

**ASME MFC-16–2007**

**[Revision of ASME MFC-16M–1995 (R2006)]**

# **Measurement of Liquid Flow in Closed Conduits With Electromagnetic Flowmeters**

**AN AMERICAN NATIONAL STANDARD**



**The American Society of  
Mechanical Engineers**

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# FOREWORD

This Standard was prepared by Subcommittee 16 of the ASME Committee on the Measurement of Liquid Flow in Closed Conduits. The chair of the subcommittee is indebted to the many individuals who contributed to this document.

Electromagnetic flowmeters were introduced to the process industries in the mid 1950s. They quickly became an accepted flowmeter for difficult applications. Subsequent improvements in technology and reductions in cost have transformed this flowmeter into one of the leading contenders for general use in water based and other electrically conducting liquid applications.

Due to differences in design of the various electromagnetic flowmeters in the marketplace, this Standard cannot address detailed performance limitations in specific applications. It covers issues that are common to all meters, including application considerations.

Suggestions for improvements to this Standard are encouraged. They should be sent to: Secretary, ASME MFC Committee, the American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ASME MFC-16-2007 was approved by the American National Standards Institute (ANSI) on March 26, 2007.



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The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

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The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in this format will be rewritten in this format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

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# MEASUREMENT OF LIQUID FLOW IN CLOSED CONDUITS WITH ELECTROMAGNETIC FLOWMETERS

## 1 SCOPE

This Standard is applicable to industrial electromagnetic flowmeters and their application in the measurement of liquid flow. The electromagnetic flowmeters covered by this Standard utilize an alternating electrical current (AC) or pulsed direct-current (pulsed-DC) to generate a magnetic field in electrically conductive and electrically-homogeneous liquids or slurries flowing in a completely filled, closed conduit.

This Standard specifically does not cover insertion-type electromagnetic flowmeters, meters used to measure flow in partially filled pipe, or those used in surgical, therapeutic, or other health and medical applications. It also does not cover applications of industrial flowmeters involving nonconductive liquids or highly conductive liquids (e.g., liquid metals).

## 2 REFERENCES

All references are to the latest published edition of these standards. The following is a list of publications referenced in this Standard.

ASME B16 Series, Standards for Valves, Fittings, Flanges, and Gaskets

ASME MFC-1M, Glossary of Terms Used in the Measurement of Fluid Flow in Pipes

Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, P.O. Box 2300, Fairfield, NJ 07007-2300

ISO 13359, Measurement of Conductive Liquid Flow in Closed Conduits — Flanged Electromagnetic Flowmeters — Overall Length

Publisher: International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Genève 20, Switzerland/Suisse

## 3 DEFINITIONS AND SYMBOLS

(a) Paragraph 3.1 lists definitions from ASME MFC-1M used in ASME MFC-16.

(b) Paragraph 3.2 lists definitions specific to this Standard.

(c) Paragraph 3.3 lists symbols used in this Standard (see Table 1).

### 3.1 Definitions From ASME MFC-1M

*accuracy*: the degree of freedom from error; the degree of conformity of the indicated value to the true value of the measured quantity.

*precision*: the closeness of agreement between the results obtained by applying the experimental procedure several times under prescribed conditions. The smaller the random part of the experimental errors that affect the results, the more precise is the procedure.

*rangeability (turndown)*: flowmeter rangeability is the ratio of the maximum to minimum flow rates or Reynolds number in the range over which the meter meets a specified uncertainty (accuracy).

*repeatability*: the closeness of agreement among a series of results obtained with the same method on identical test material, under the same conditions (same operator, same apparatus, same laboratory, and short intervals of time).

*uncertainty (of measurement)*: the range within which the true value of the measured quantity can be expected to lie with a specified probability and confidence level.

### 3.2 Definitions for ASME MFC-16

*bias*: the systematic errors (i.e., those that cannot be reduced by increasing the number of measurements taken under fixed flow conditions).

*flowmeter primary*: includes the flowtube, process connections, electromagnetic coils, and electrodes. Flowmeter primary is also known by other names such as: flowmeter primary device, primary device, primary etc.

*flowmeter secondary*: includes the electronic transmitter, measurement of the  $emf_v$ , and in most cases the power for the electromagnet coils of the flowmeter primary.

*linearity*: linearity refers to the constancy of the meter factor over a specified range, defined by either the pipe Reynolds number or the flow rate.

*meter factor*: the number, determined by liquid calibration, that enables the output flow signal to be related to the volumetric flow rate under defined reference conditions.

### 3.3 Symbols

See Table 1.





**Table 1 Symbols**

	Quantity	Dimensions [Note (1)]	SI Unit	USC Units
$C$	A dimensionless parameter that depends on the specific design of the flowmeter (see section 4) [Note (2)]	...	...	...
$D$	Inner diameter of the flowtube [Note (3)]	$L$	m	in. (inch)
$K$	Meter factor, typically determined by liquid flow calibration [Note (2)]	$M^{-1}LT^2I$	$m^3/s/volt$	$ft^3/s/volt$
$V$	Average special velocity [Note (3)]	$LT^{-1}$	m/s	ft/s
$B_o$	Average magnetic field between the electrodes [Note (2)]	$MT^{-2}I^{-1}$	Tesla	...
$q$	Flow rate, volumetric	$L^3T^{-1}$	$m^3/s$	$ft^3/s$
$emf$	Electromotive force	$ML^2T^{-3}I^{-1}$	volt	Volt
$emf_c$	Electrochemical electromotive force [Note (2)]	$ML^2T^{-3}I^{-1}$	volt	Volt
$emf_v$	Velocity related electromotive force [Note (2)]	$ML^2T^{-3}I^{-1}$	volt	Volt
$emf_t$	Transformer related electromotive force [Note (2)]	$ML^2T^{-3}I^{-1}$	volt	Volt
$emf_F$	Electromotive force per Faraday's Law	$ML^2T^{-3}I^{-1}$	volt	Volt
$\bullet$	Indicates scalar product	Dimensionless	...	...

## NOTES:

- (1) Dimensions:  $M$  = mass,  $L$  = length,  $T$  = time,  $I$  = current.  
(2) Symbols defined specifically for this Standard.  
(3) Symbols identical to ASME MFC-1M.

**4 THEORY AND MEASUREMENT TECHNIQUE**

A partial sketch of an industrial electromagnetic flowmeter is shown in Fig. 1.

Figure 2 shows a typical installation of the electromagnetic flowmeter.

**4.1 Flow-Related Electromotive Force**

Faraday's Law of Induction applied to this physical configuration predicts the generation of an electromotive force (a voltage) between the electrodes when a conductive liquid flows through the flowtube. This electromotive force is

$$emf_v = C \cdot D \cdot B_o \cdot V \quad (1)$$

where

$B_o$  = magnetic field at the center of the flowtube, Tesla

$C$  = a dimensionless parameter that depends on the specific design of the flowmeter and to a limited extent on the velocity profile. The velocity profile sensitivity of  $C$  also depends on the specific design of the flowmeter (see paras. 6.2.2 and 6.4.1.1).

$D$  = inner diameter of the flowtube, m

$emf_v$  = electromotive force, volt

$V$  = flow velocity. The average axial liquid velocity in a cross-sectional plane of the flowtube, m/s.

For added details on the theory and measurement techniques related to electromagnetic flowmeters see Nonmandatory Appendix A.

**4.2 Electrochemical Electromotive Force**

In addition to the flow-related electromotive force,  $emf_v$ , an electrochemical electromotive force,  $emf_c$ , is present between the electrodes. The  $emf_c$  is an electrochemical  $emf$  produced in the flowmeter primary similar to that generated in a battery. It can be similar in magnitude to  $emf_v$  and changes slowly. In order to reduce  $emf_c$ , which would be a measurement bias, an alternating electromagnetic field is used. There exist a number of variations of the basic AC and DC fields shown in this Standard. See para. A-2.1 for additional information. This electrochemical voltage, which varies slowly in time, is substantially reduced in magnitude by utilizing an alternating electromagnetic field.

The manner in which the electromagnetic field is varied includes the following:

(a) AC — field is varied in a sinusoidal fashion [see Fig. 3, illustration (a)]

(b) DC — field is varied in a stepwise fashion [see Fig. 3, illustrations (b) and (c)]

**4.3 Types of Electrodes**

An alternating electromagnetic field generates an alternating  $emf_v$ . Two types of electrodes can be used with an alternating electromagnetic field

(a) wetted electrodes that protrude through the pipe wall/liner into the flow stream [see Fig. 4, illustration (a)]

(b) nonwetted (capacitive) electrodes located behind or within the tube wall/liner [see Fig. 4, illustration (b)]

**4.4 Calculation of Volumetric Flow Rate**

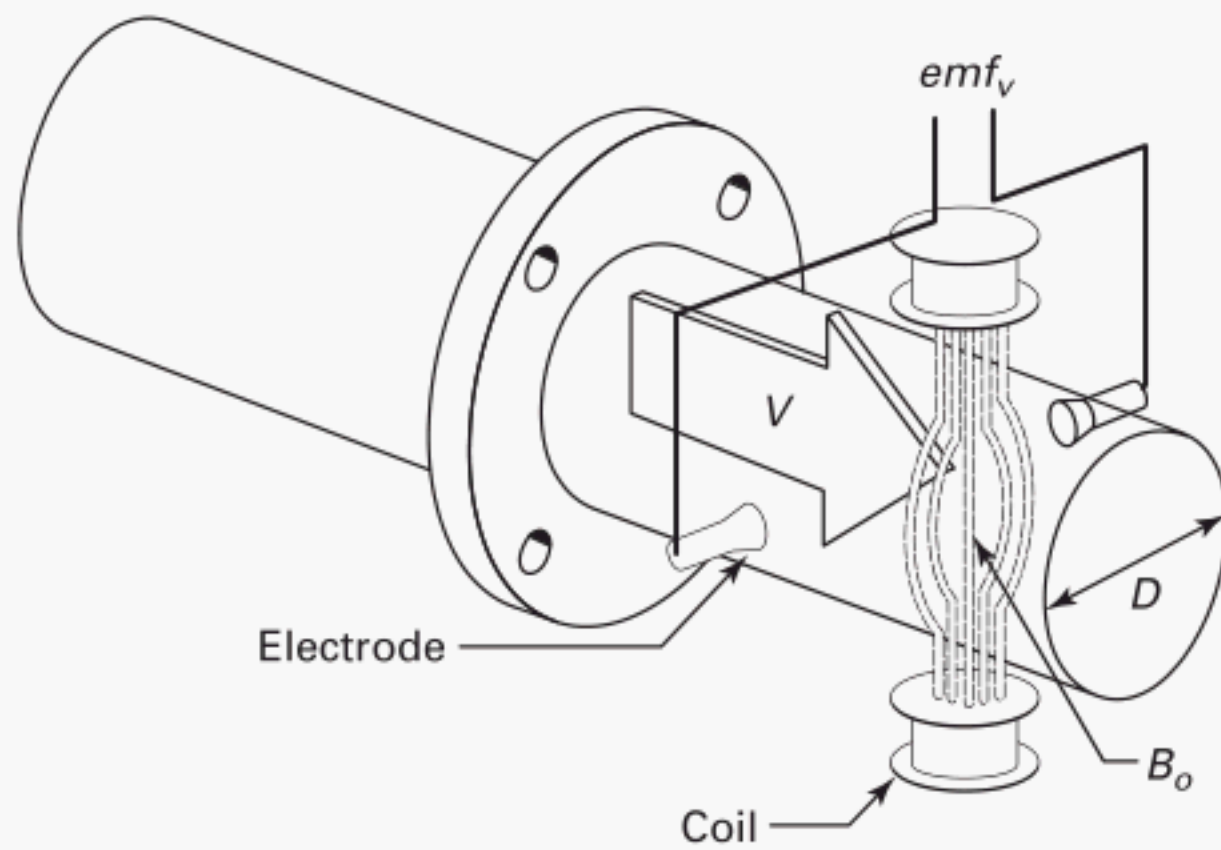
From eq. (1) the flow velocity is given by

$$V = emf_v / C \cdot D \cdot B_o$$





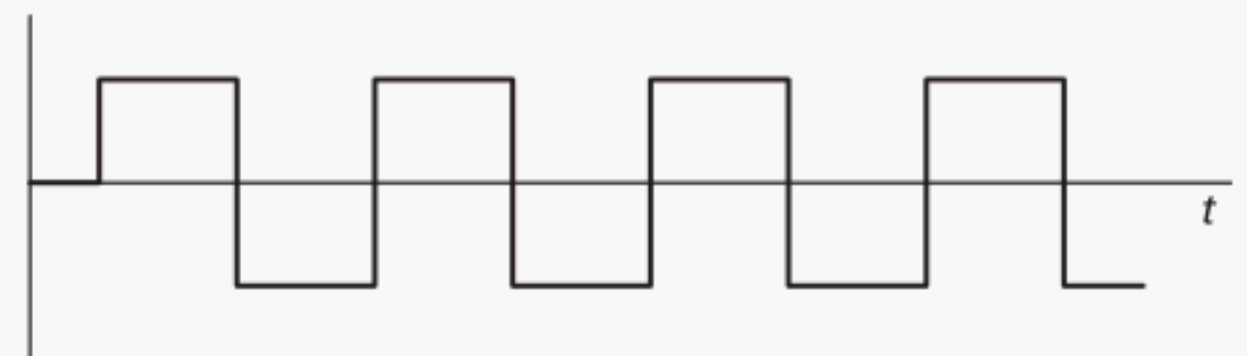
**Fig. 1 Basic Components of an Electromagnetic Flowmeter**



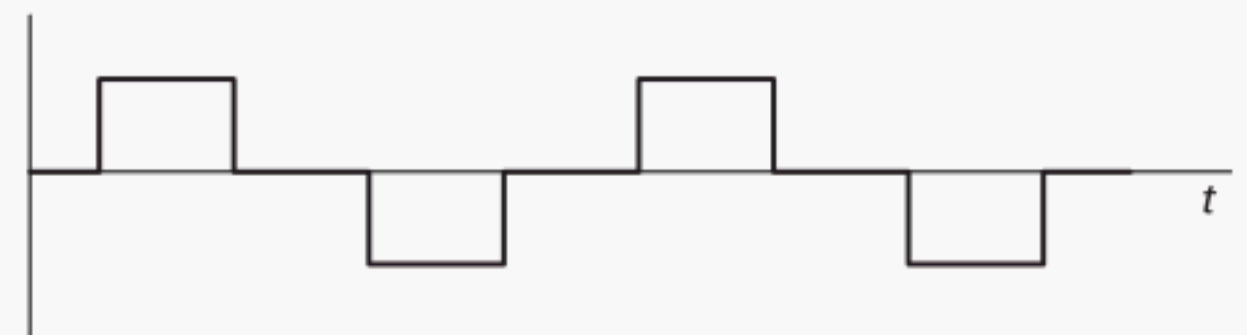
**Fig. 3 Examples of Electromagnetic Field ( $B_0$ ) Variation With Time**



**(a) AC Excitation (Sinusoidal)**

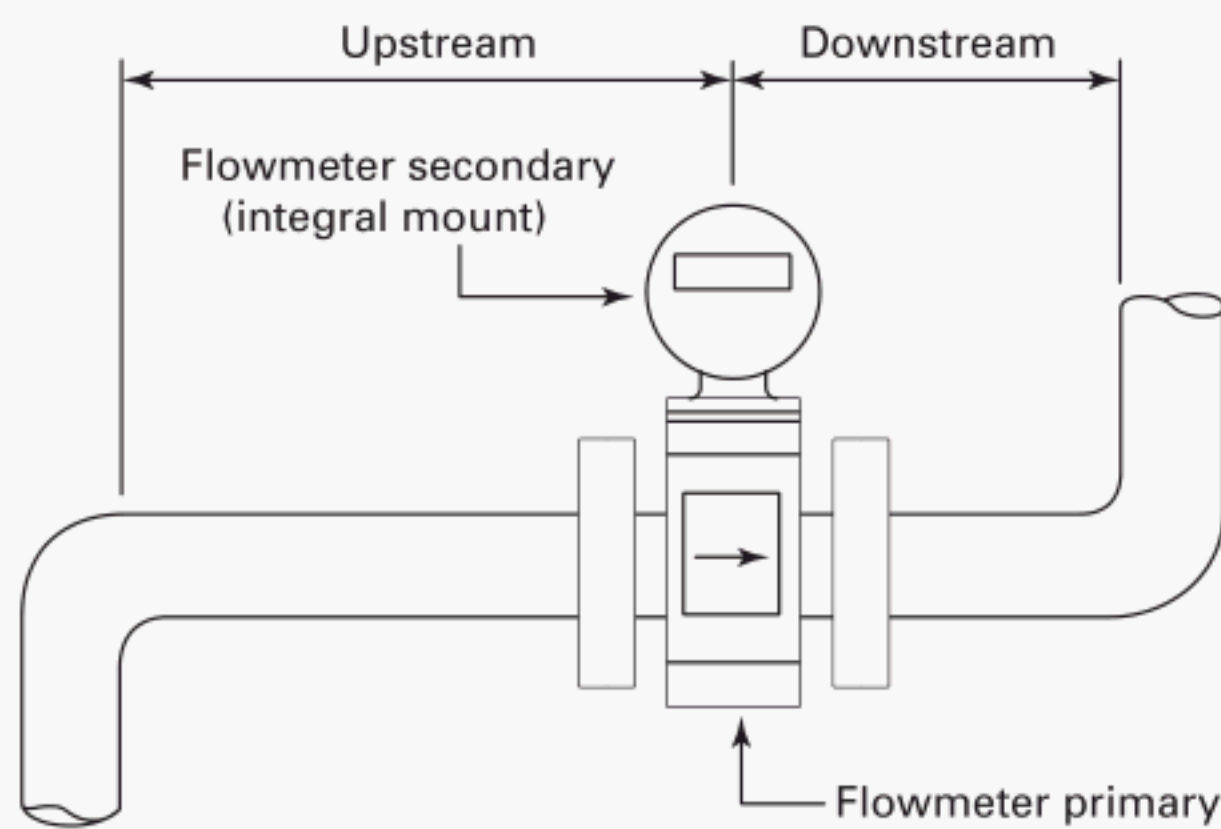


**(b) Pulsed-DC Excitation (Stepwise Fashion)**

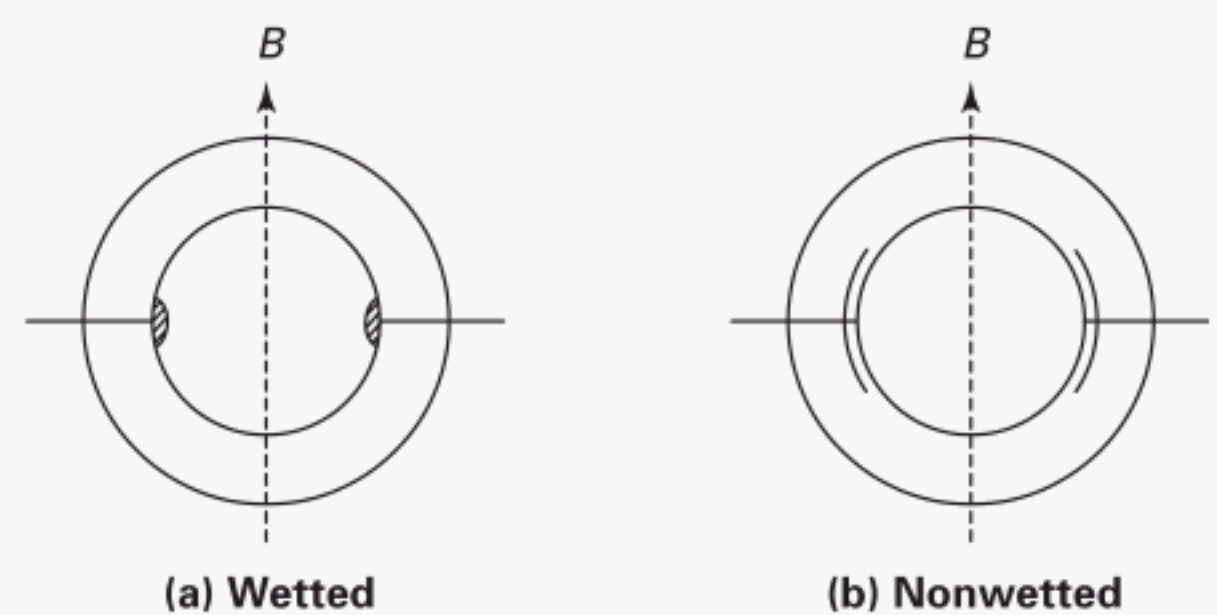


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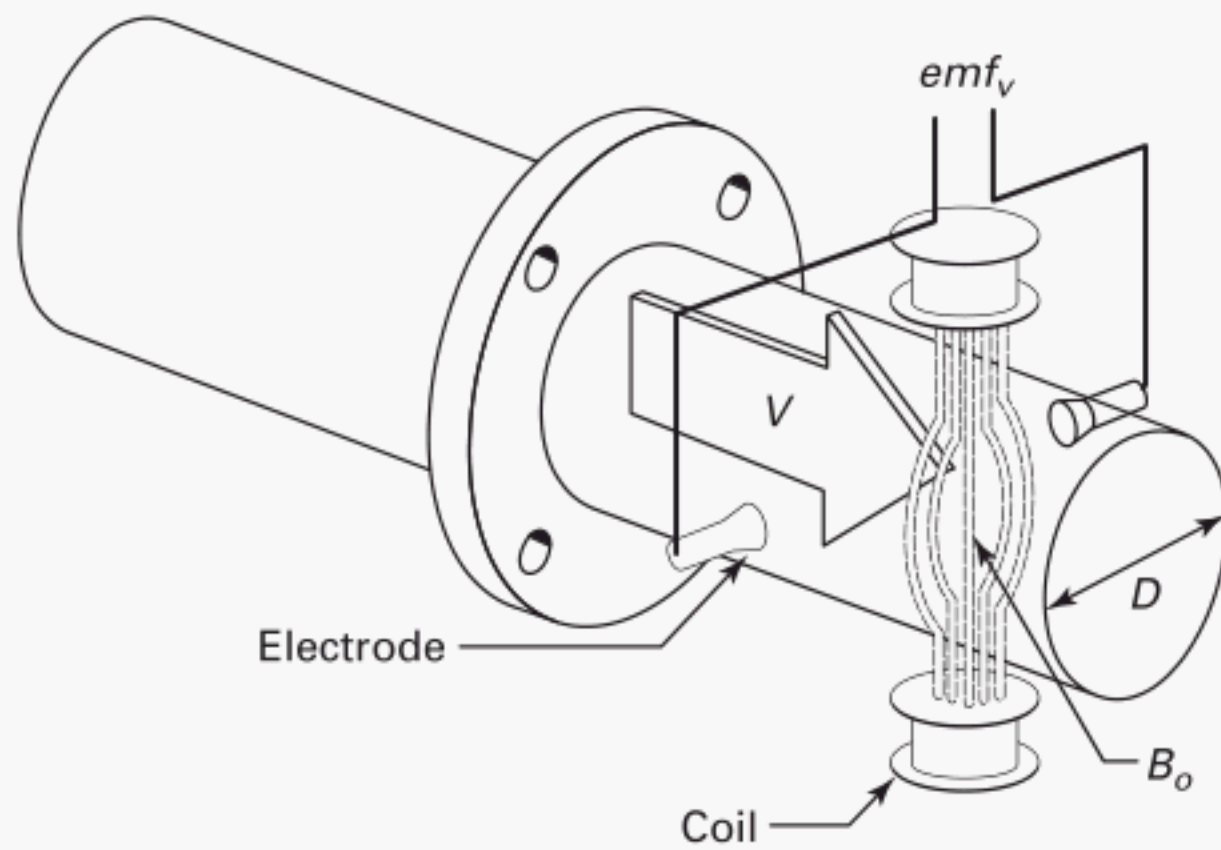
**Fig. 2 Electromagnetic Flowmeter System**



