitivity DC

Therefore

Loading Effects AC > Loading Effect DC ----$Range_{dc}$=10 V, $Range_{ac}$=10 Vrms



REFRESH LOADING EFFECT (DC VOLTMETER)

Actual value of E_2,

$$E_{R2,\,actual} = \frac{R_2}{R_1 + R_2}(E_{dc}) = 10V$$

DC voltmeter,

$$S_{dc} = \frac{1}{I_{fs}} = \frac{1}{100\mu A} = 10\frac{k\Omega}{V}$$

$$R_T = S_{dc} x Range_{dc} = 10\frac{k\Omega}{V} x10V = 100k\Omega$$

$$E_{R2,\,DCvoltemeter} = \frac{R_T \| R_2}{(R_T \| R_2) + R_1}(20V) = 9.52V$$

LOADING EFFECTS OF AC METER (CONT'D)

HALF-WAVE	FULL-WAVE
$S_{hw} = 0.45 S_{dc} = 4.5 \frac{k\Omega}{V}$	$S_{fw} = 0.9 S_{dc} = 9.0 \frac{k\Omega}{V}$
$R_T = S_{hw} x Range_{dc} = 4.5 \frac{k\Omega}{V} x 10V = 45k\Omega$	$R_T = S_w x Range_{dc} = 4.5 \frac{k\Omega}{V} x 10V = 45k\Omega$
$E_{R2,\,HalfWave} = \frac{R_T \Vert R_2}{(R_T \Vert R_2) + R_1}(E_{dc}) = 9.0V$	$E_{R2,\,FullWave} = \frac{R_T \Vert R_2}{(R_T \Vert R_2) + R_1}(E_{dc}) = 9.47V$

SENSITIVITY AC < SENSITIVITY DC

$$S_{hw} = 0.45 S_{dc} = 4.5 \frac{k\Omega}{V}$$

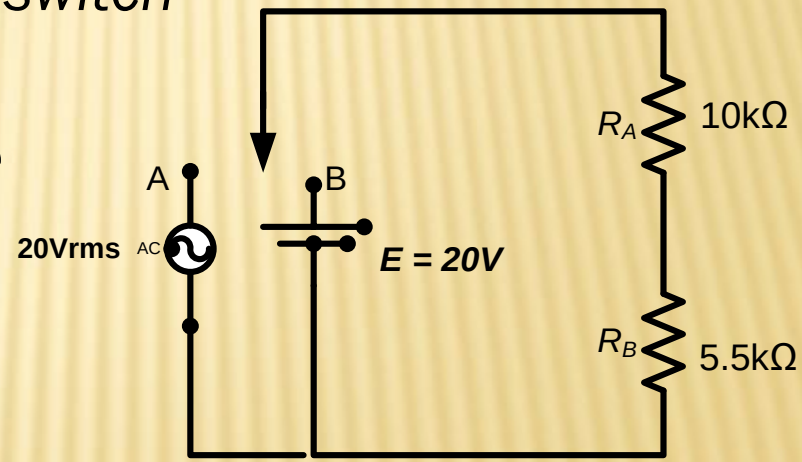
$$S_{fw} = 0.9 S_{dc} = 9.0 \frac{k\Omega}{V}$$

$$S_{dc} = \frac{1}{I_{fs}} = \frac{1}{100\mu A} = 10 \frac{k\Omega}{V}$$

EXAMPLE 4

a) *Determine the reading obtained with a DC voltmeter at R_B when the switch is set at point B.*

b) *Determine the reading at the same R_B using ½ wave and Full wave rectifier AC meter respectively when the switch is set at point A.*



Given that Ifs = 100-μA and set at 10-V dc or rms range.

END OF PART 2