**Fig. 4 Examples of Electrodes for an Electromagnetic Flowmeter**



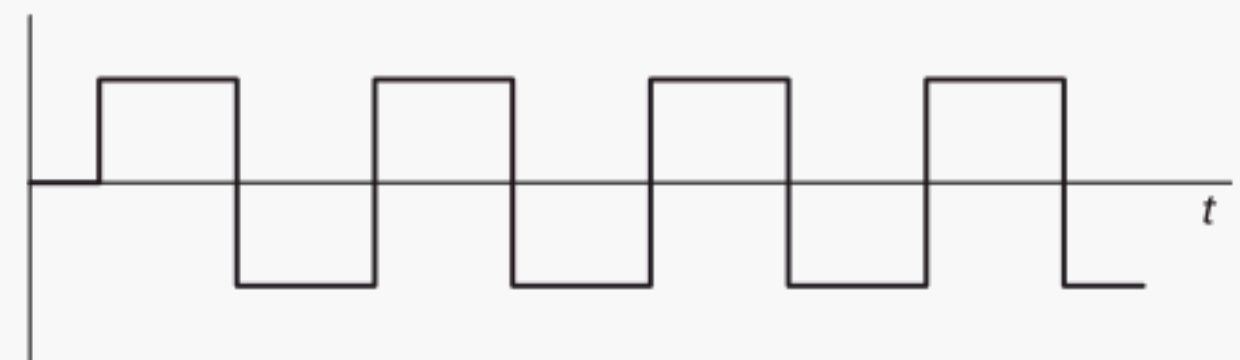
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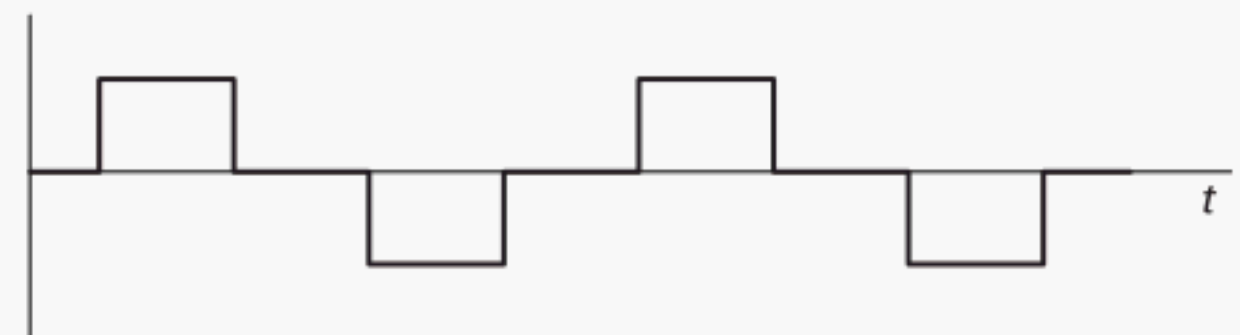
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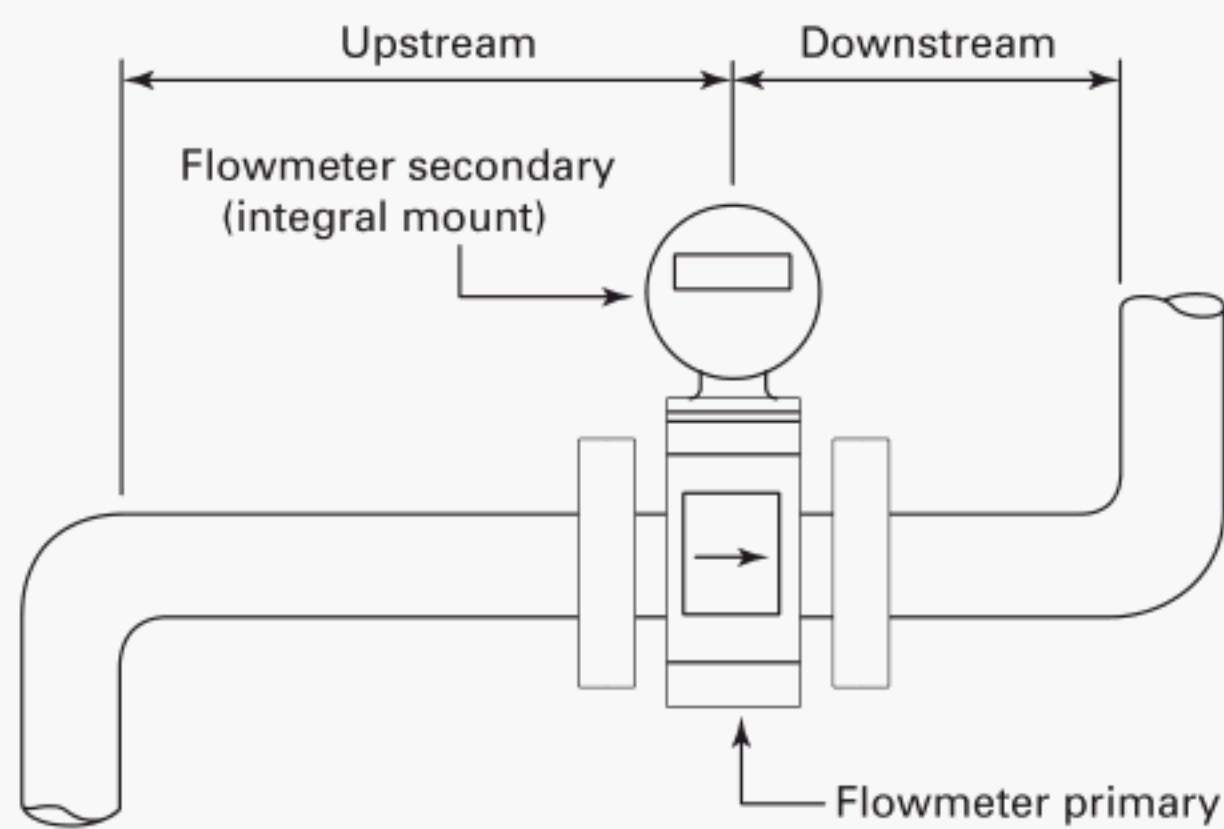


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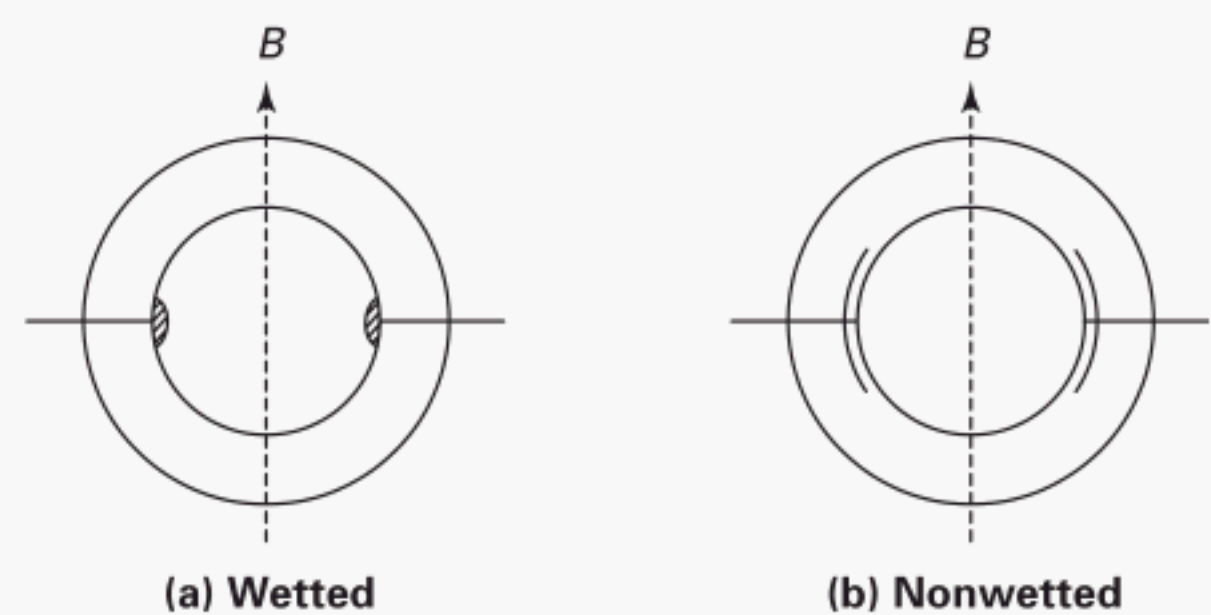


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**Fig. 4 Examples of Electrodes for an Electromagnetic Flowmeter**

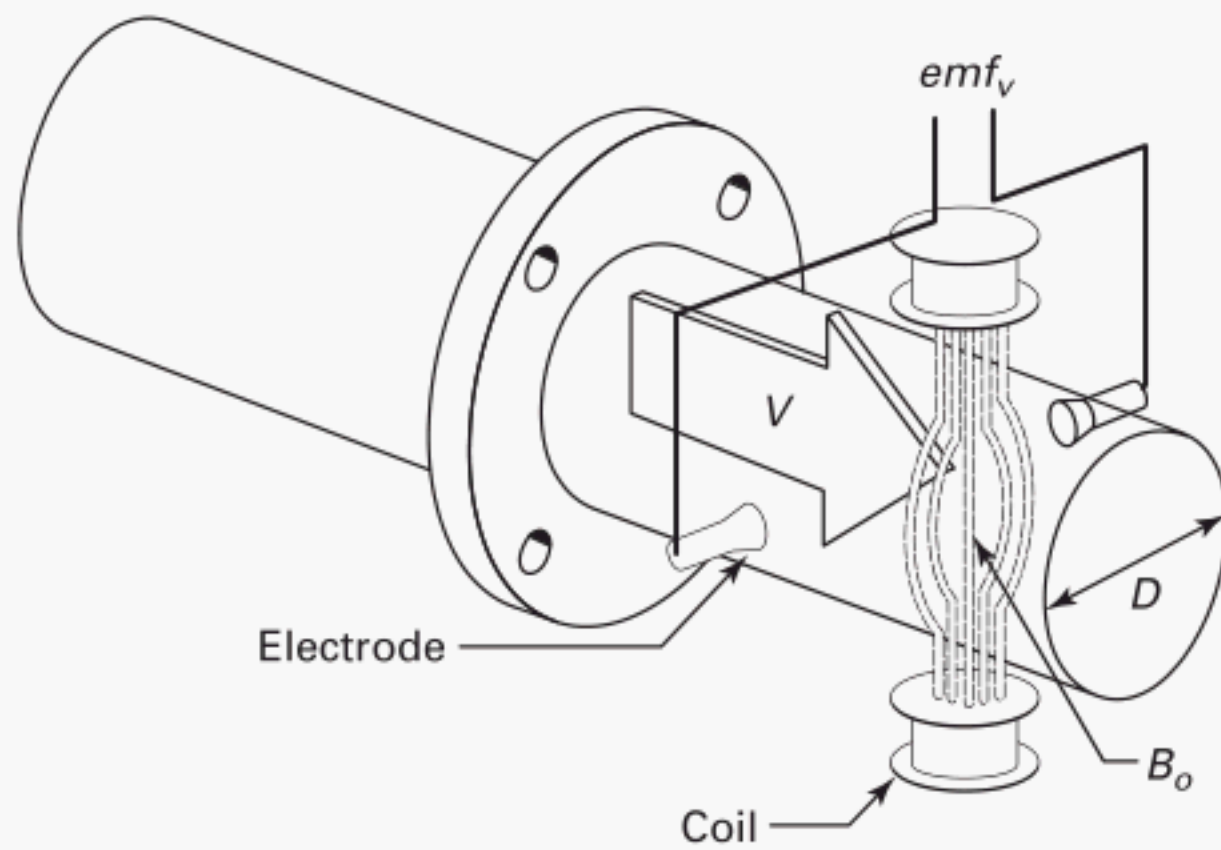


**(a) Wetted**

**(b) Nonwetted**



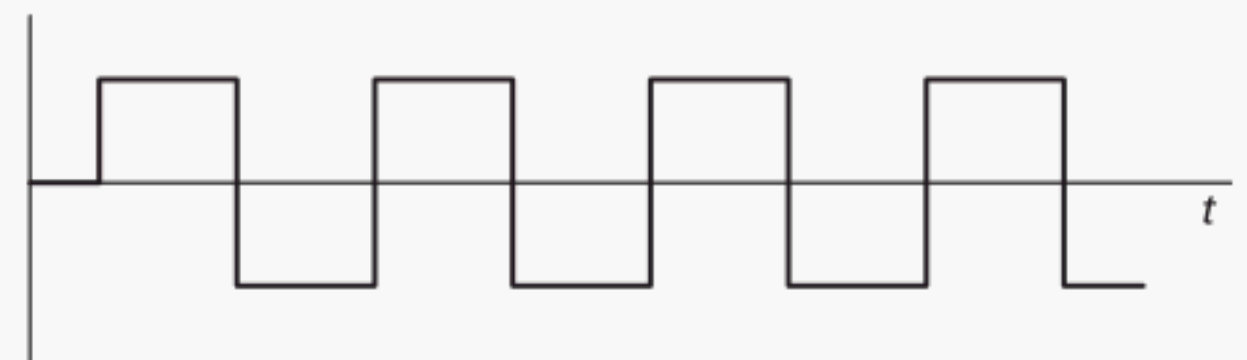
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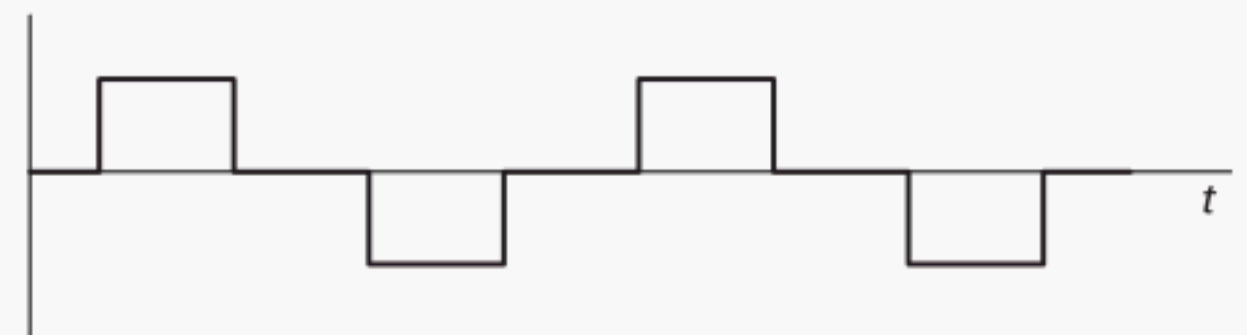
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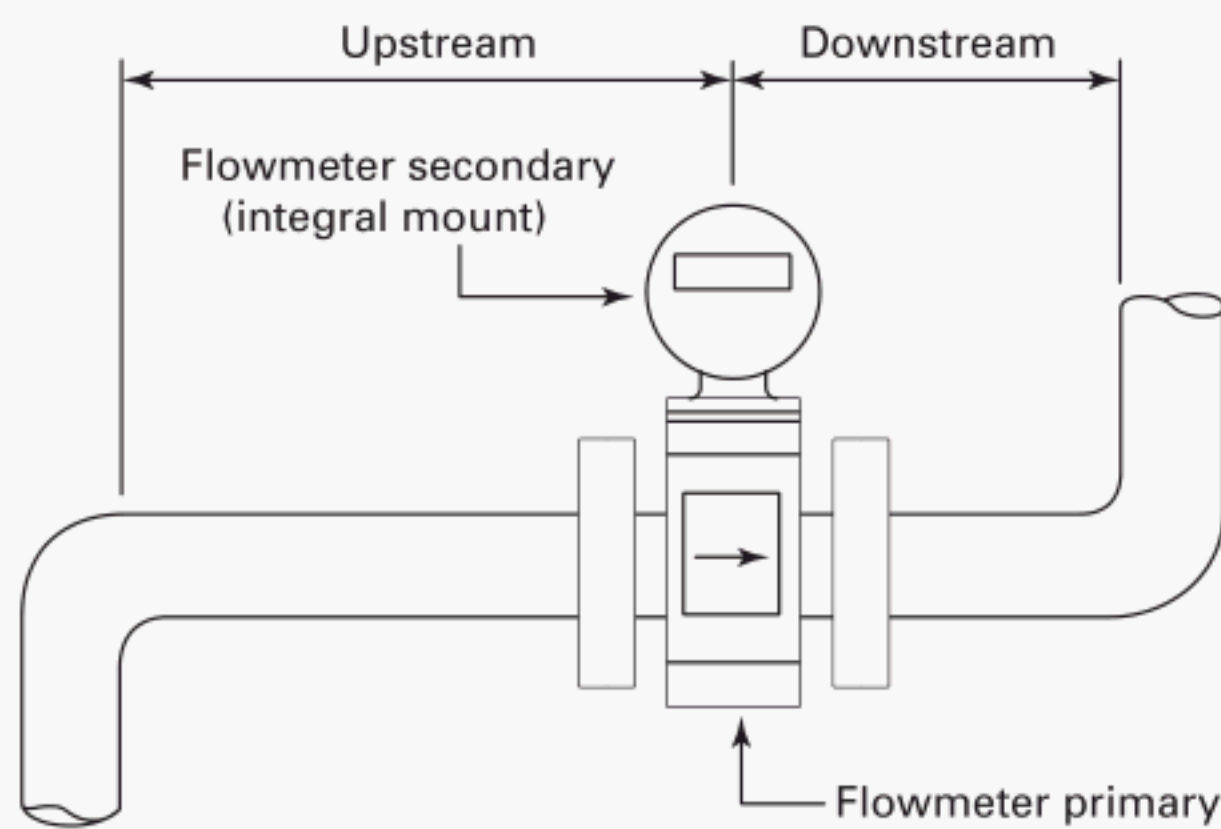


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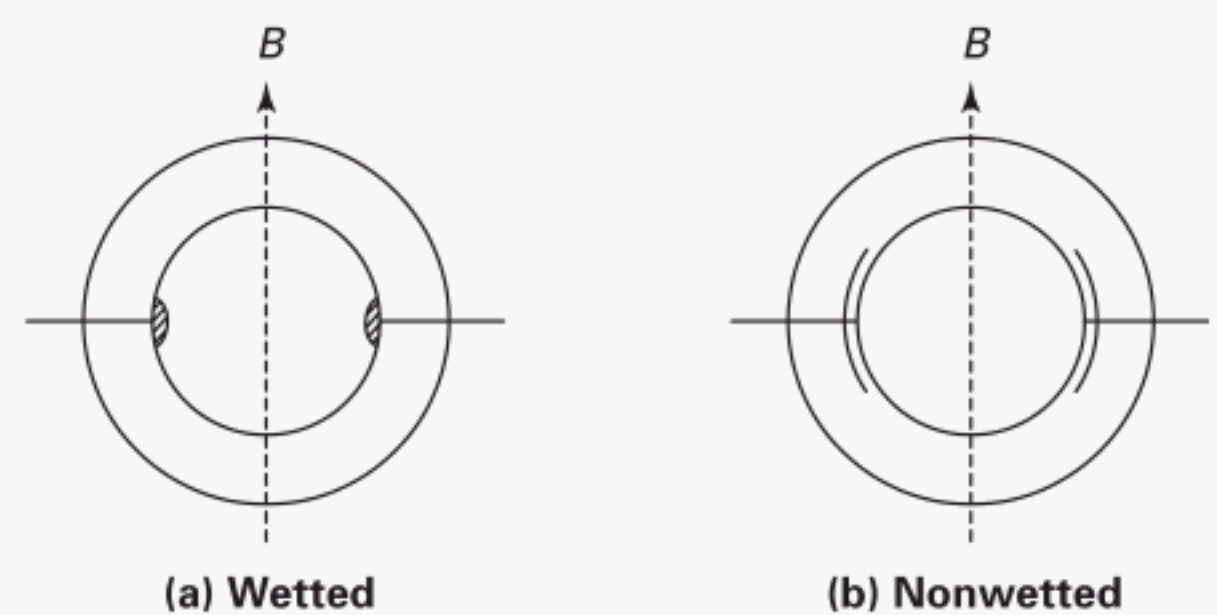


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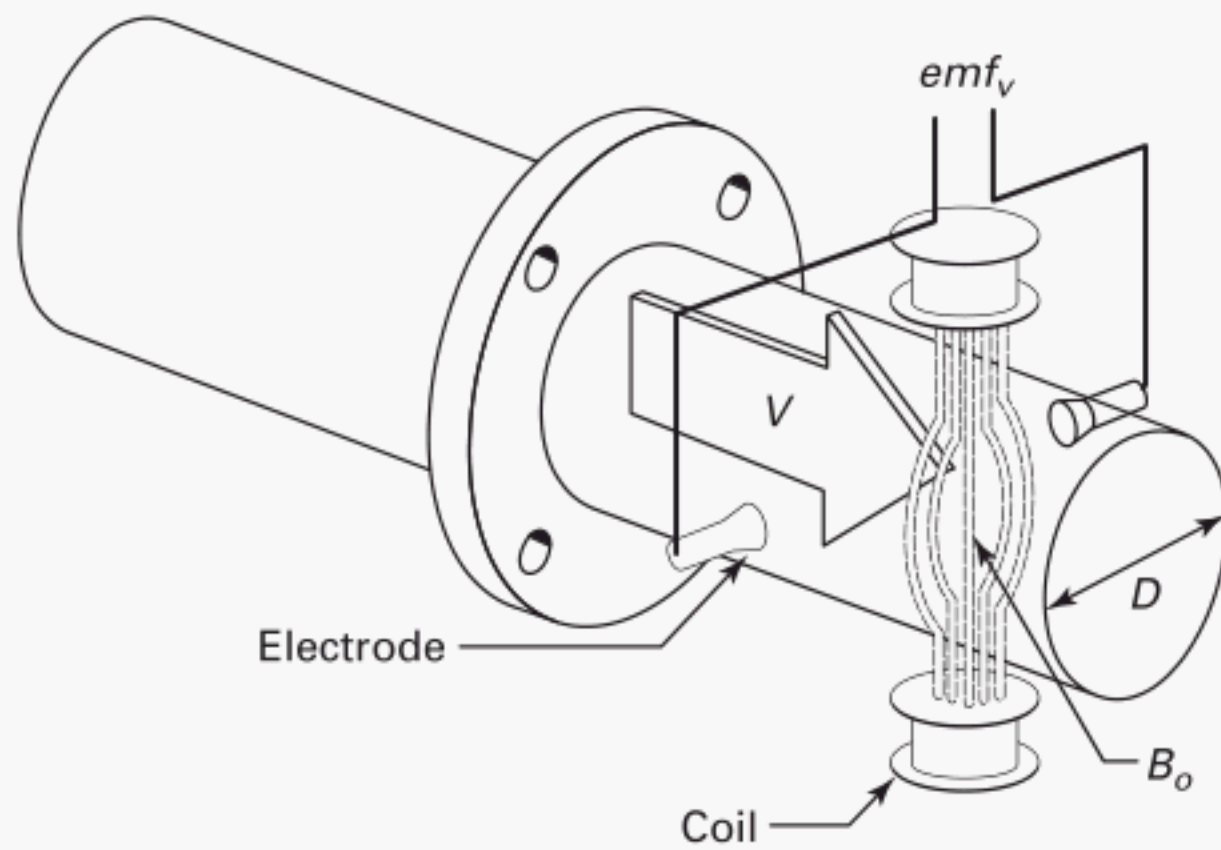
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**Fig. 4 Examples of Electrodes for an Electromagnetic Flowmeter**



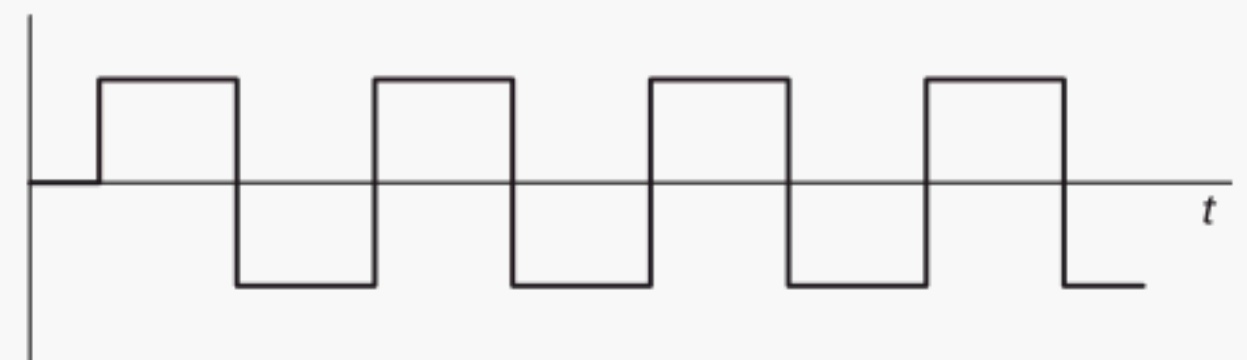
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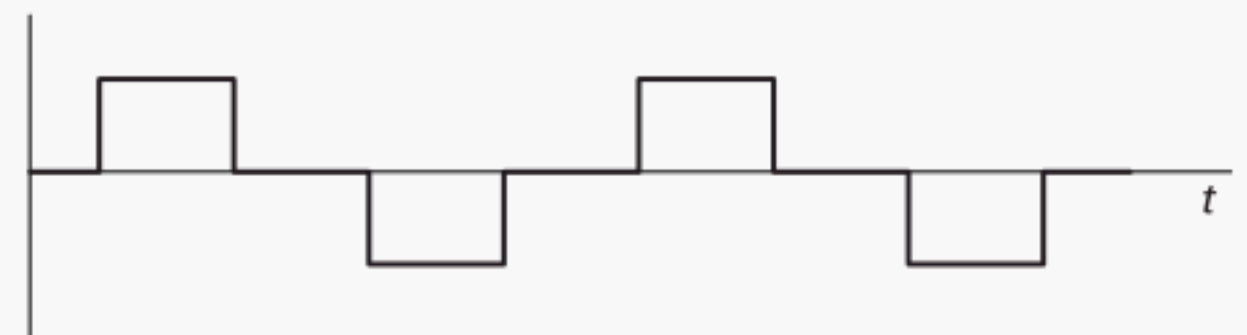
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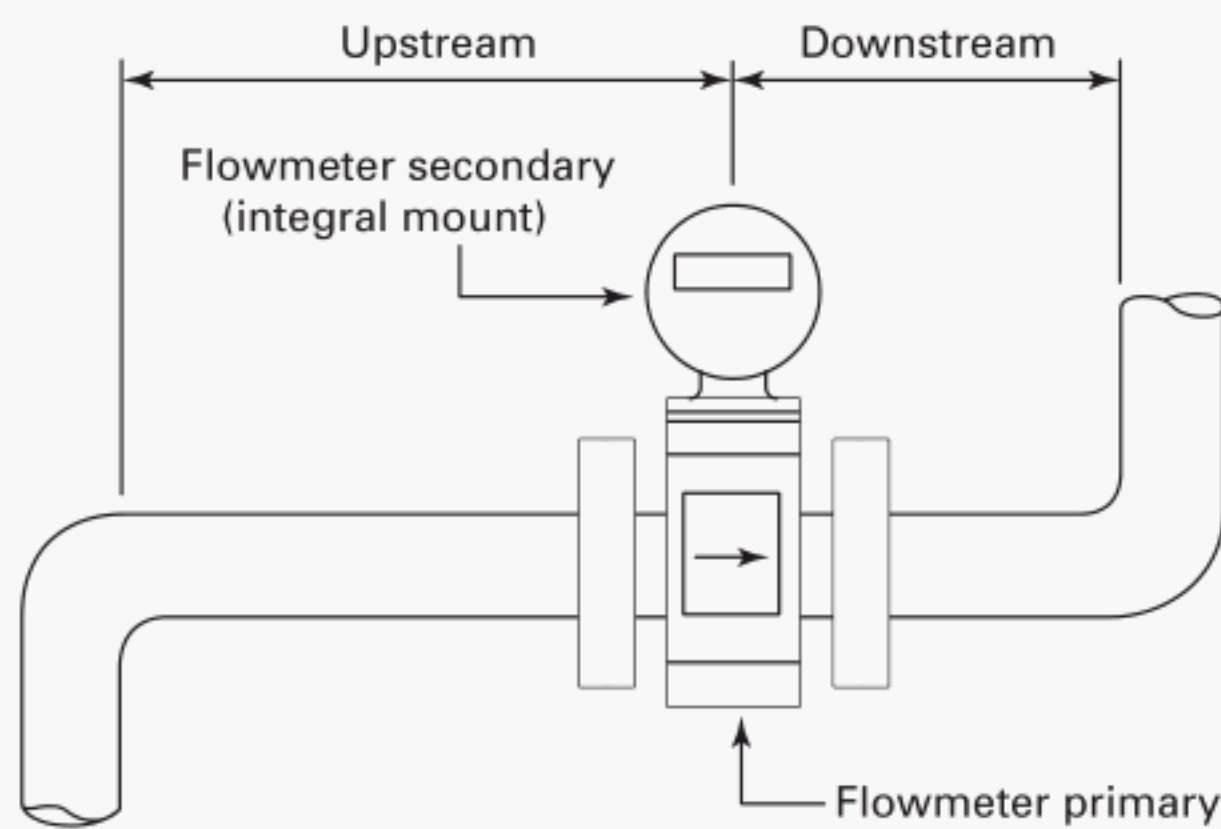


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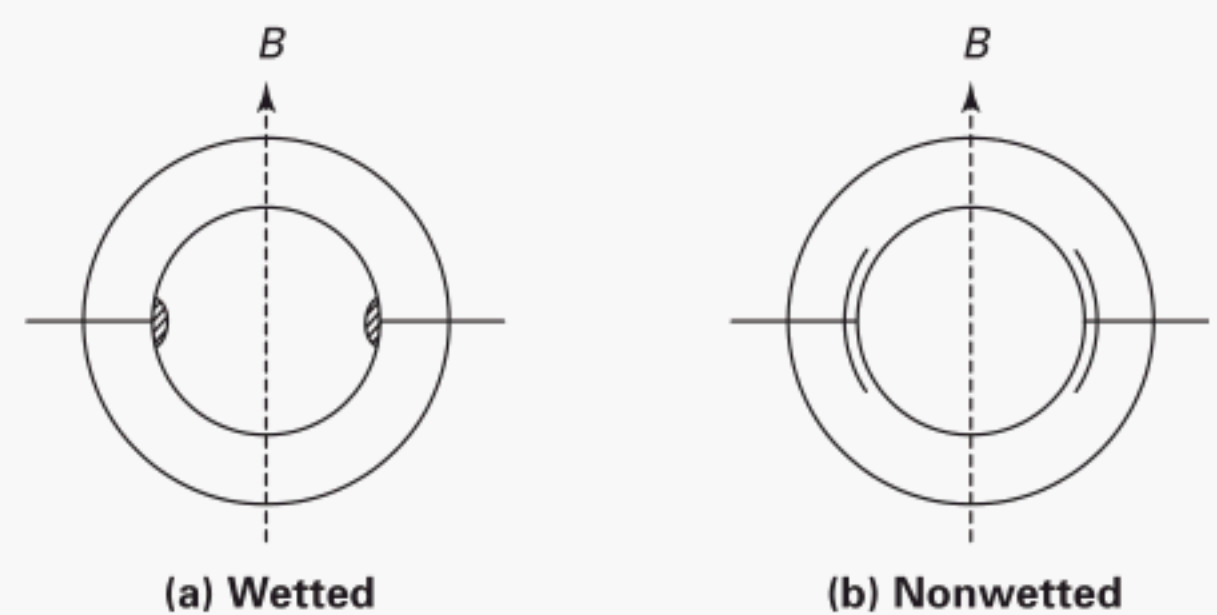


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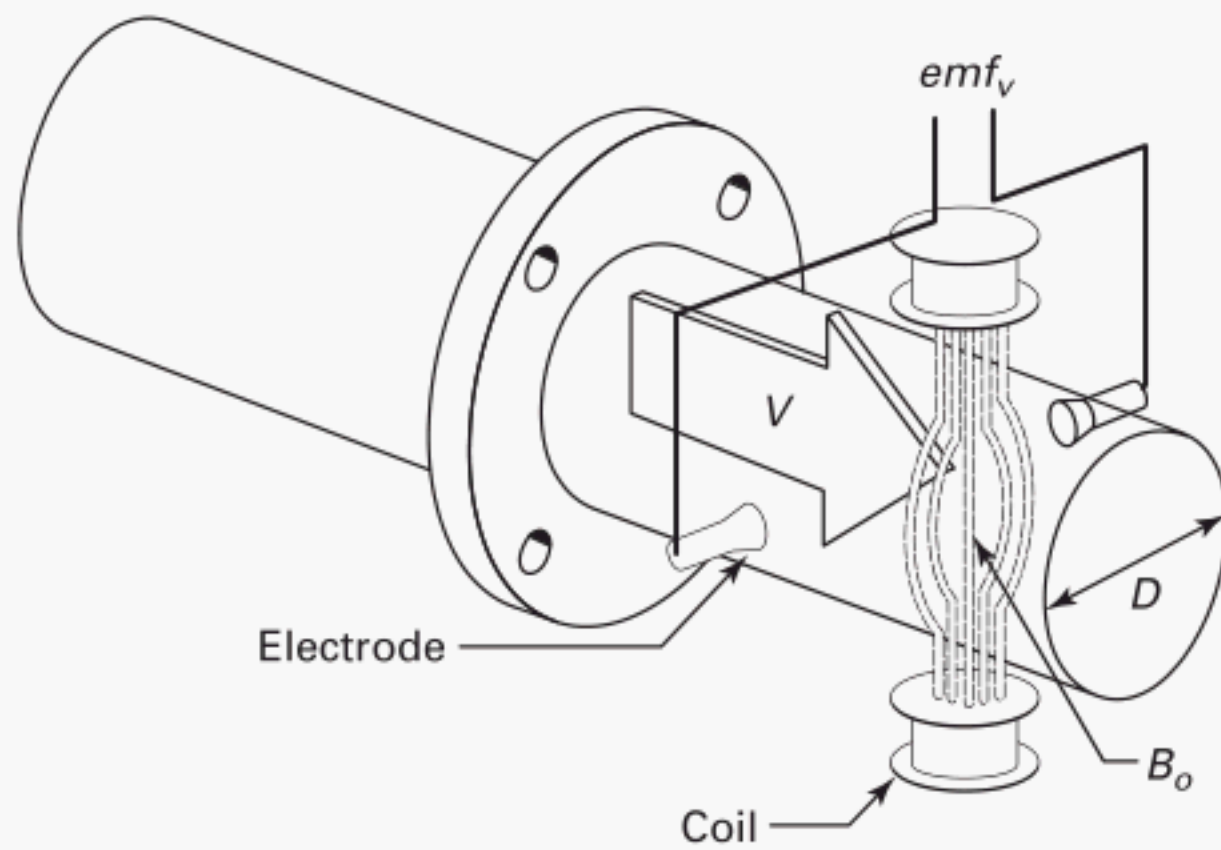


**Fig. 4 Examples of Electrodes for an Electromagnetic Flowmeter**





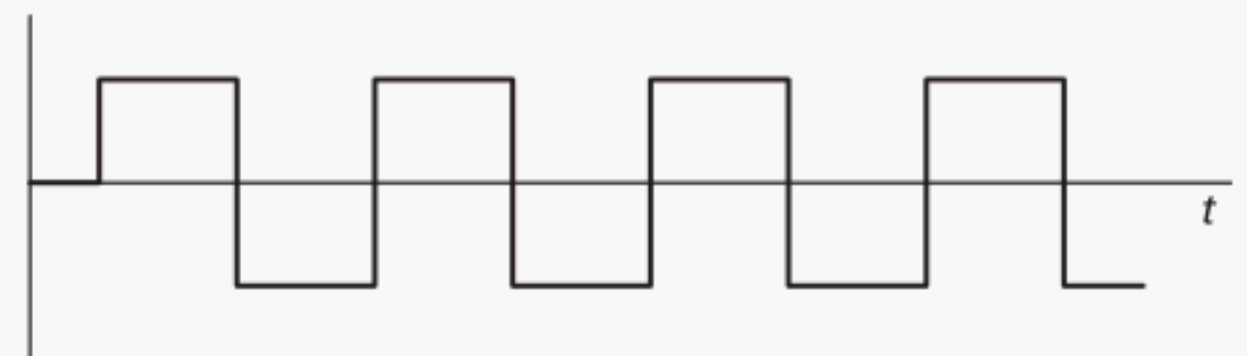
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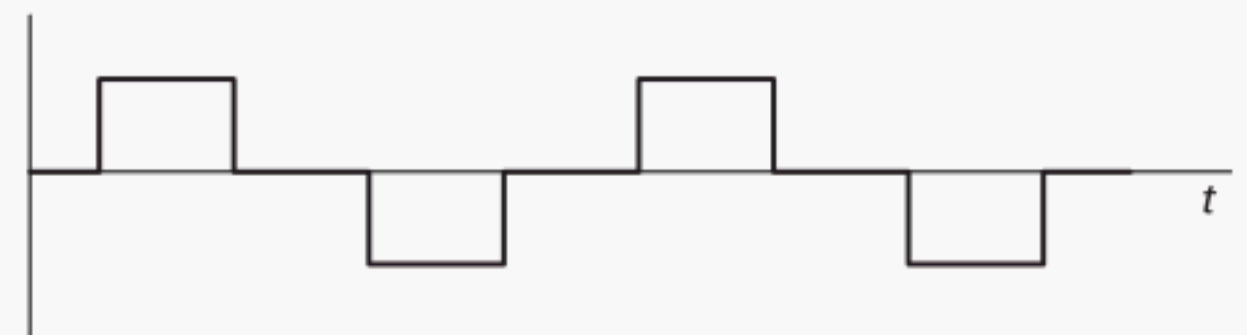
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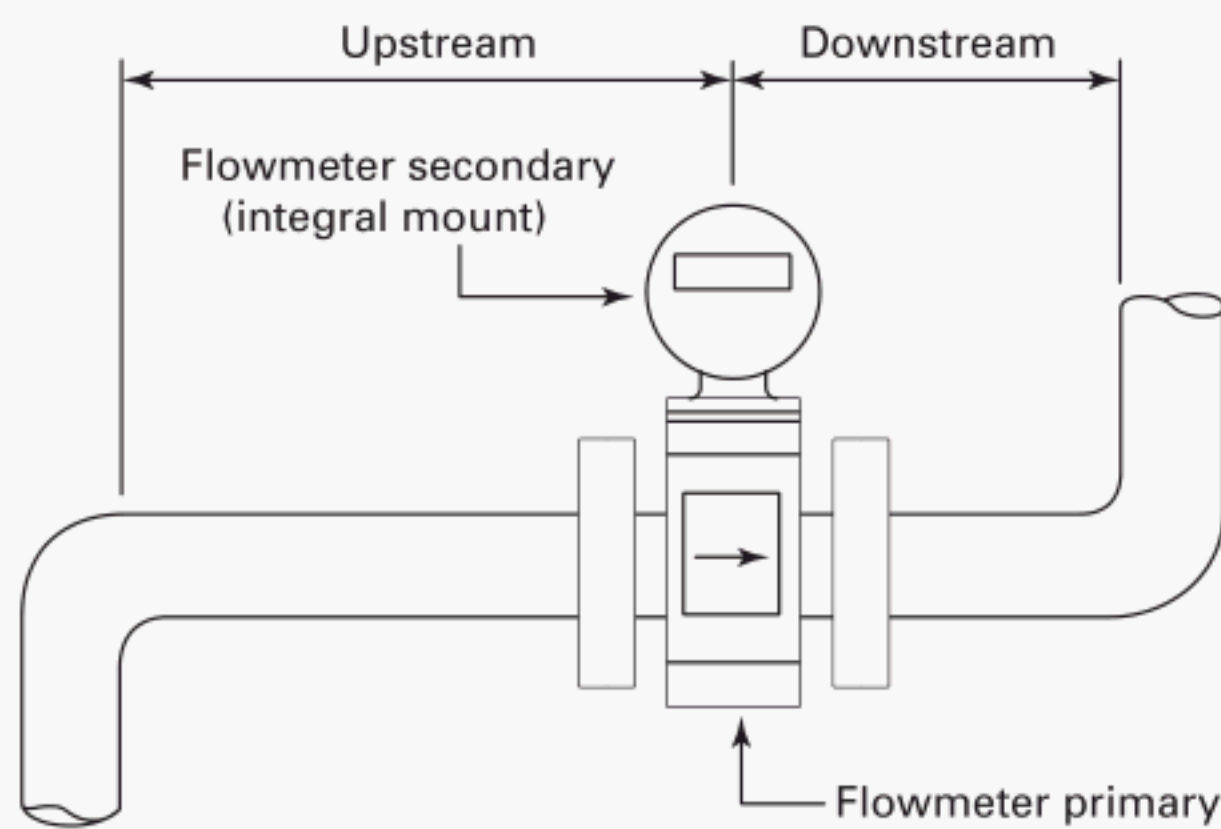


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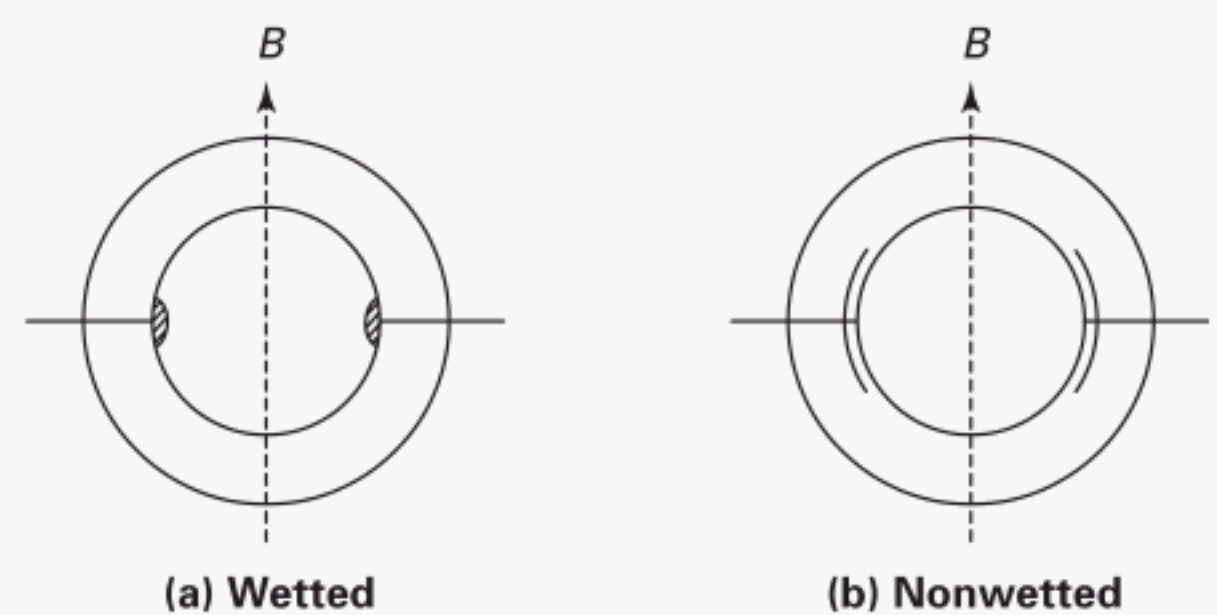


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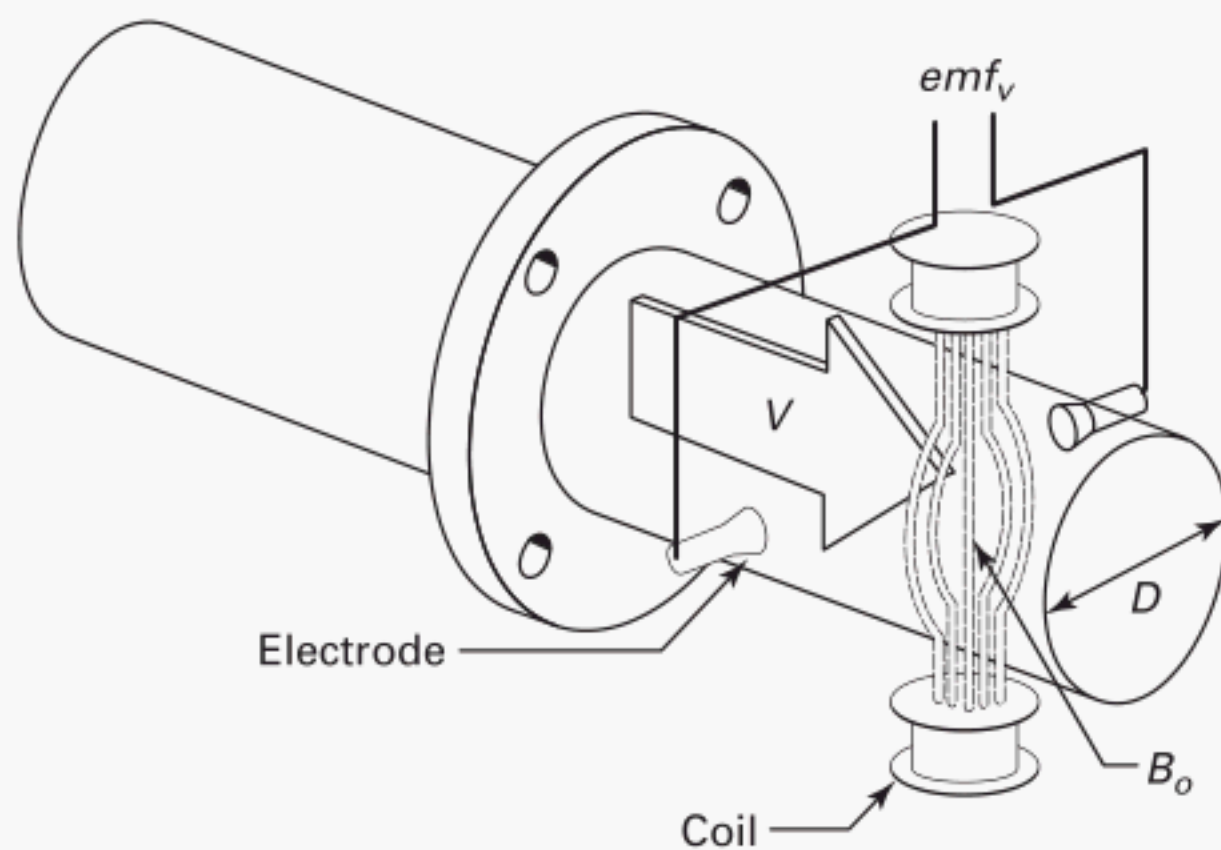
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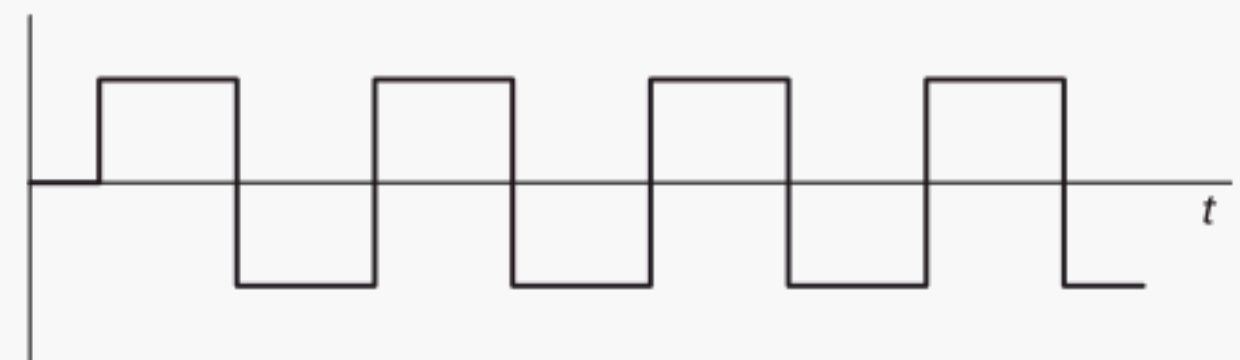
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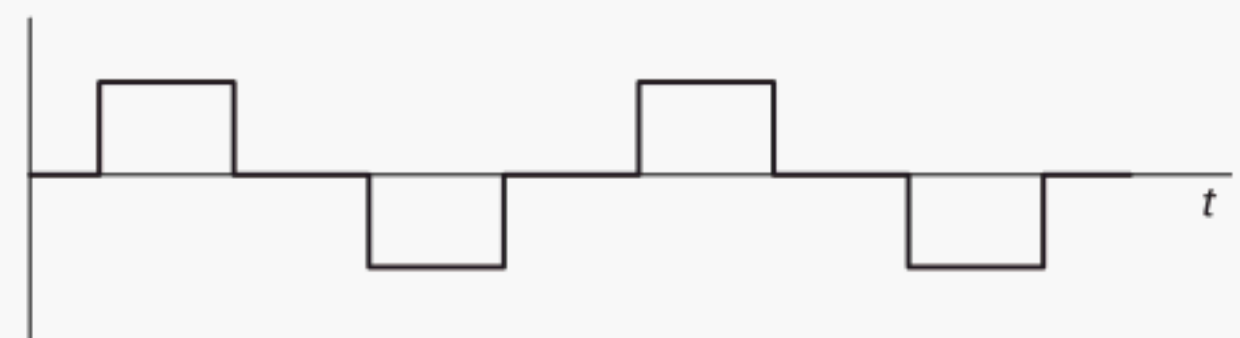
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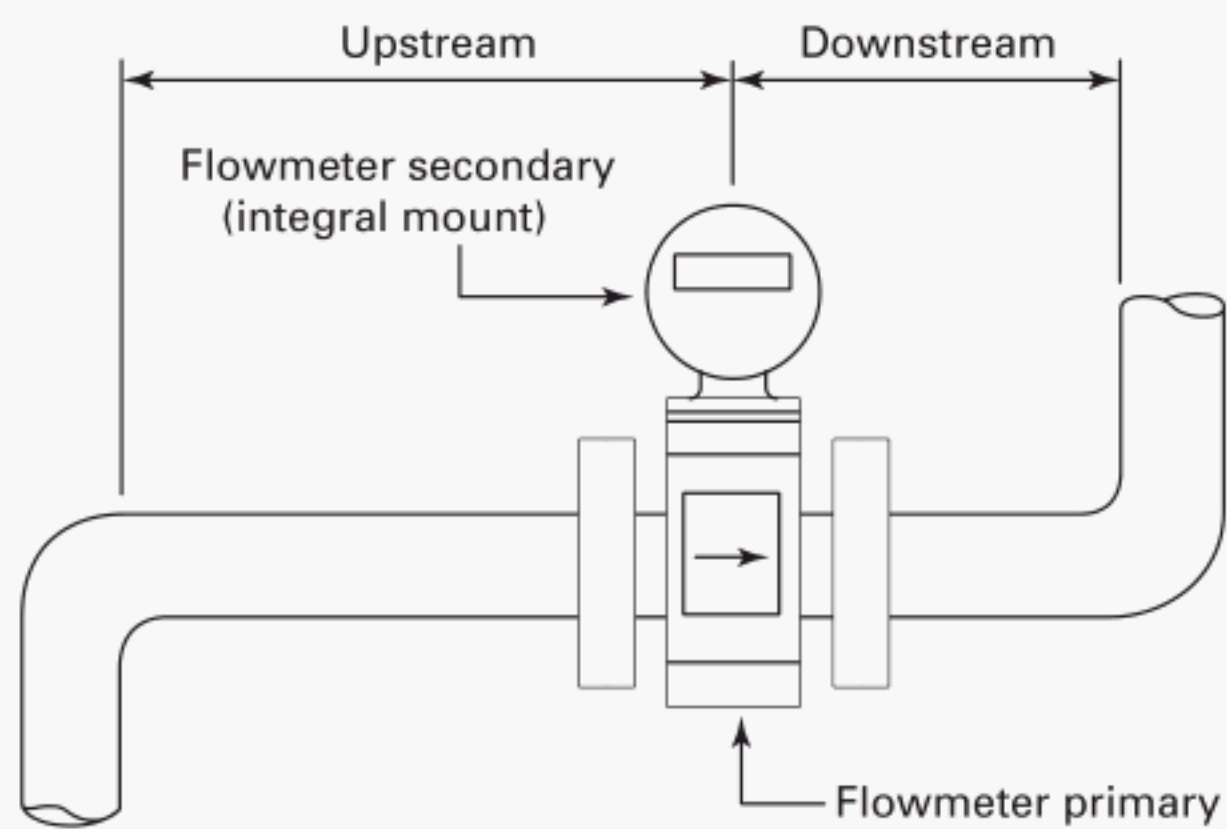


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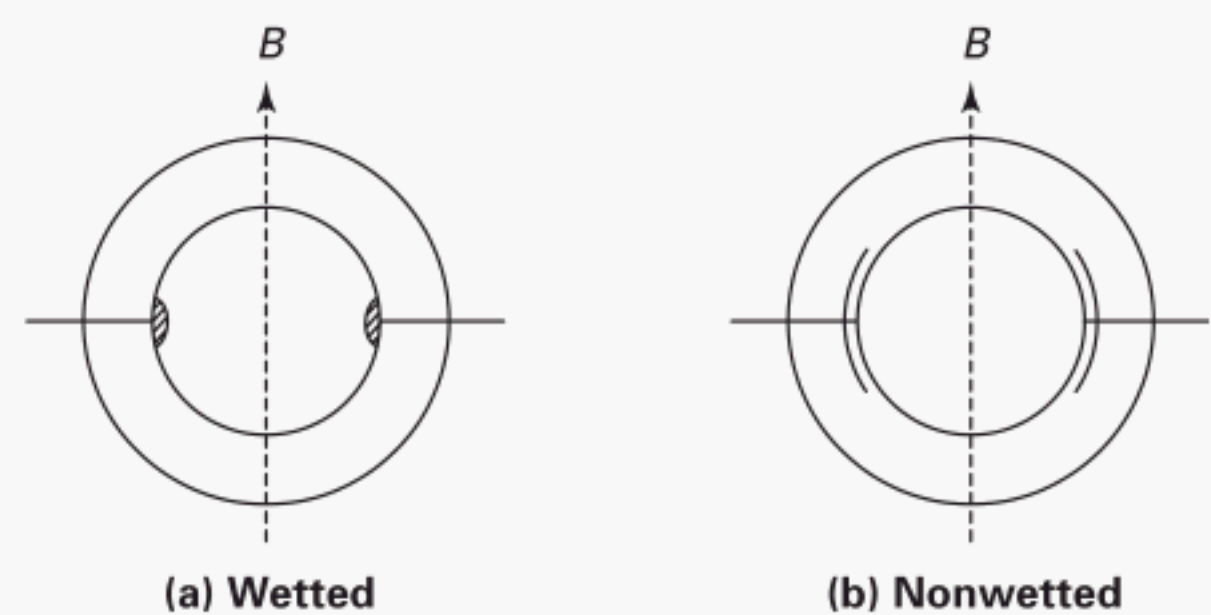


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**Fig. 2 Electromagnetic Flowmeter System**



**Fig. 4 Examples of Electrodes for an Electromagnetic Flowmeter**

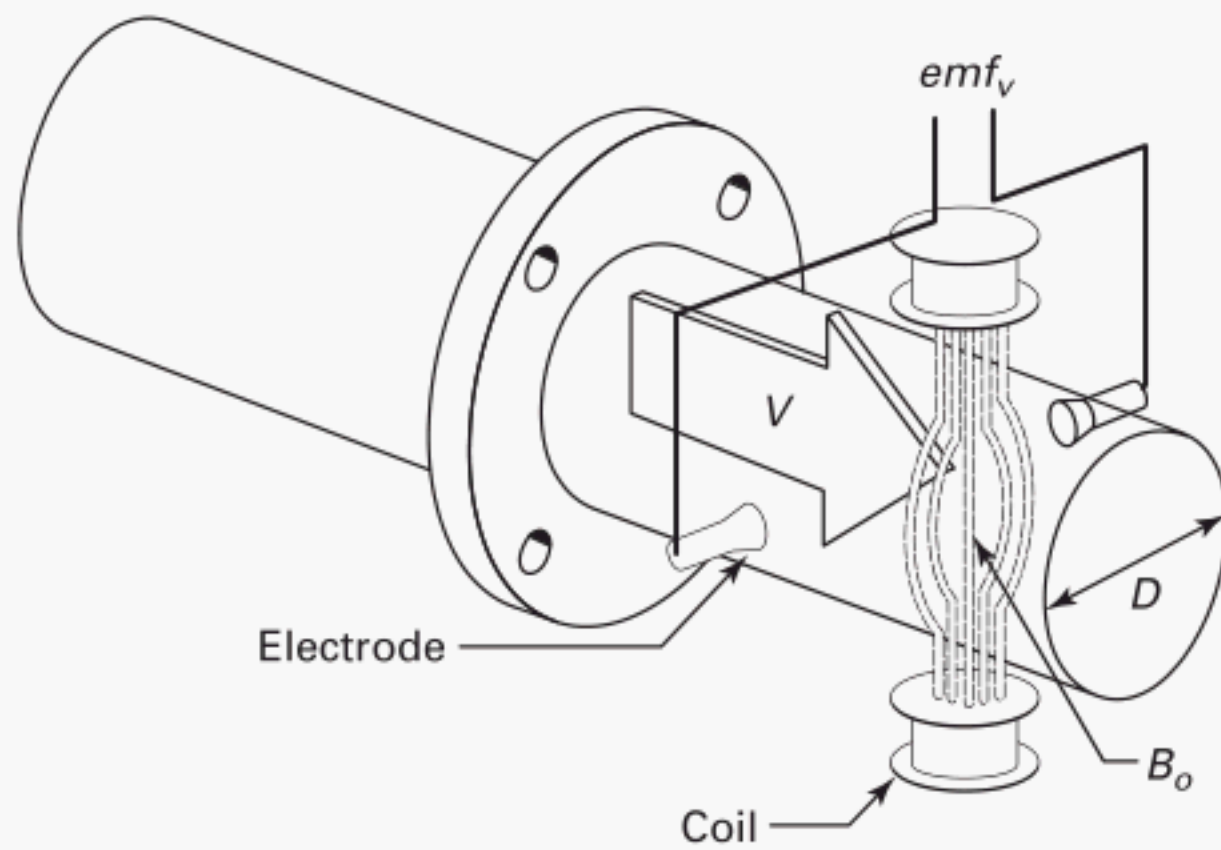


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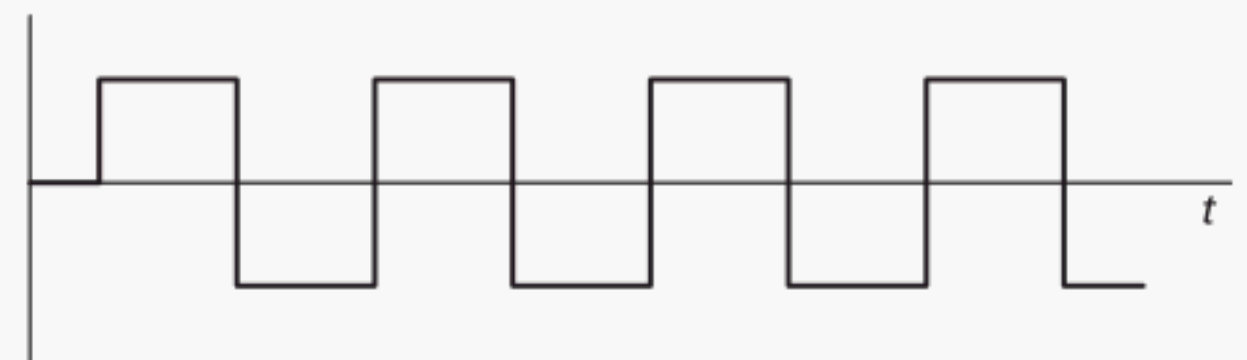
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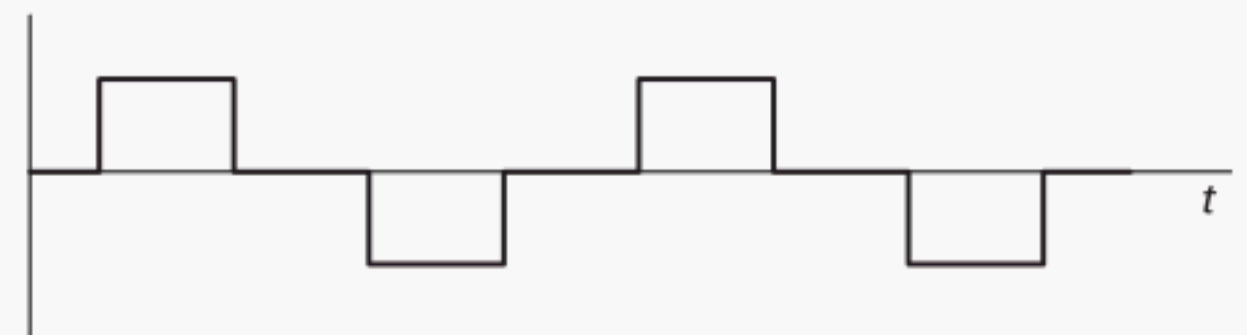
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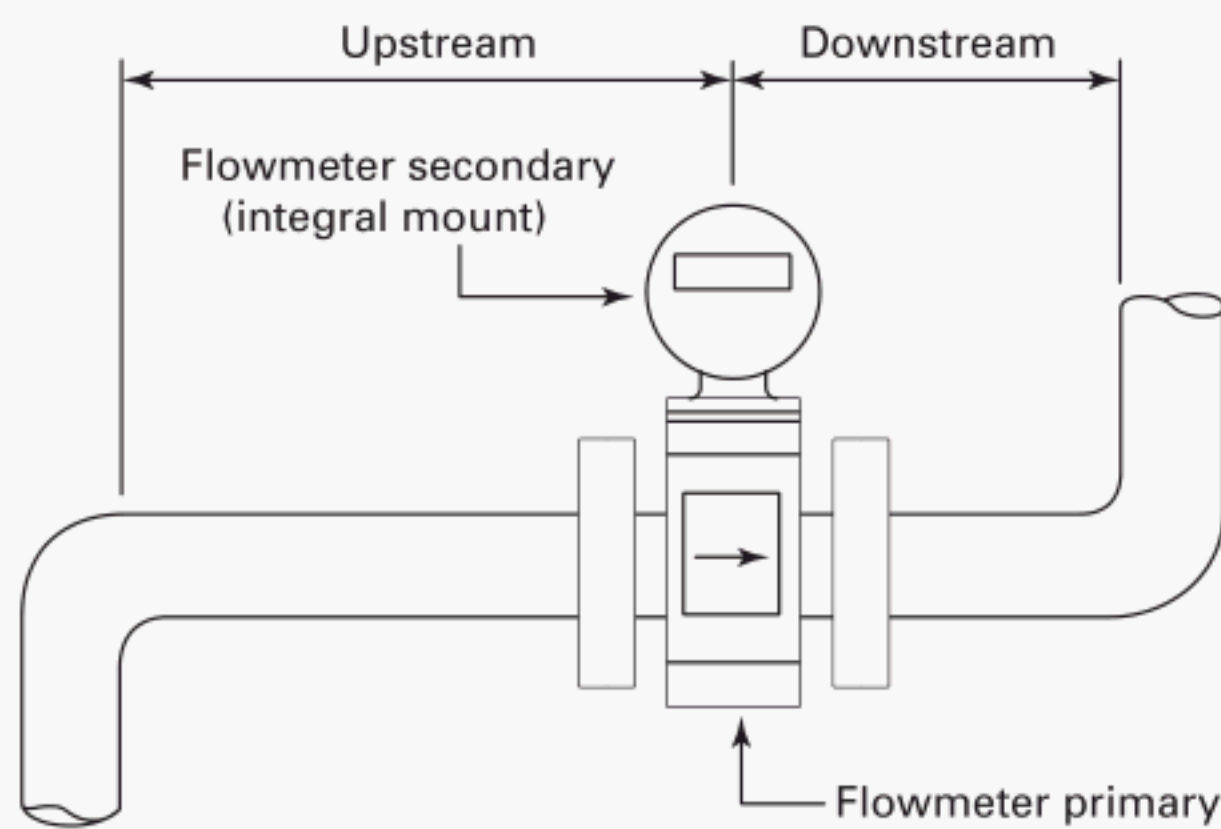


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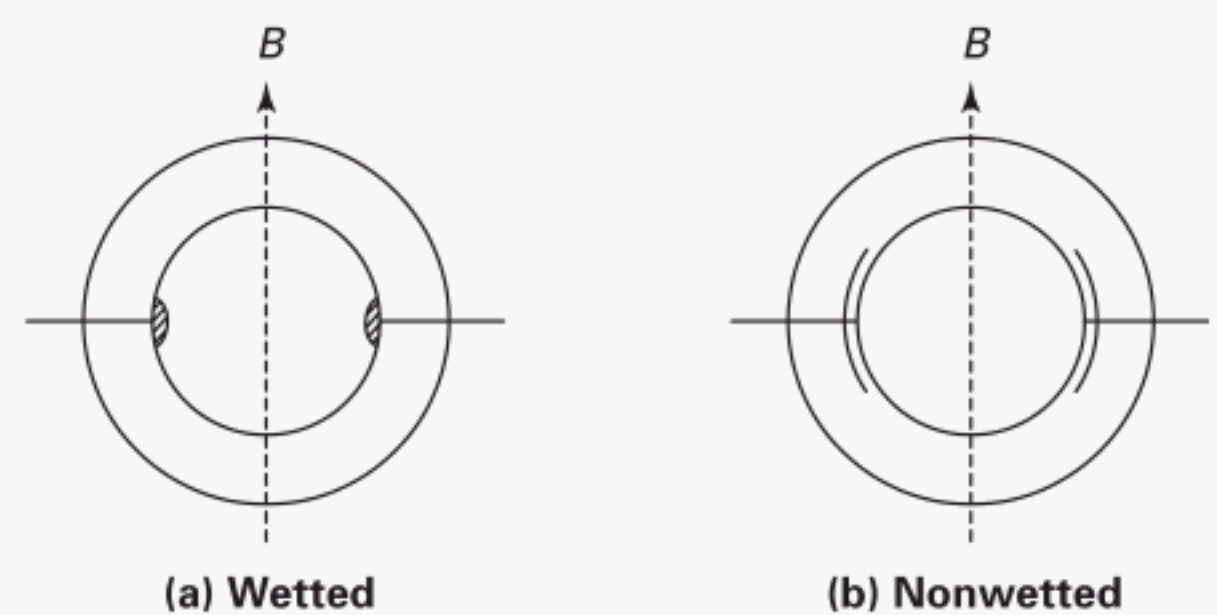


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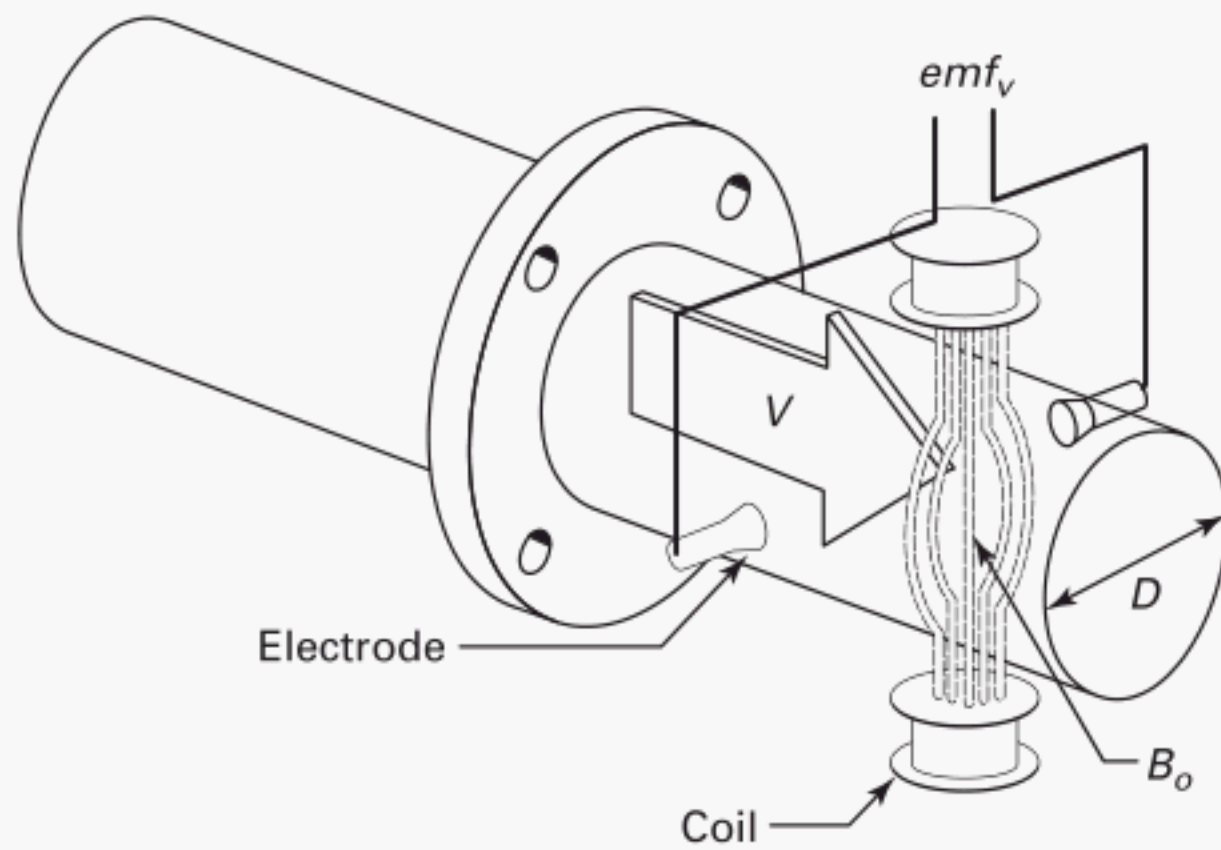
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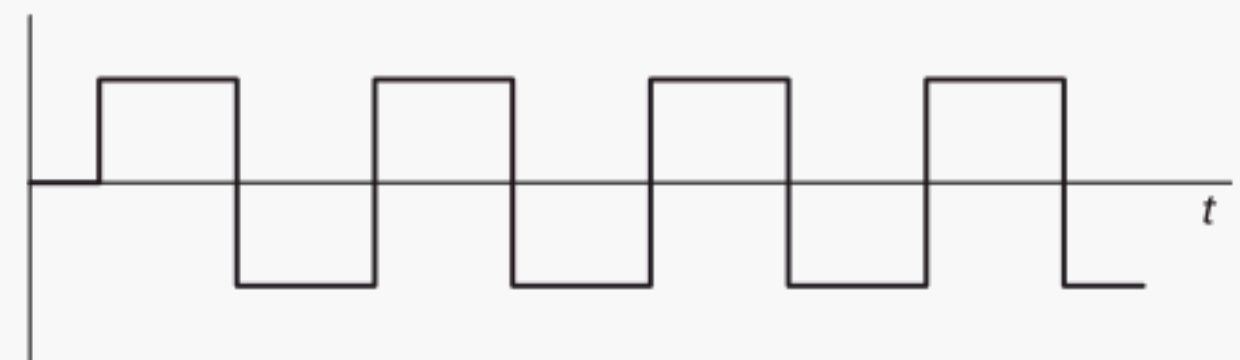
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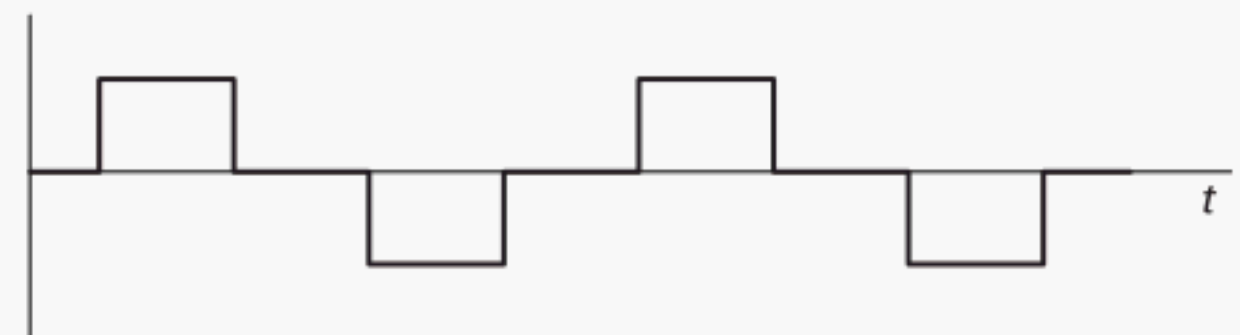
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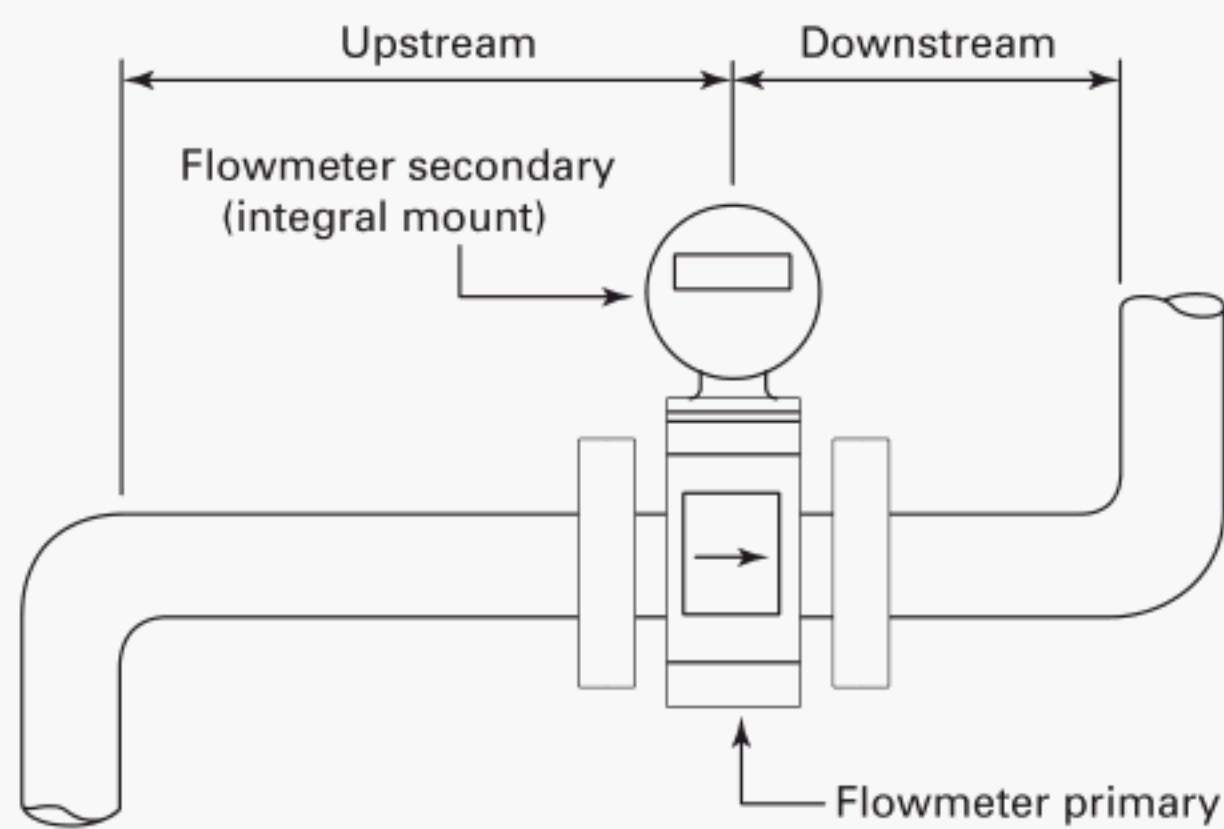


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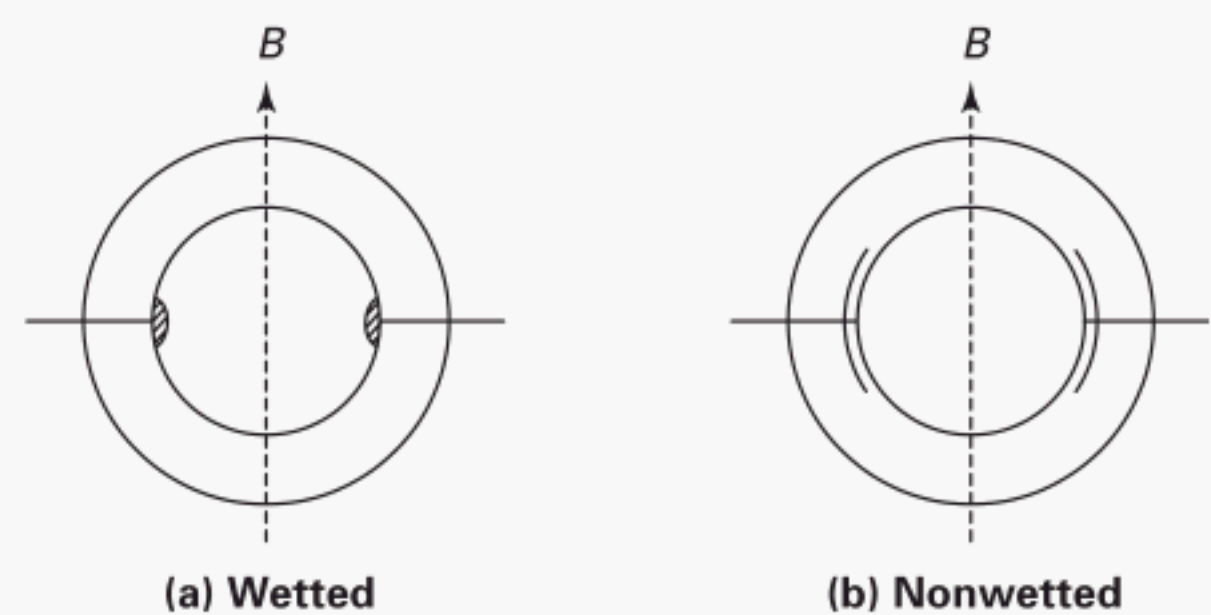


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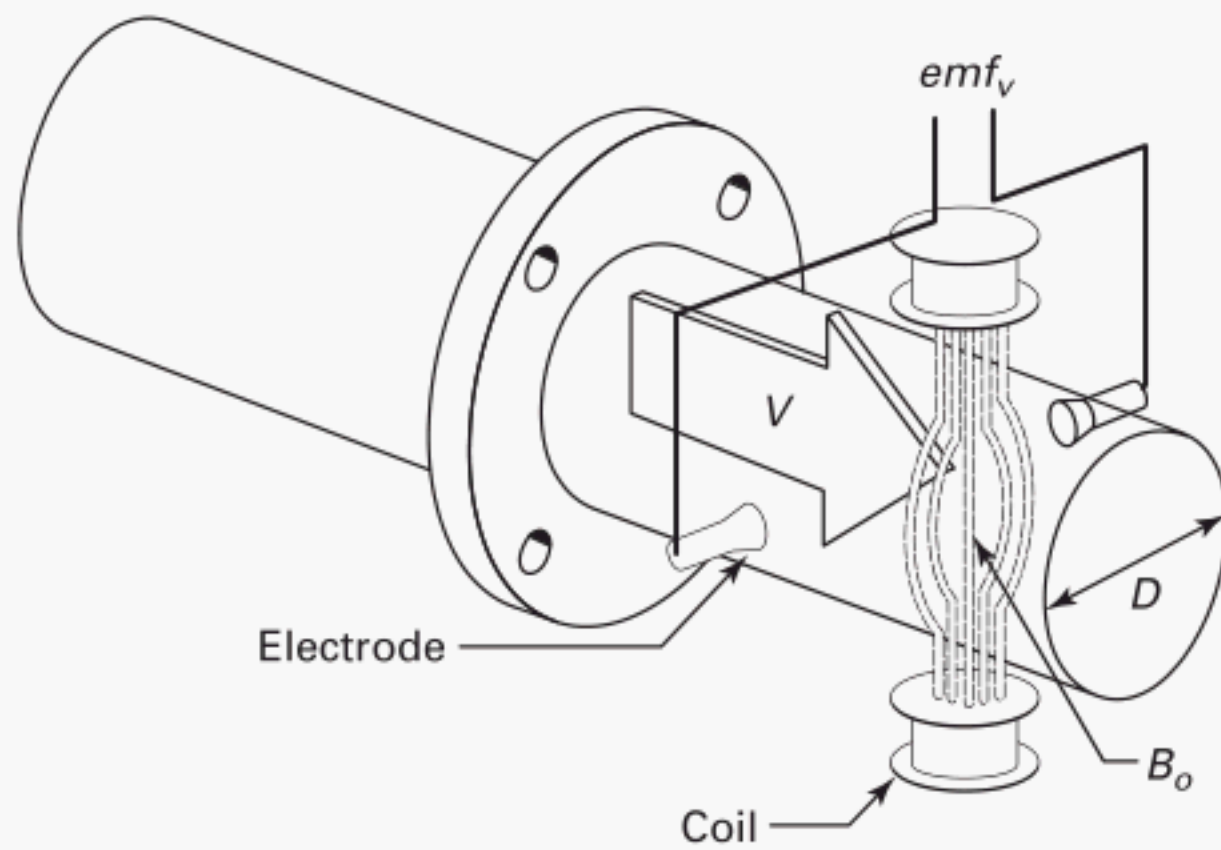


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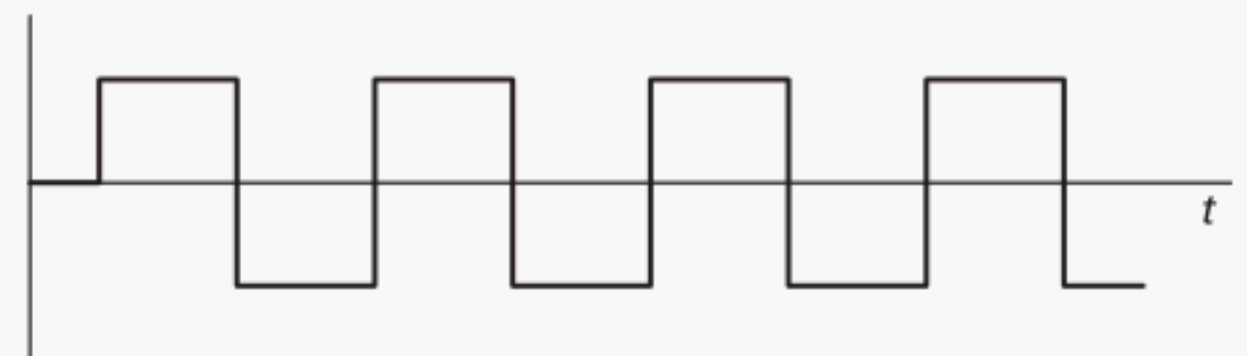
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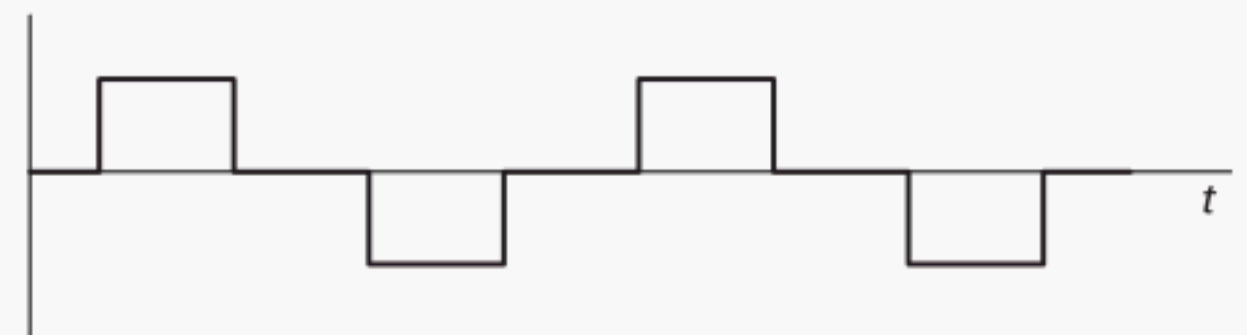
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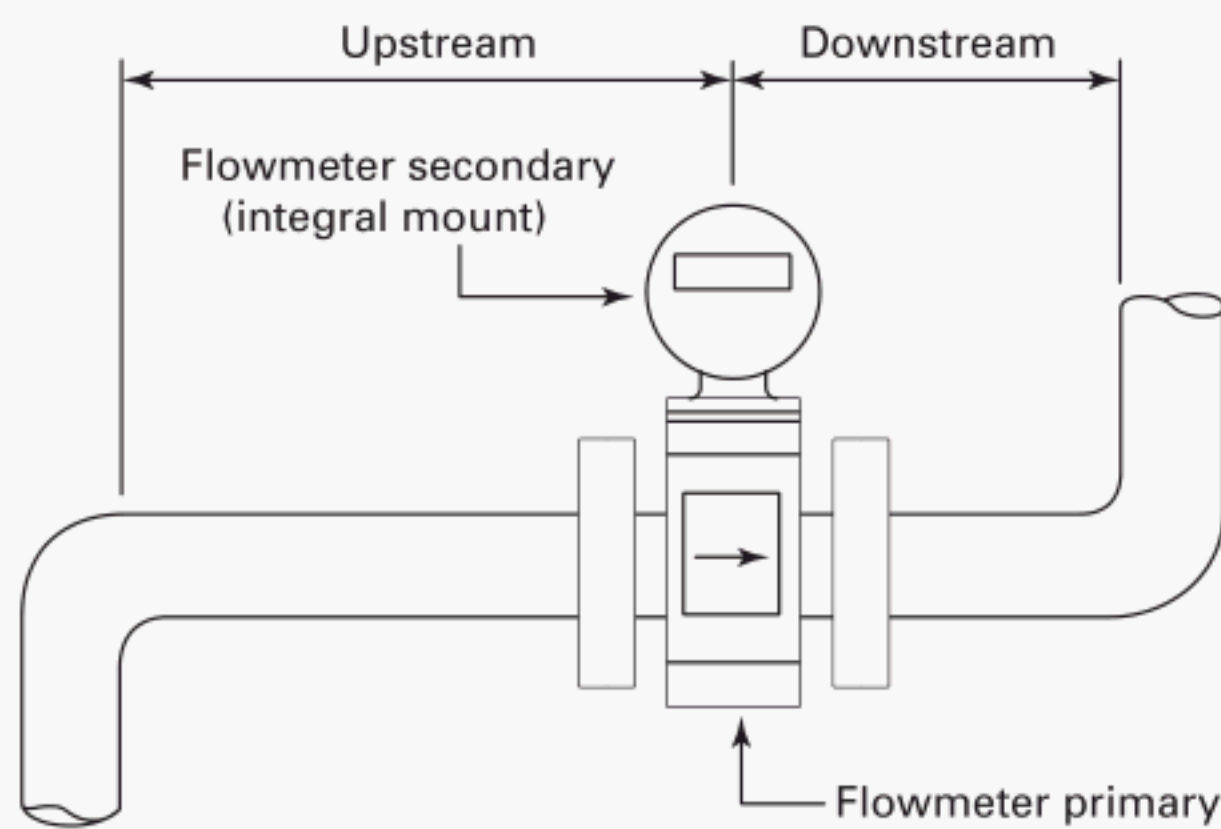


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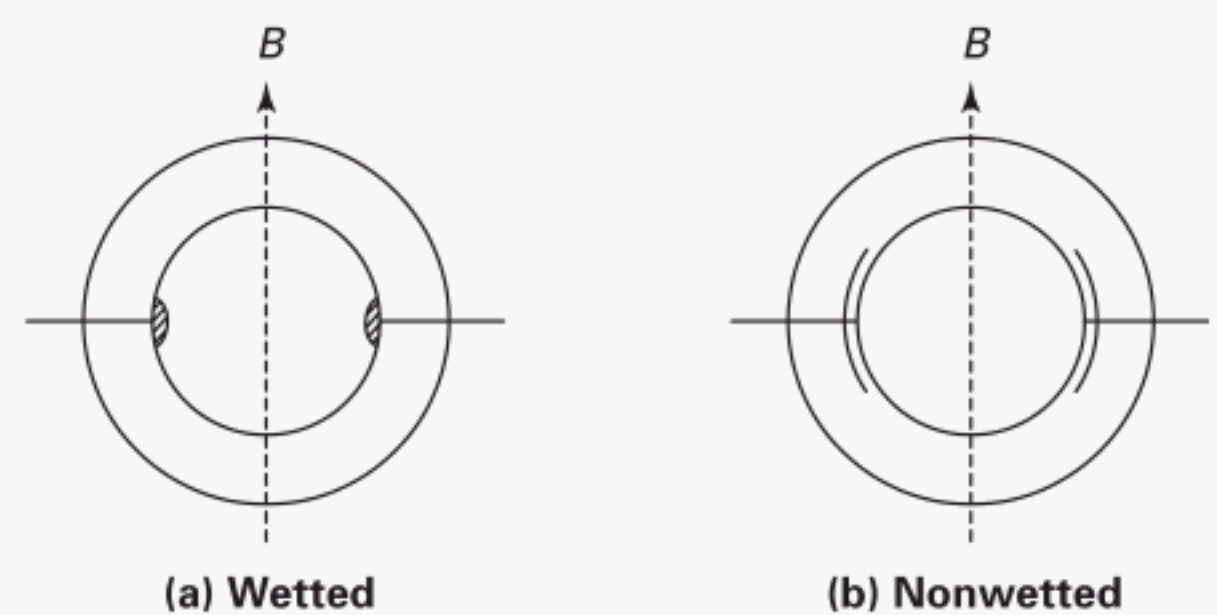


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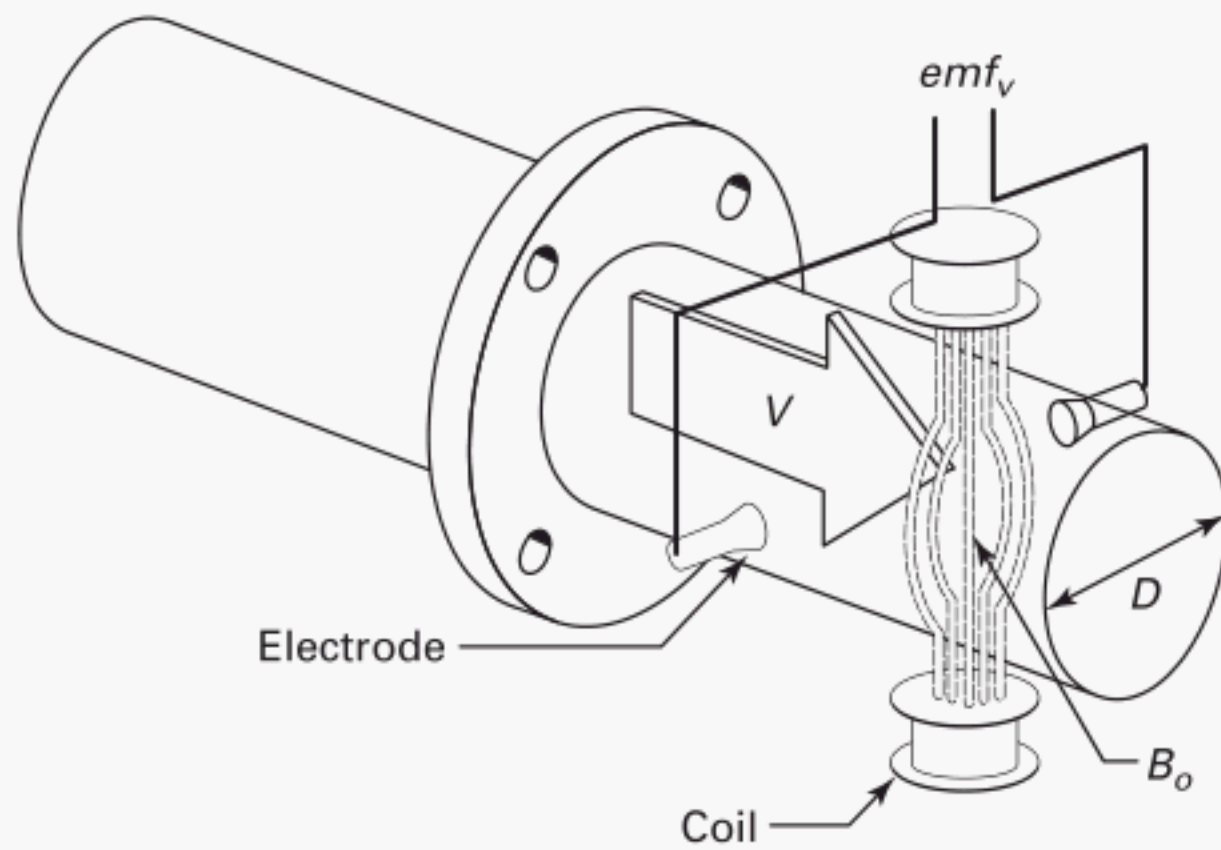
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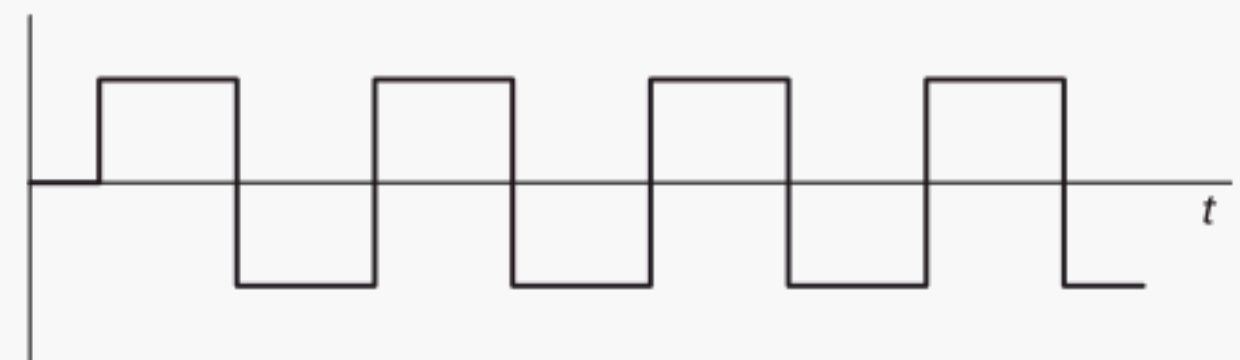
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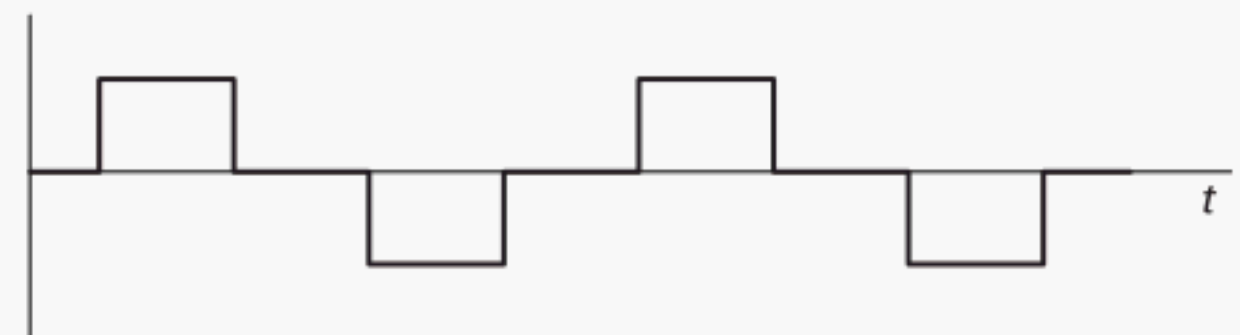
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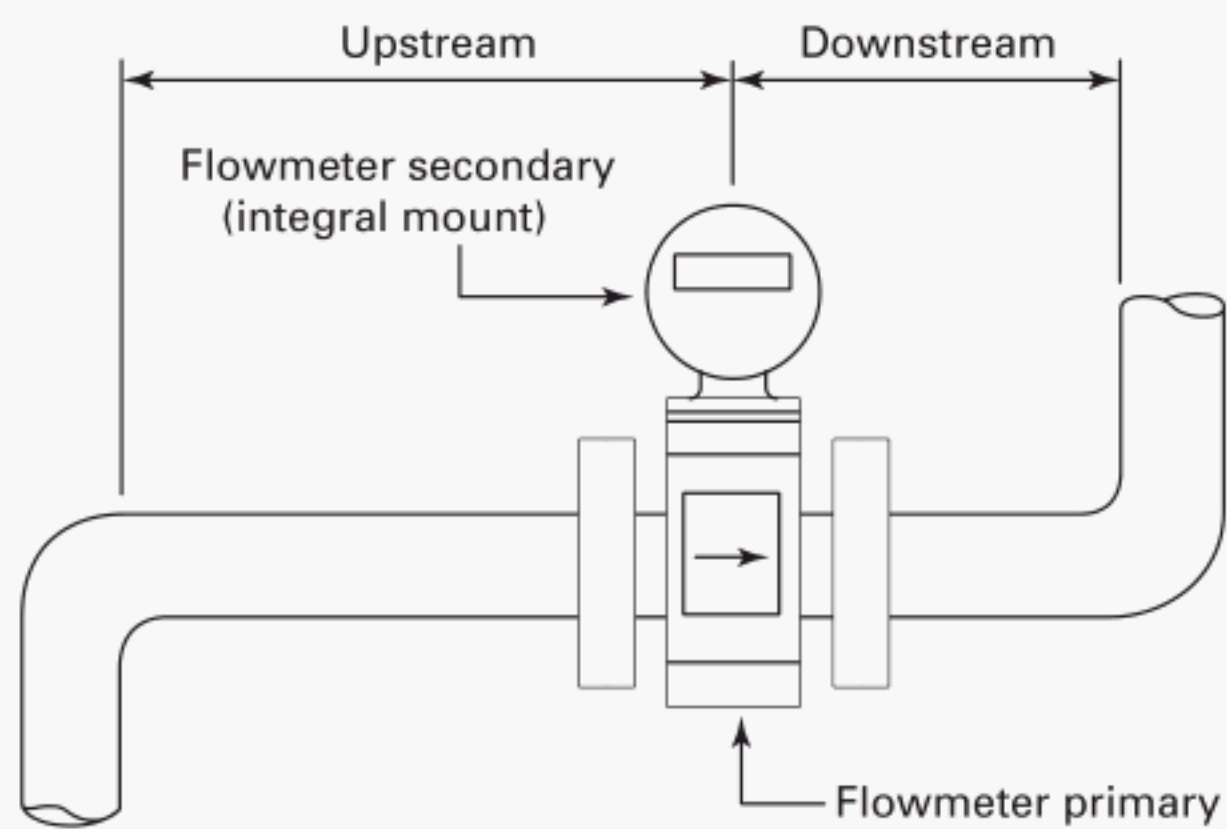


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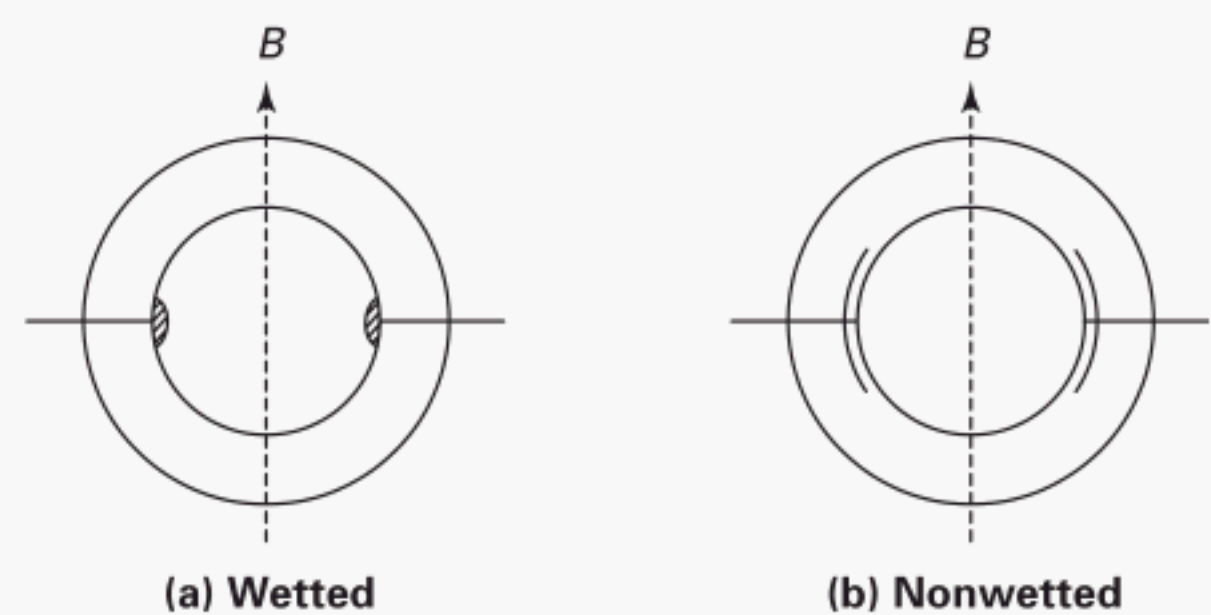


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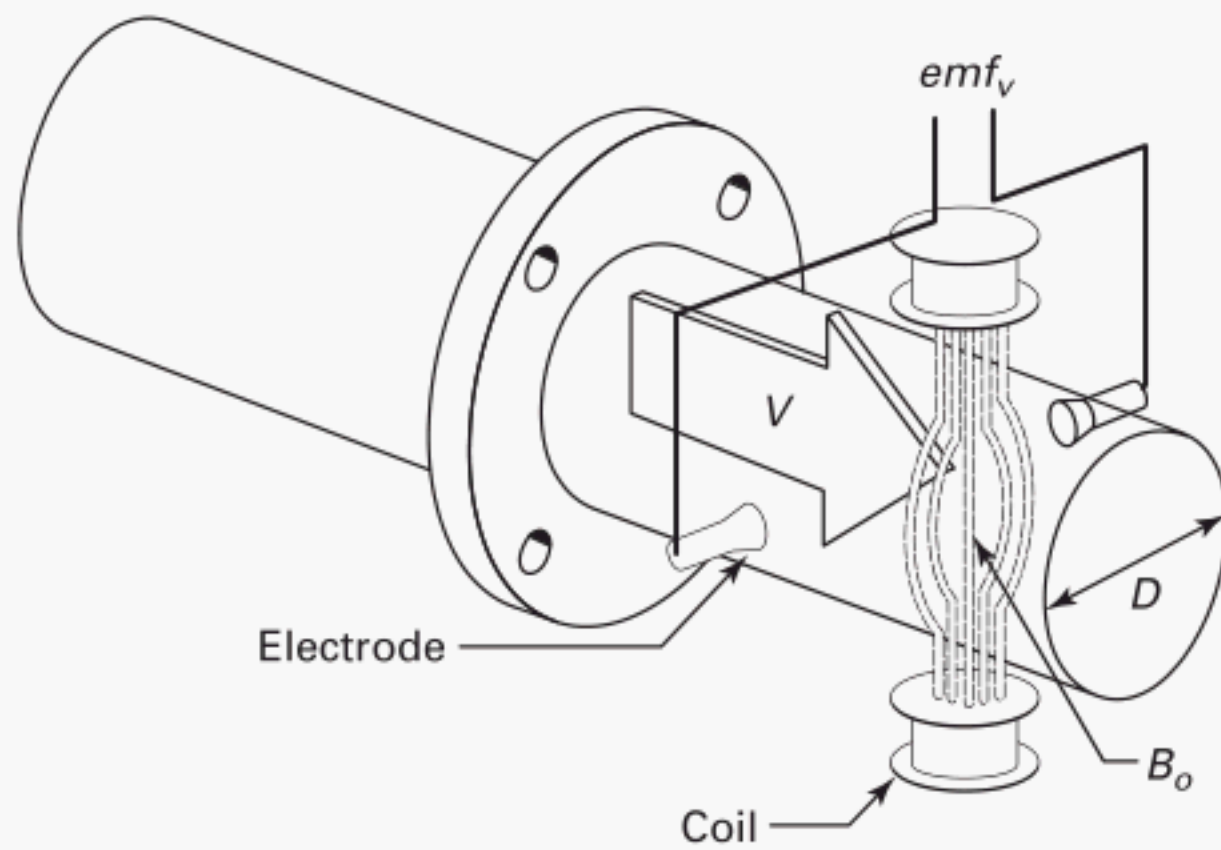


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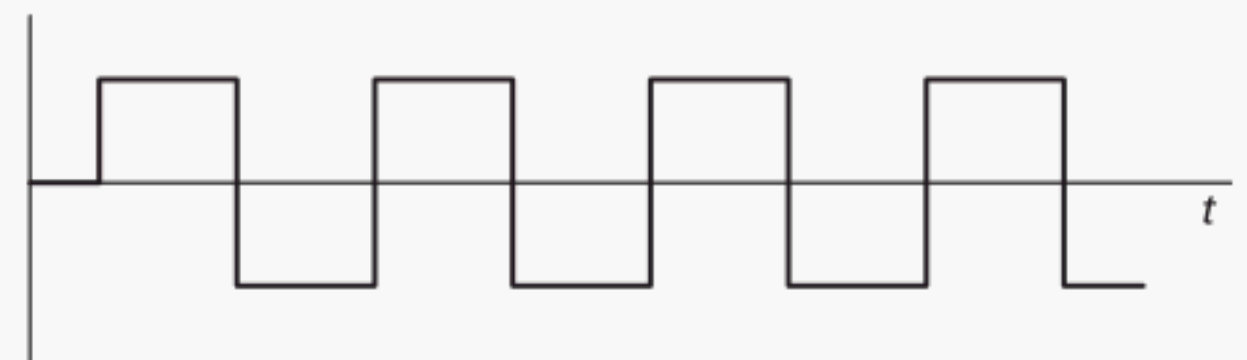
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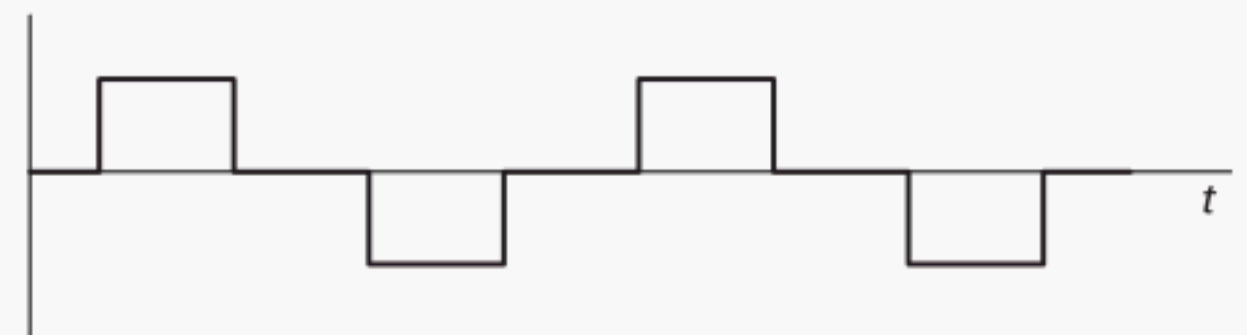
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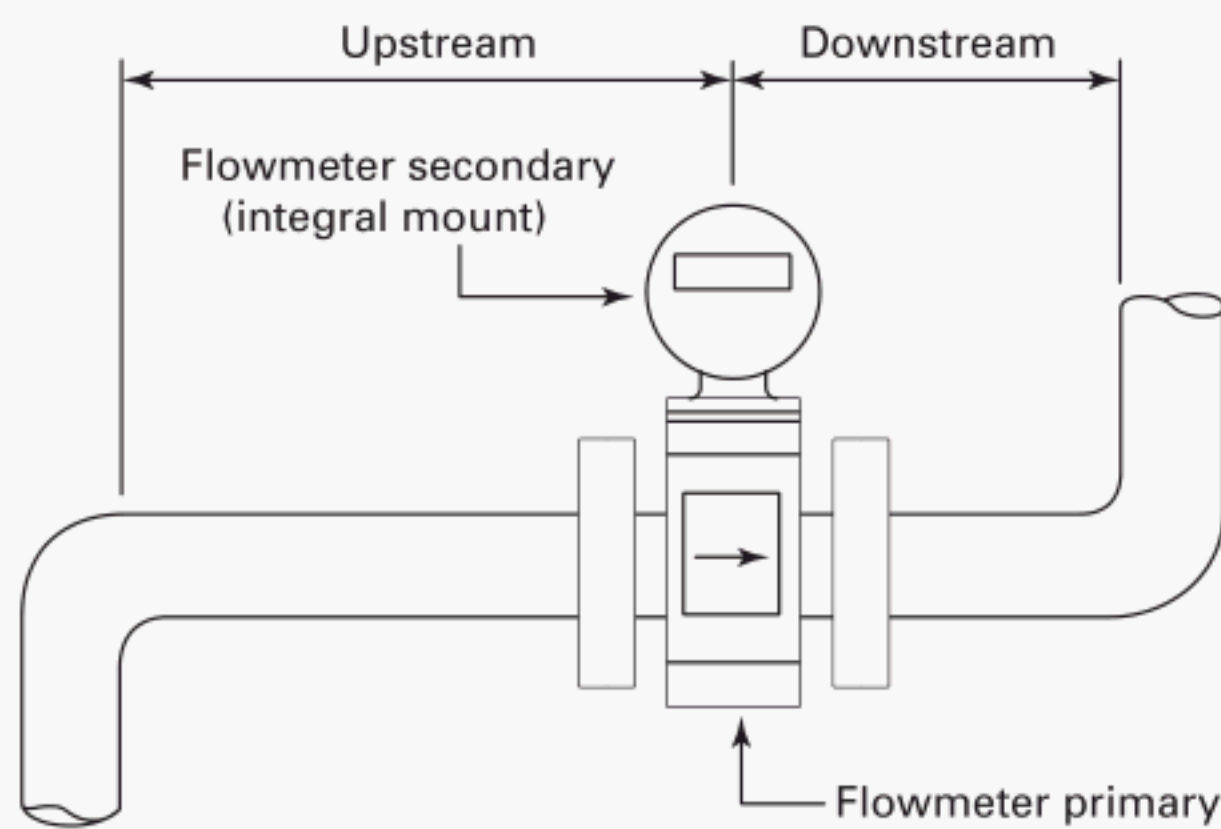


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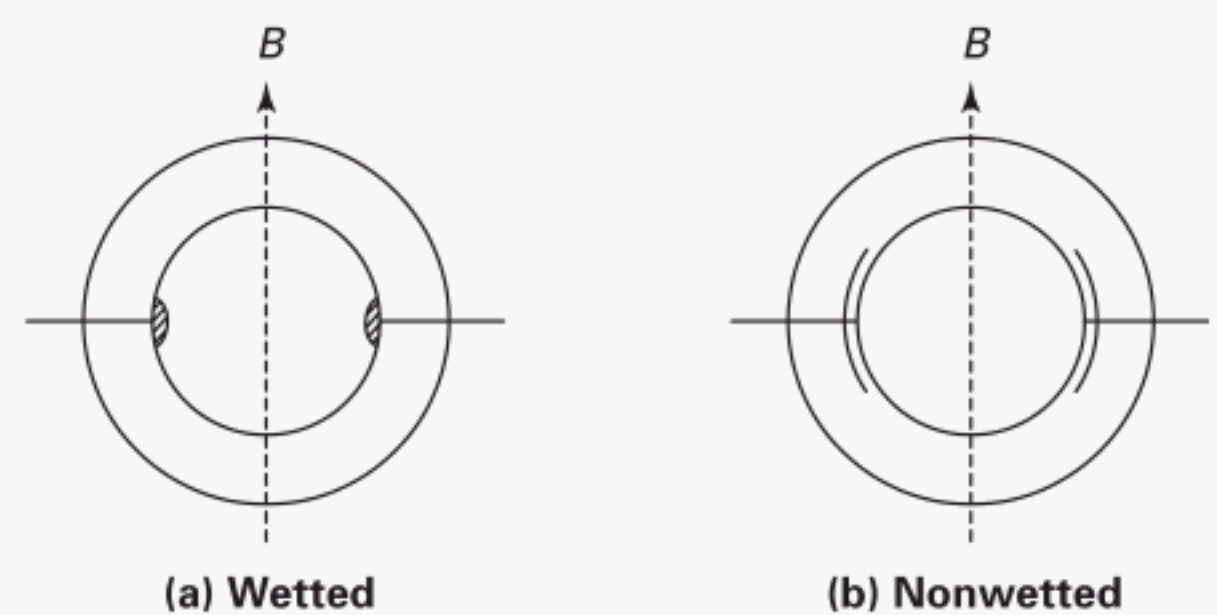


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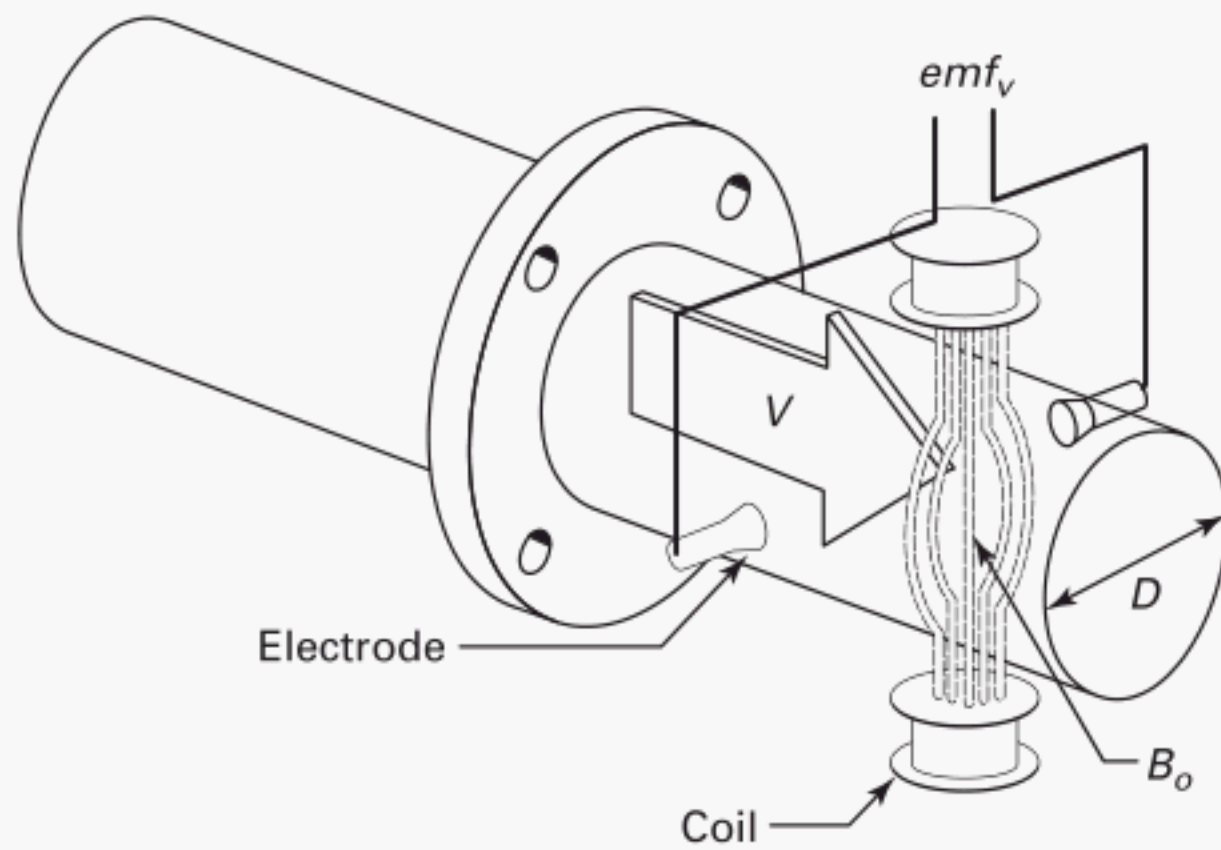
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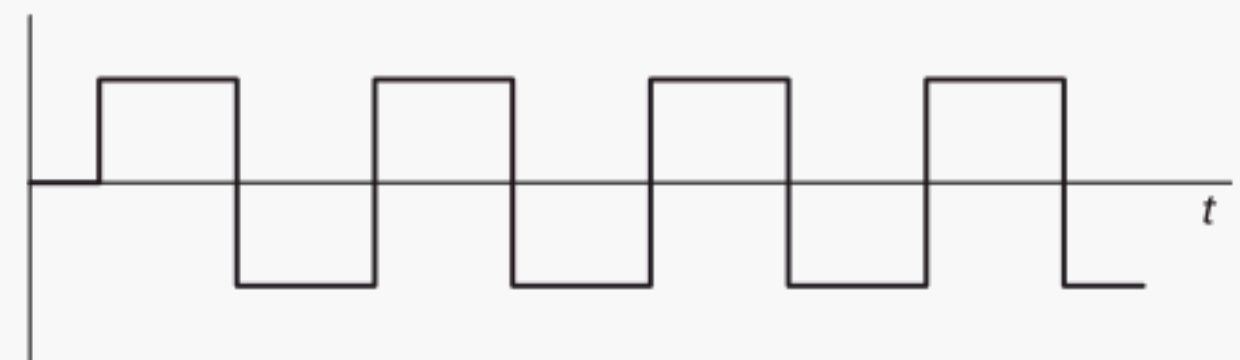
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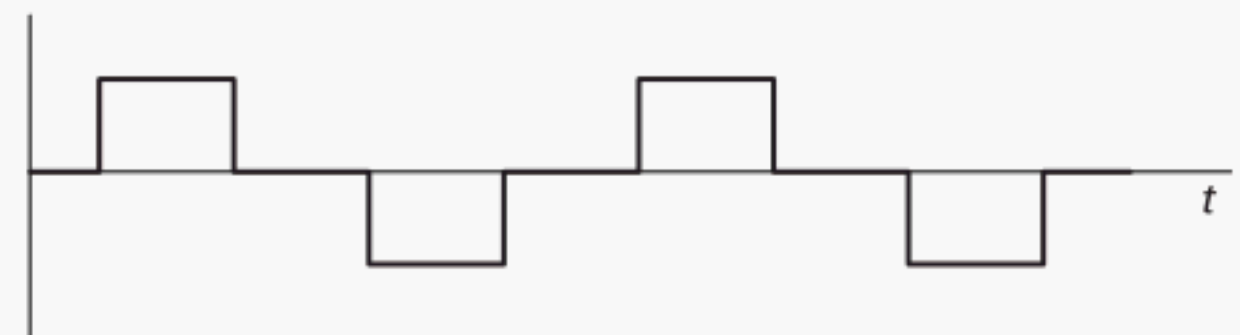
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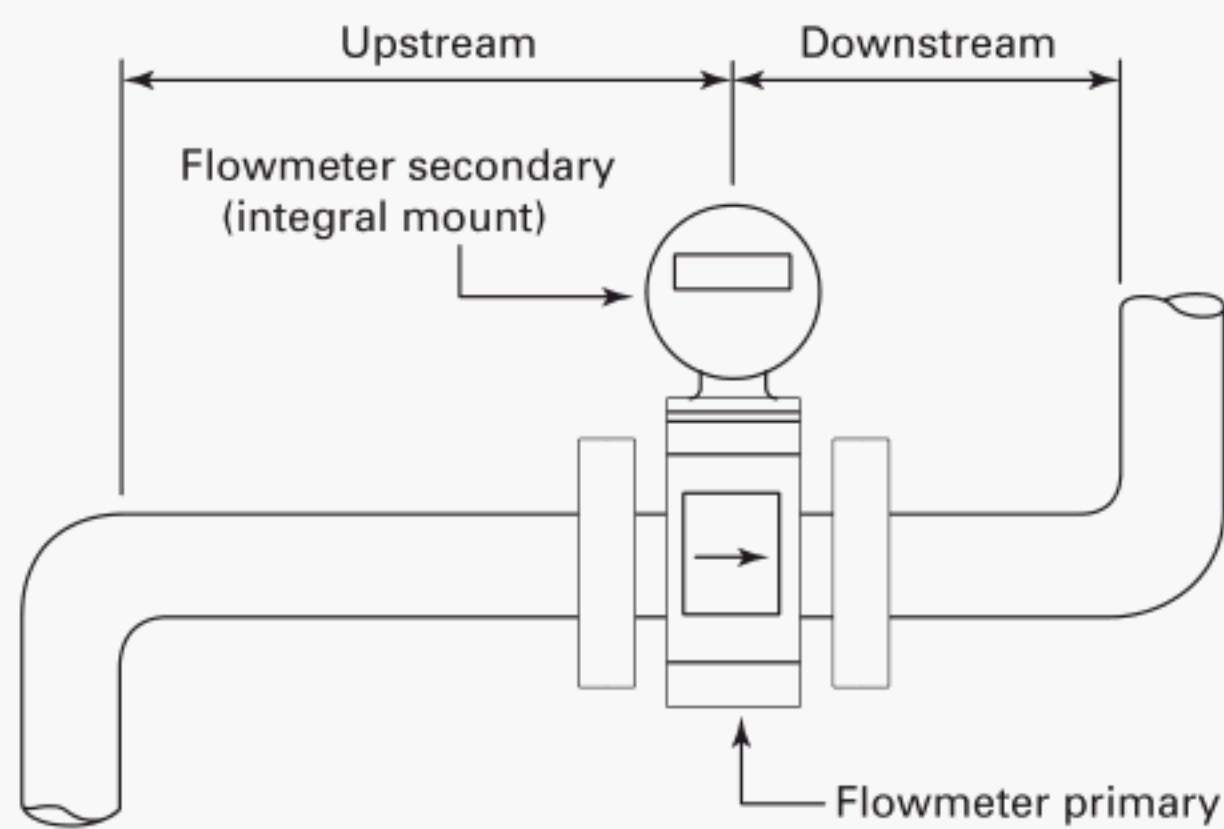


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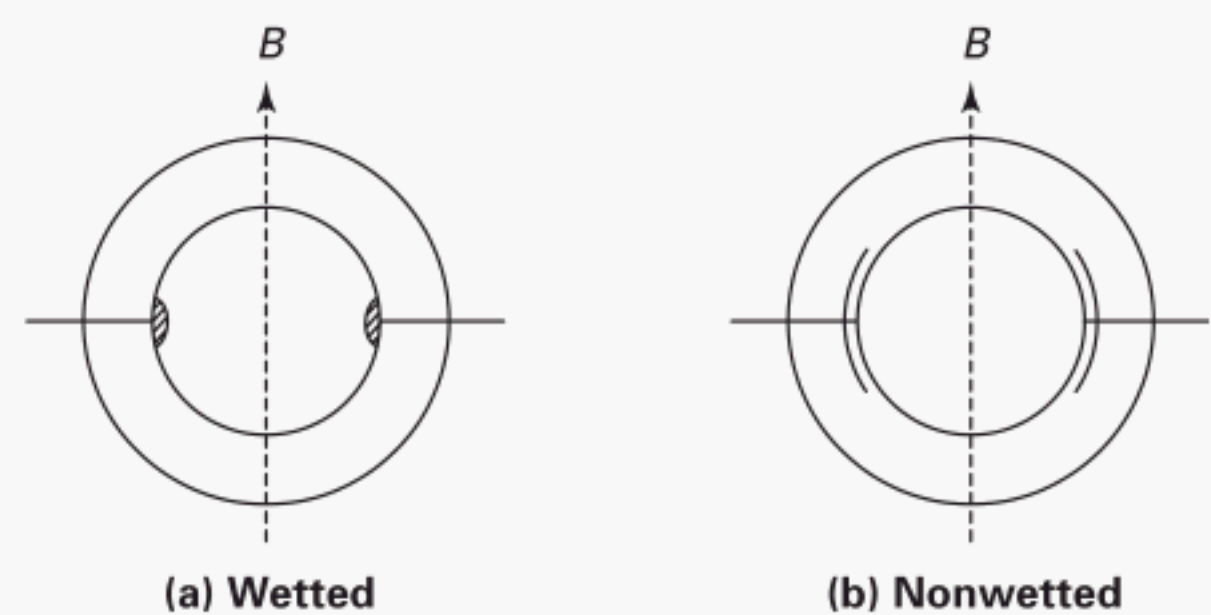


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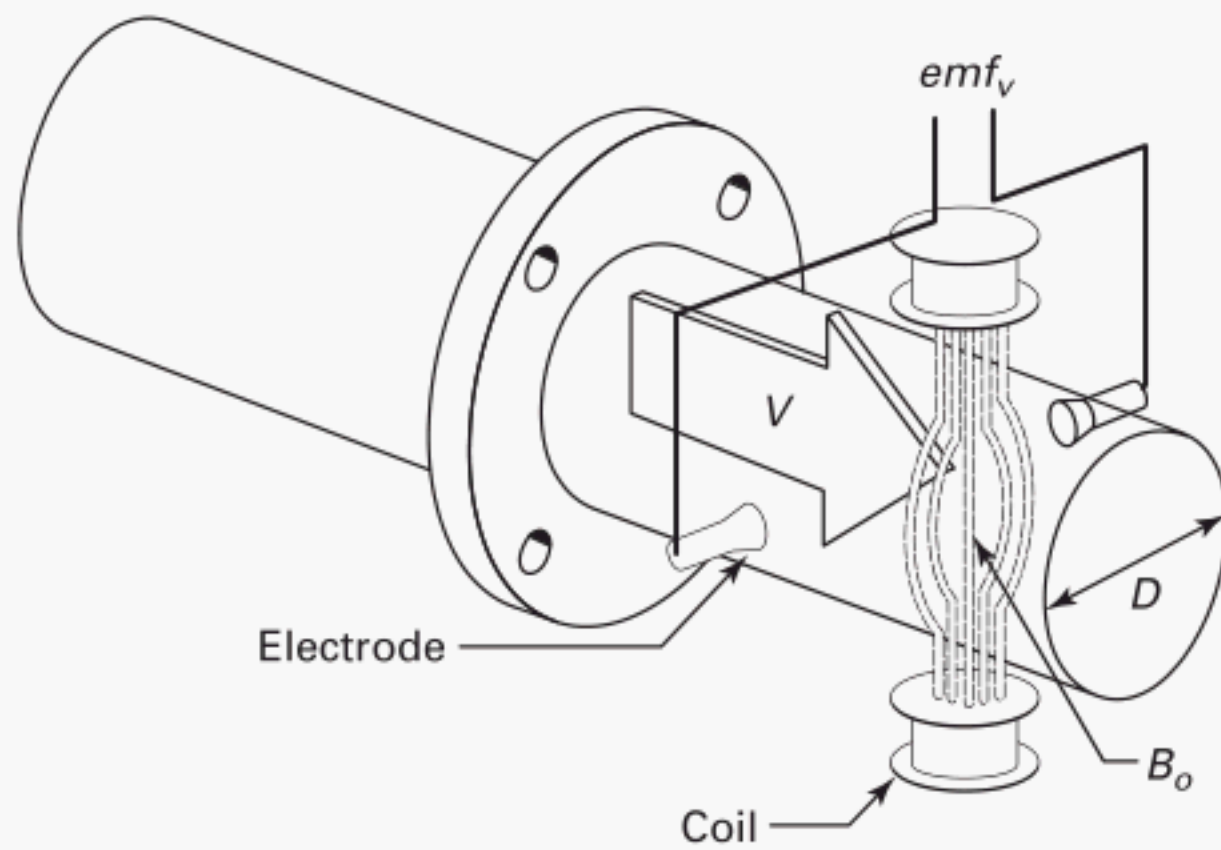


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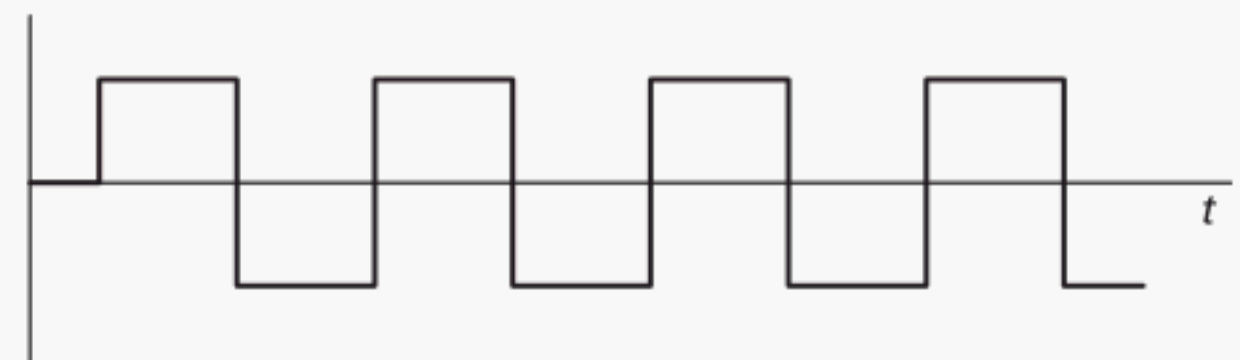
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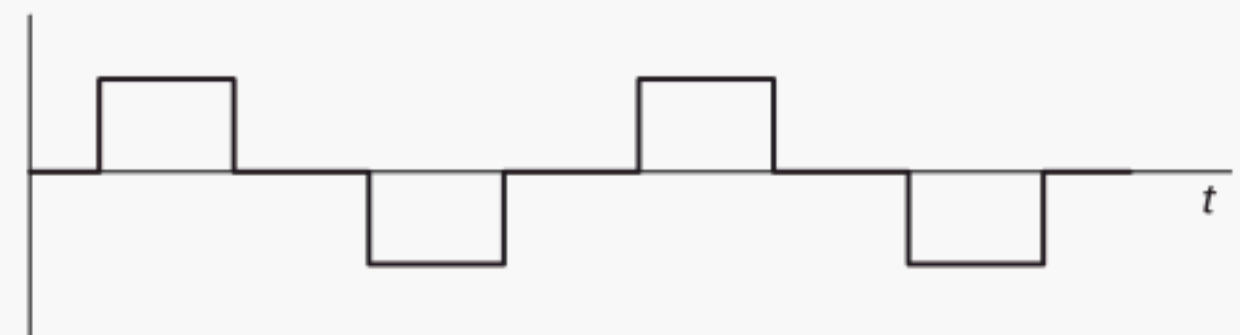
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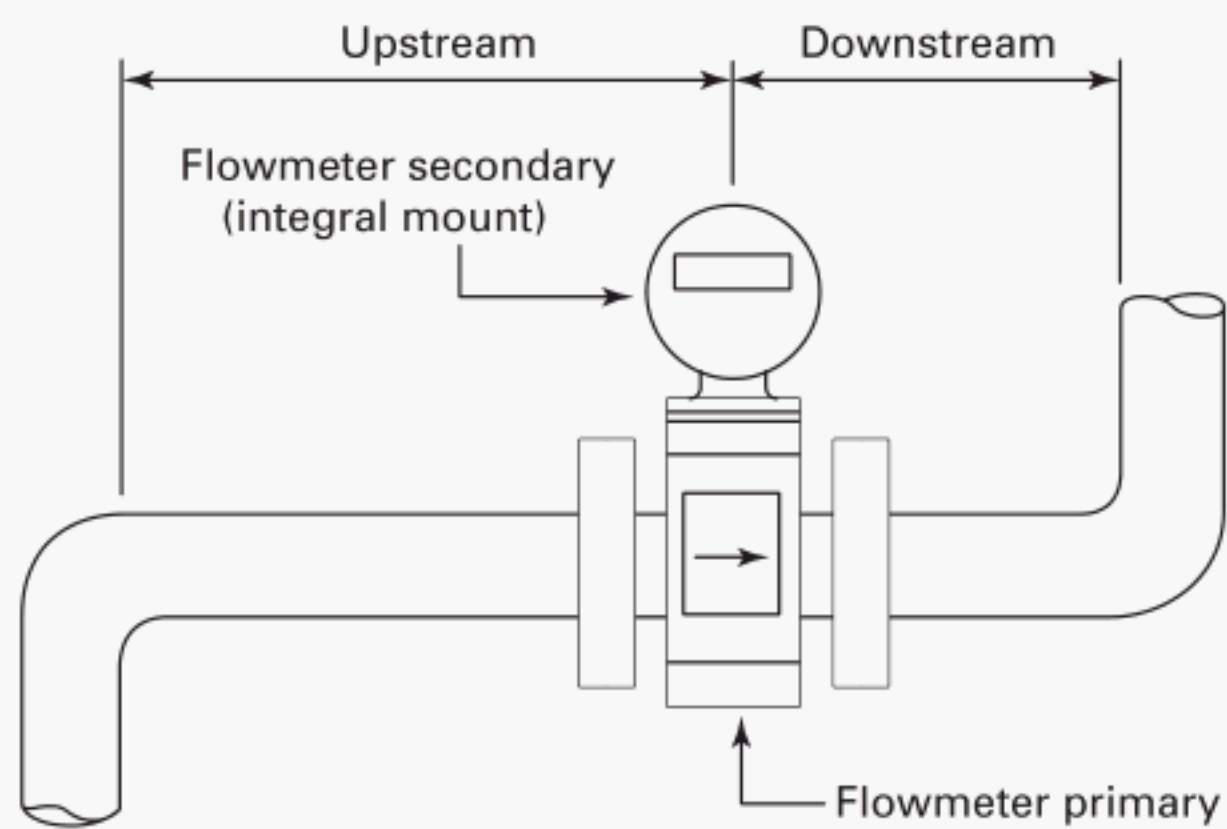


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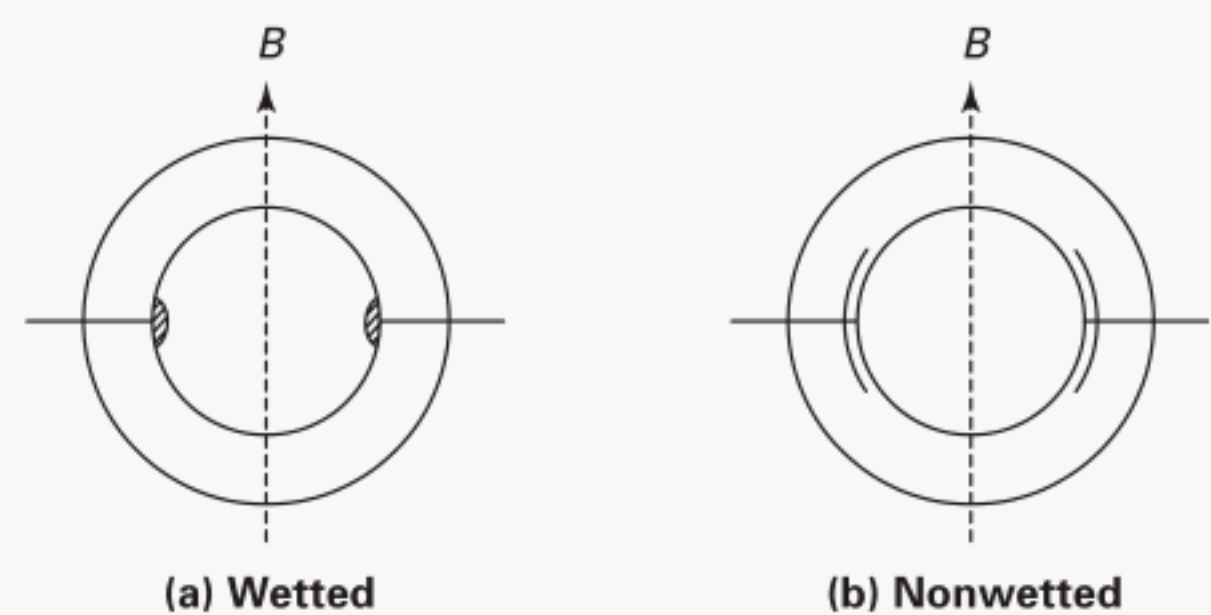


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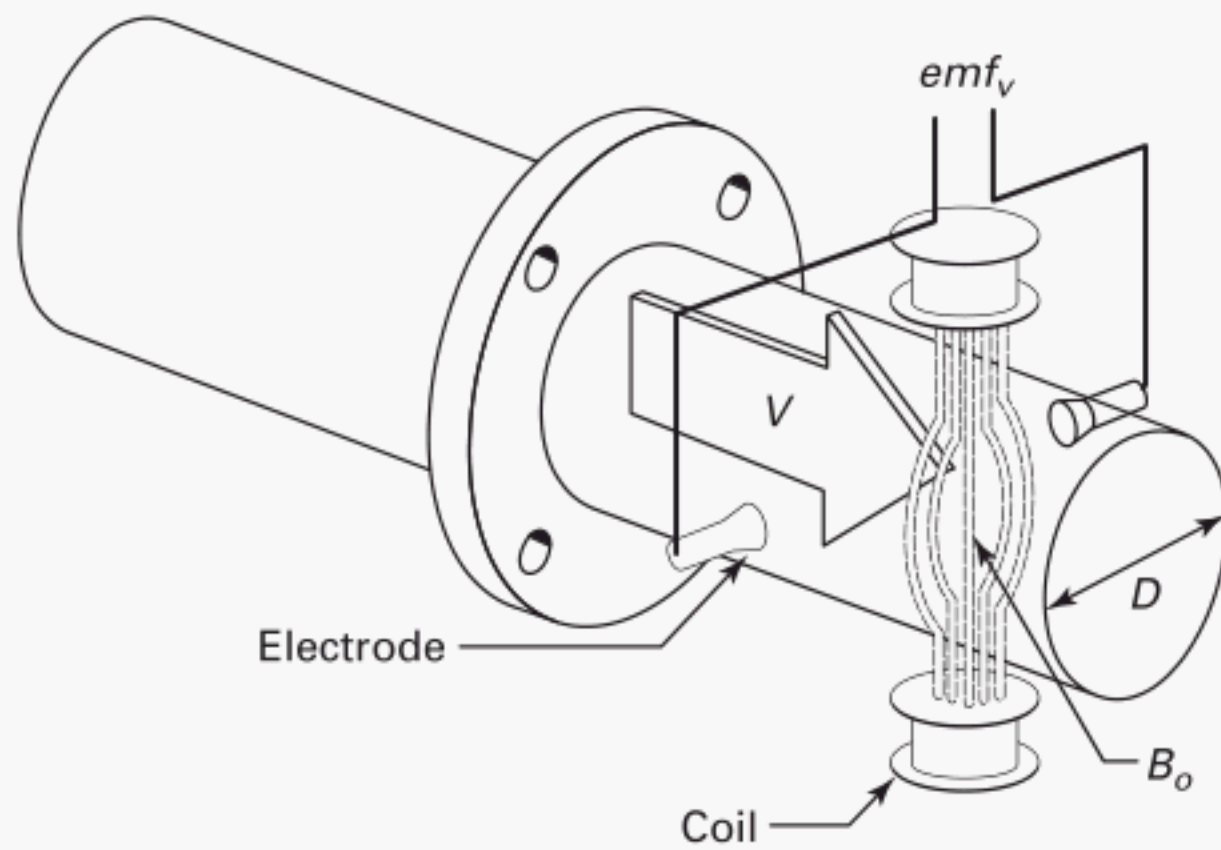
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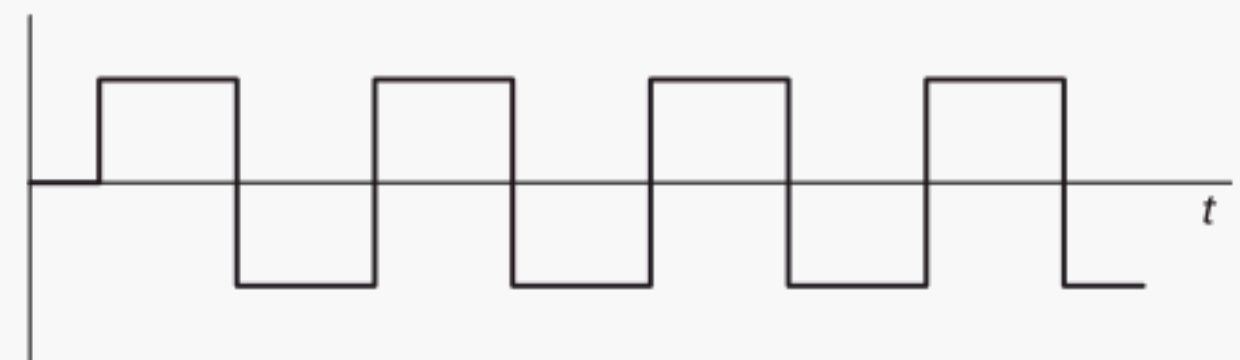
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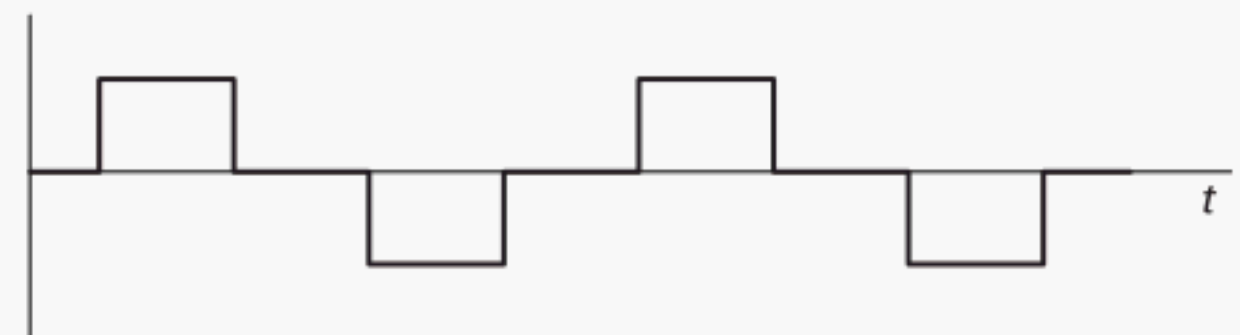
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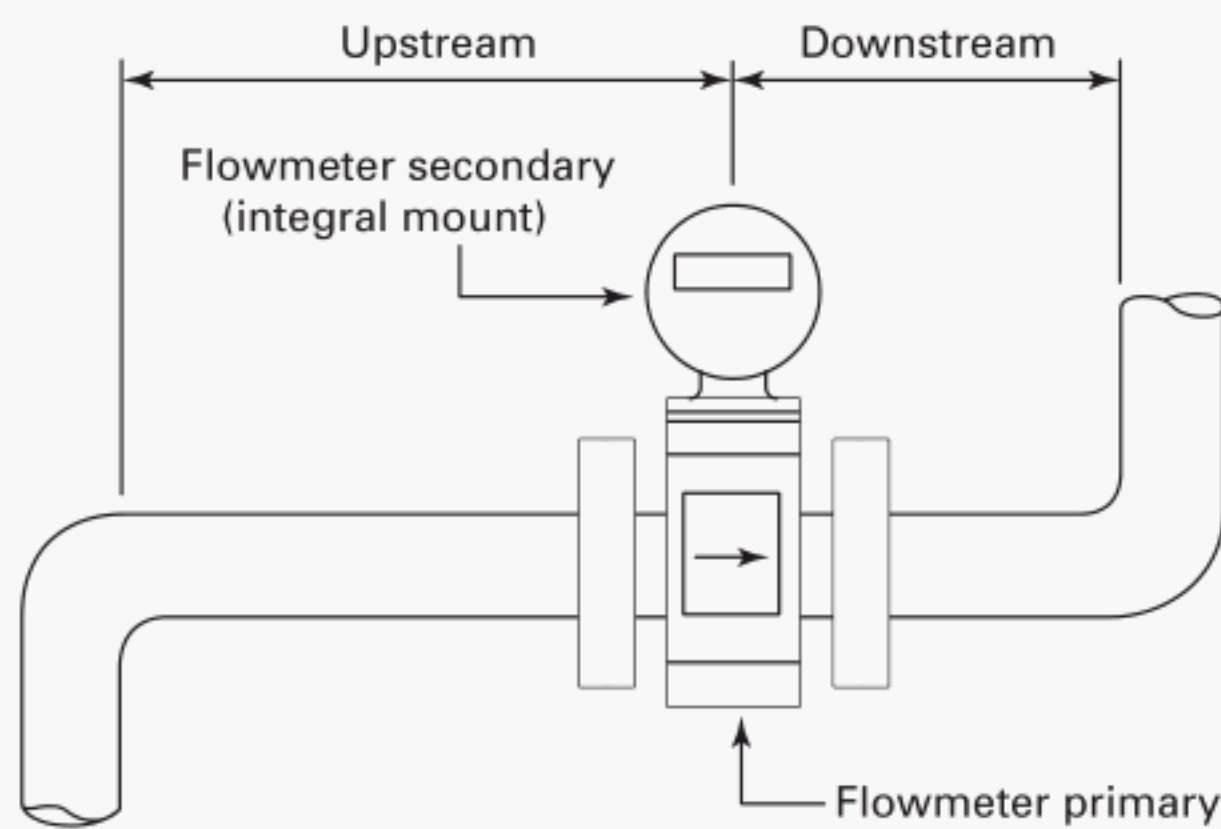


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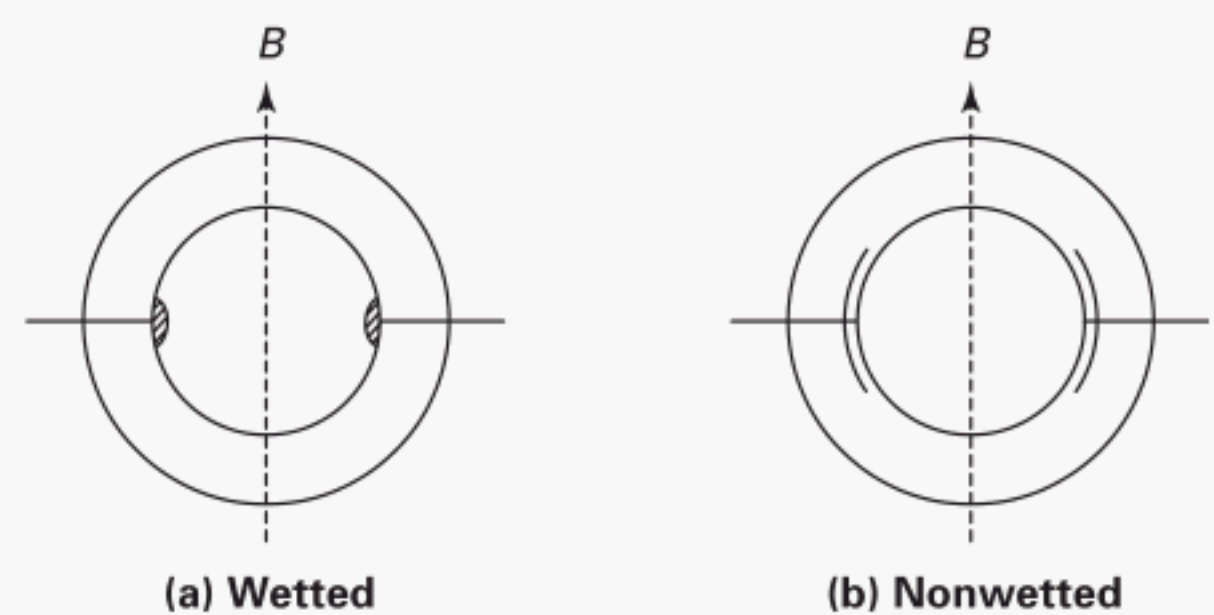


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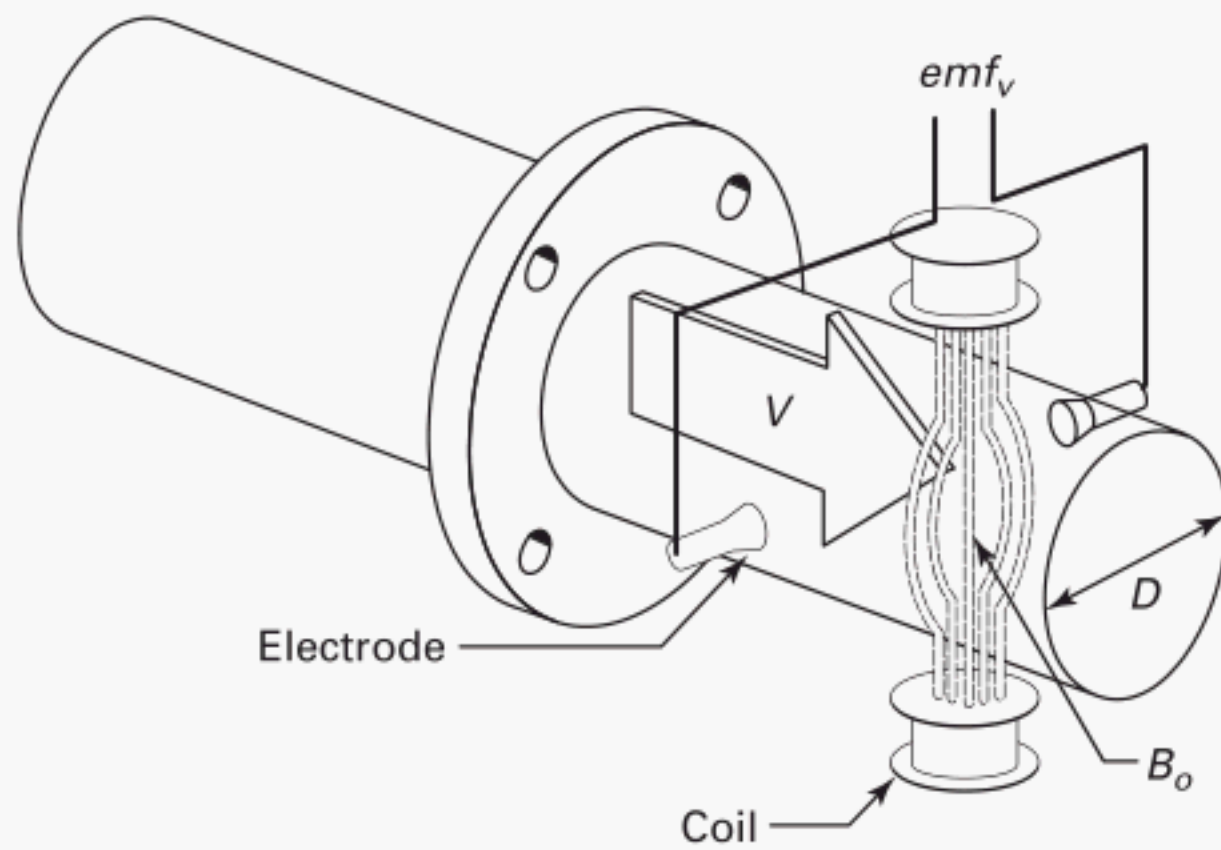


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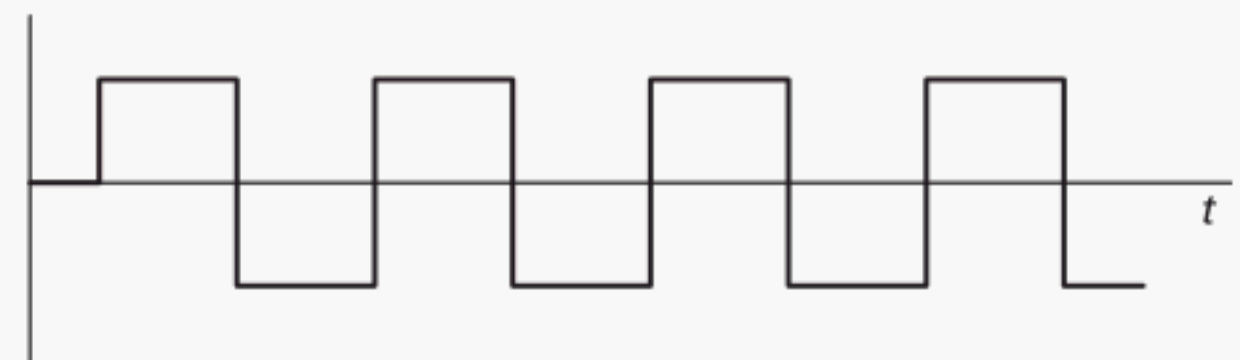
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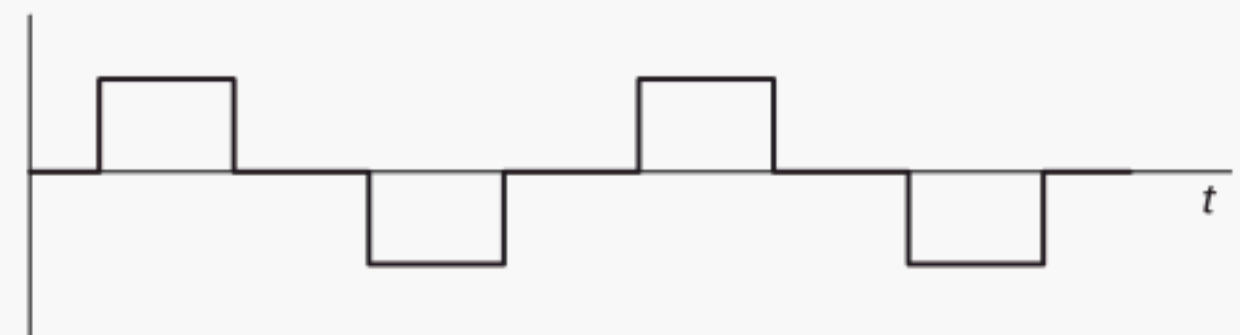
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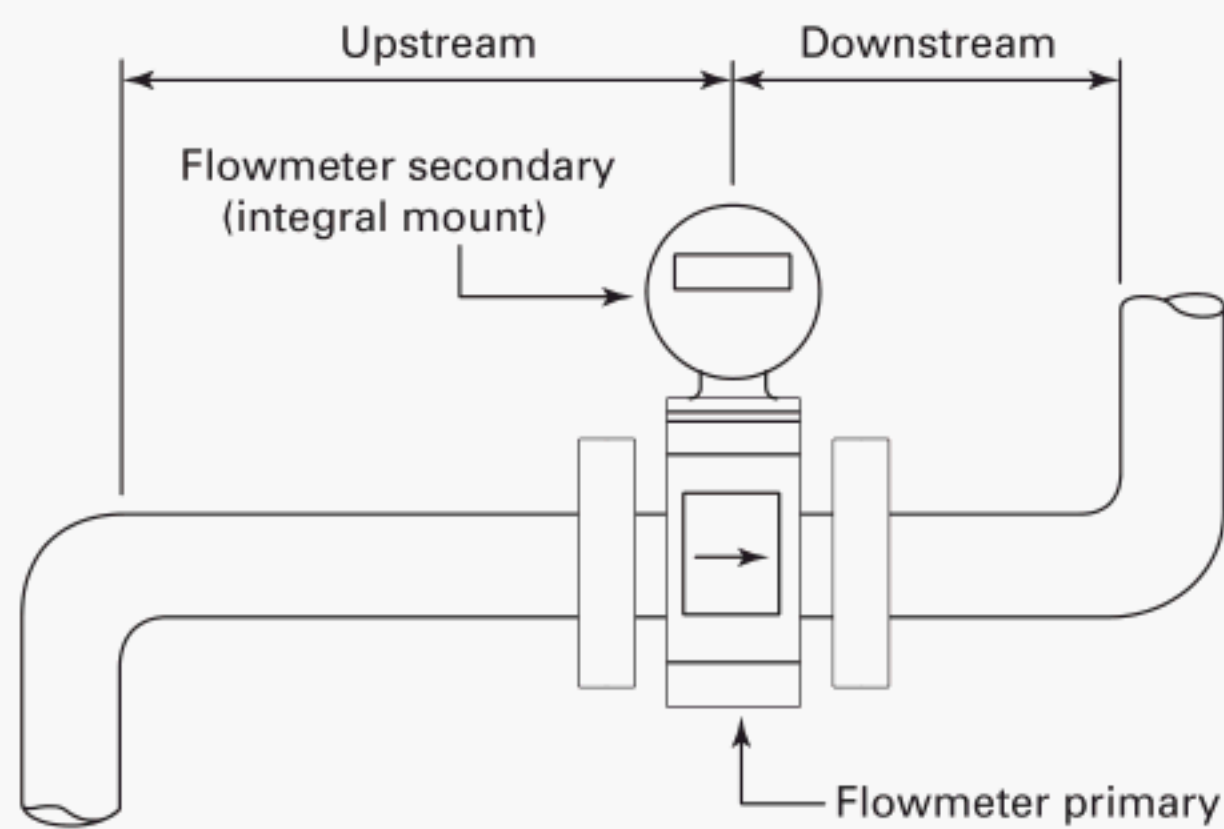


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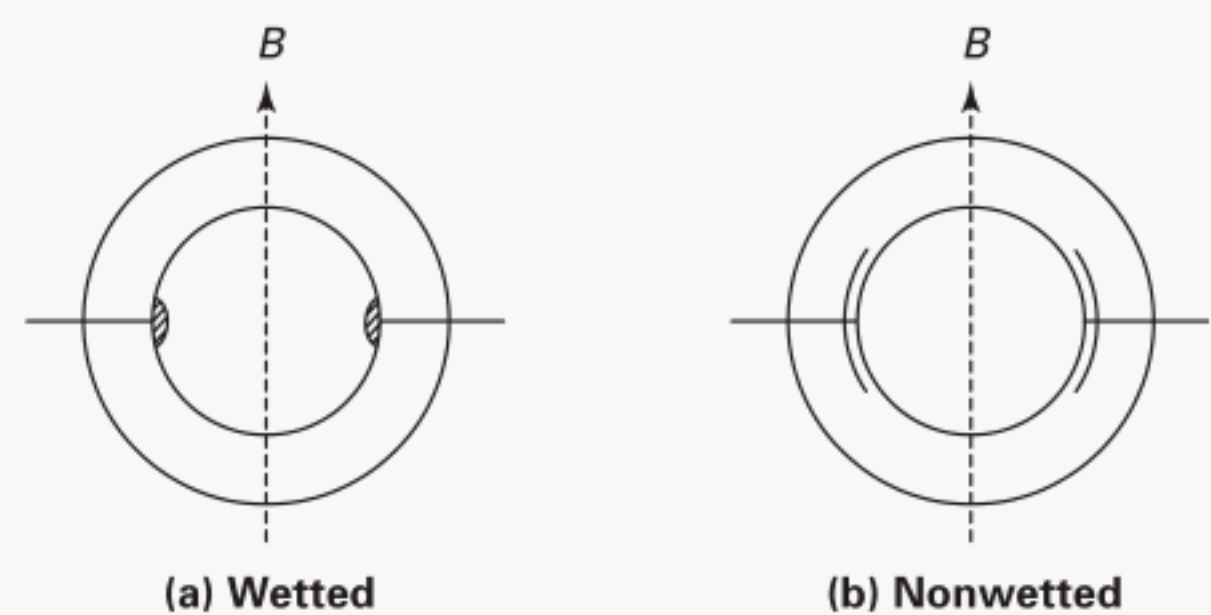


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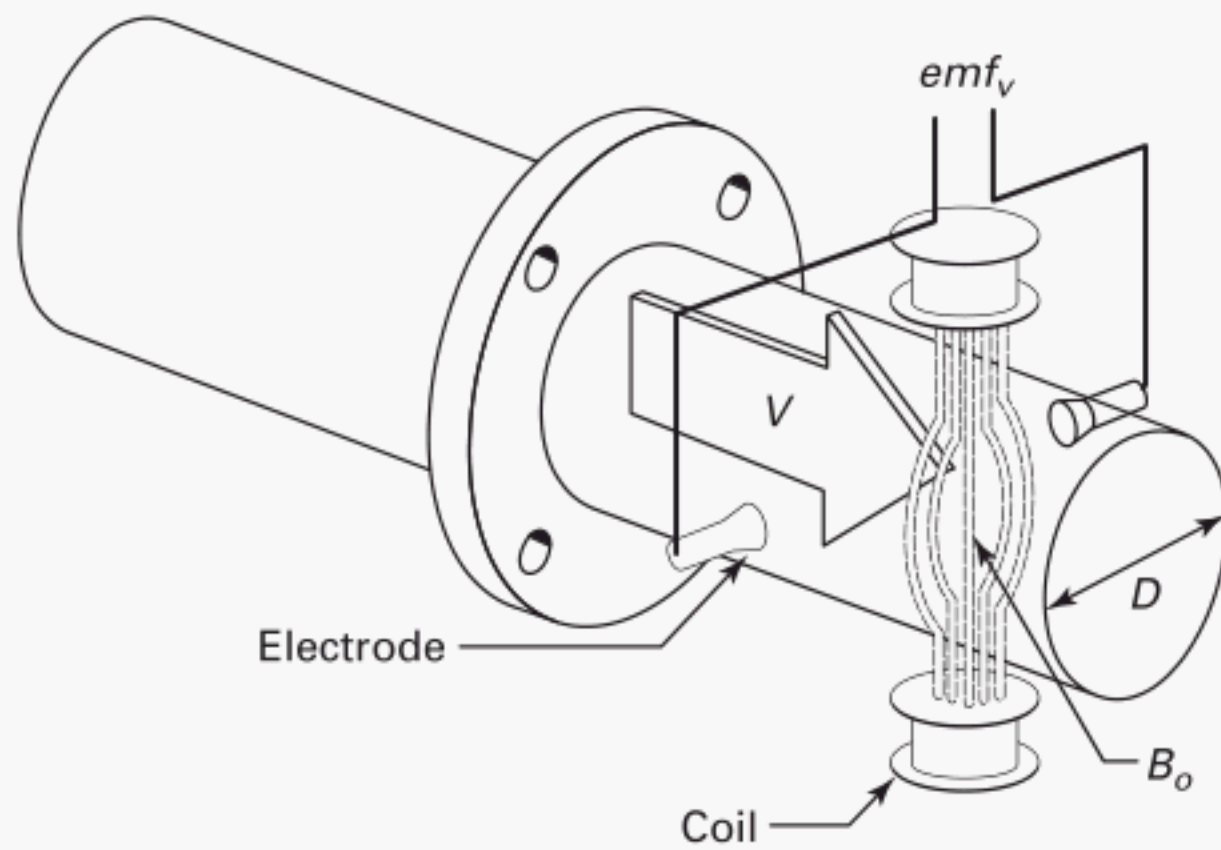
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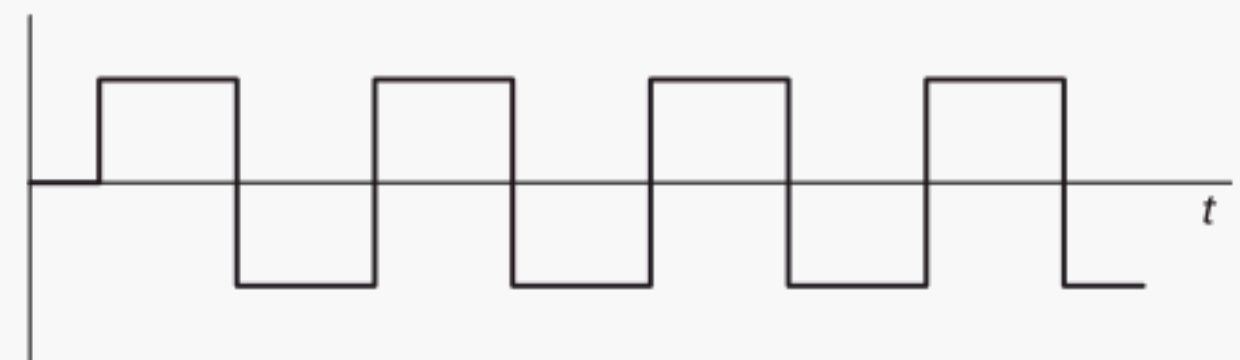
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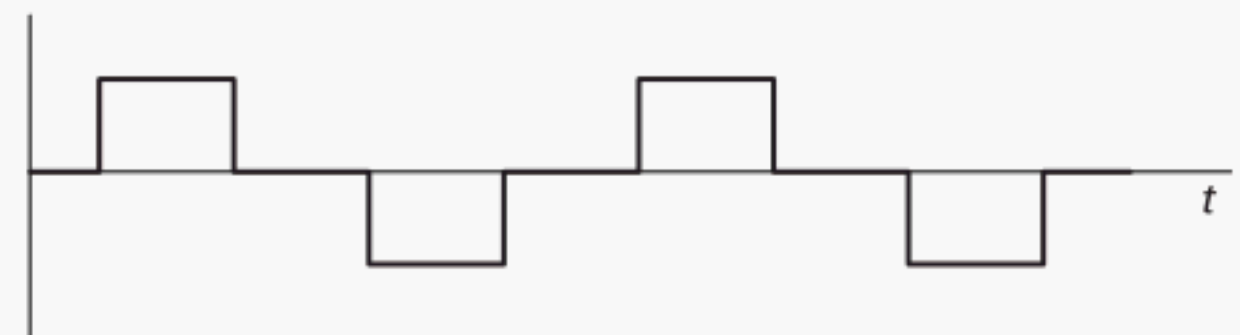
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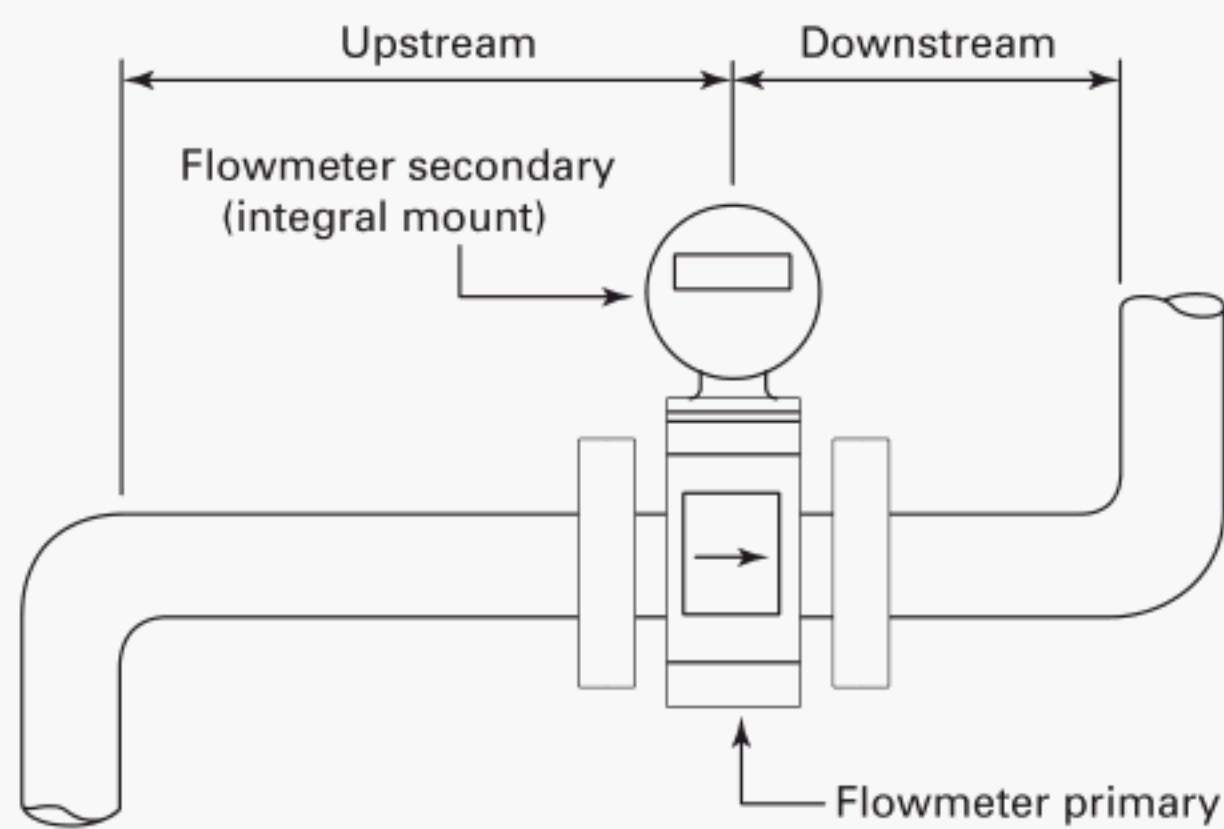


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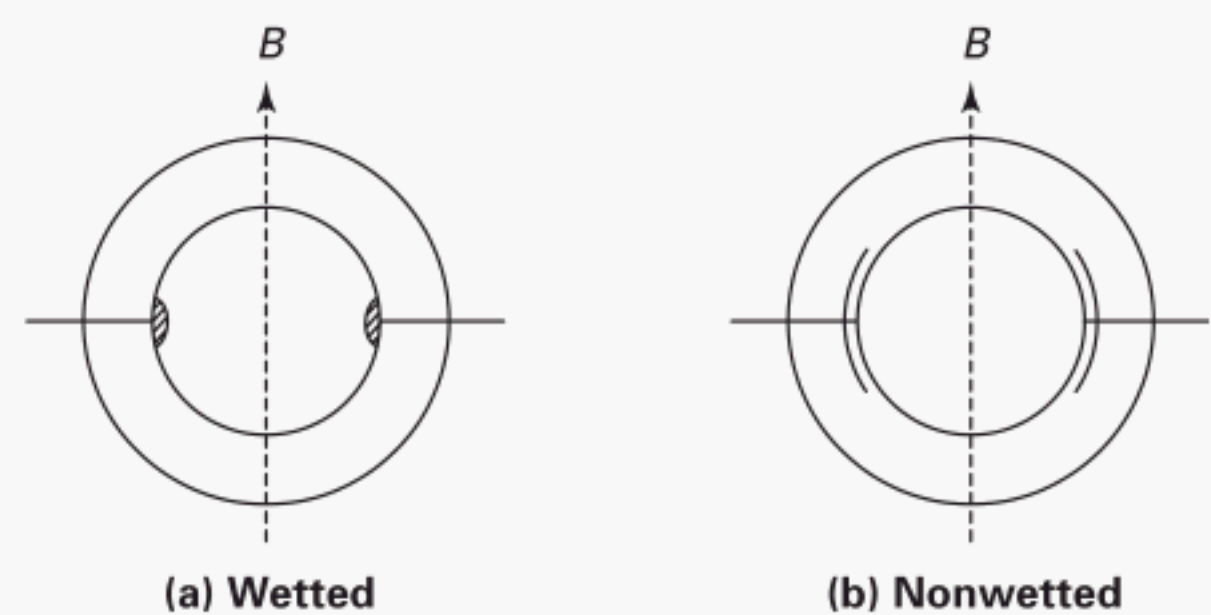


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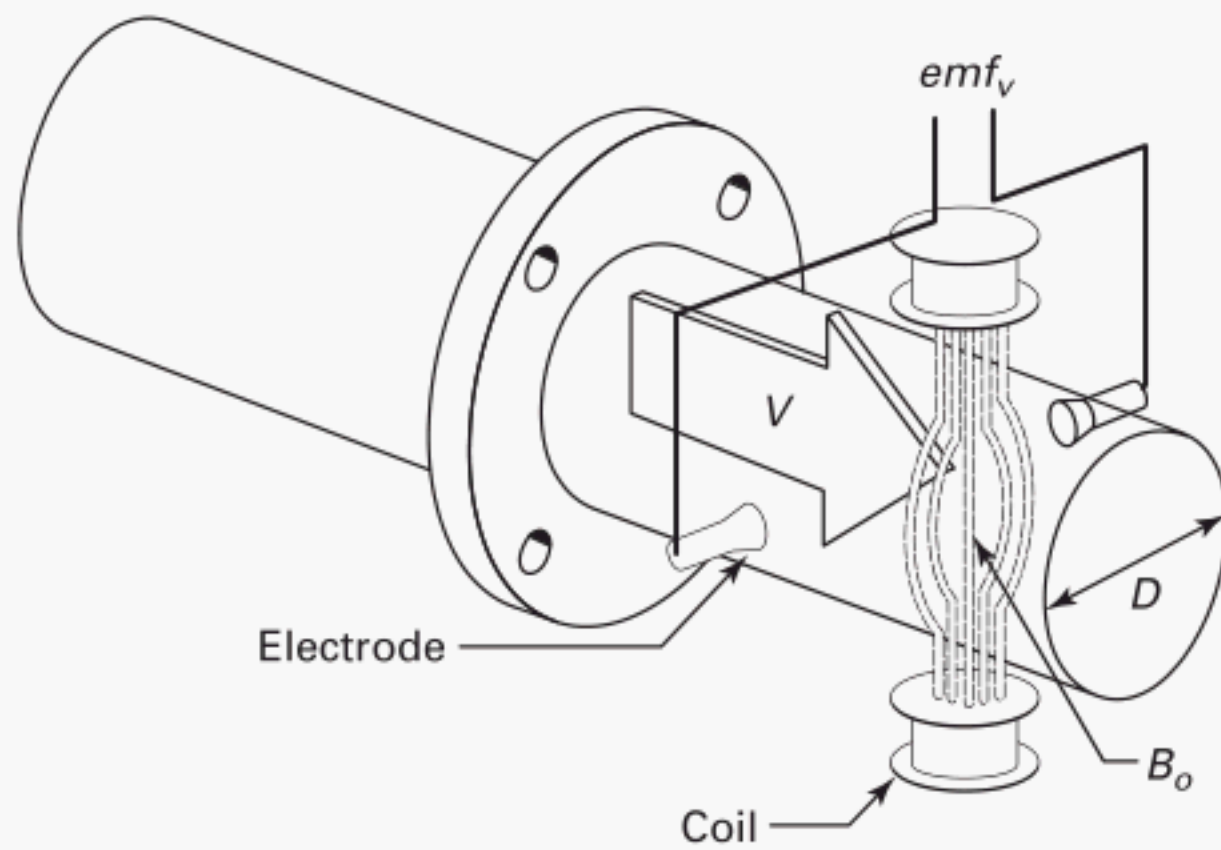


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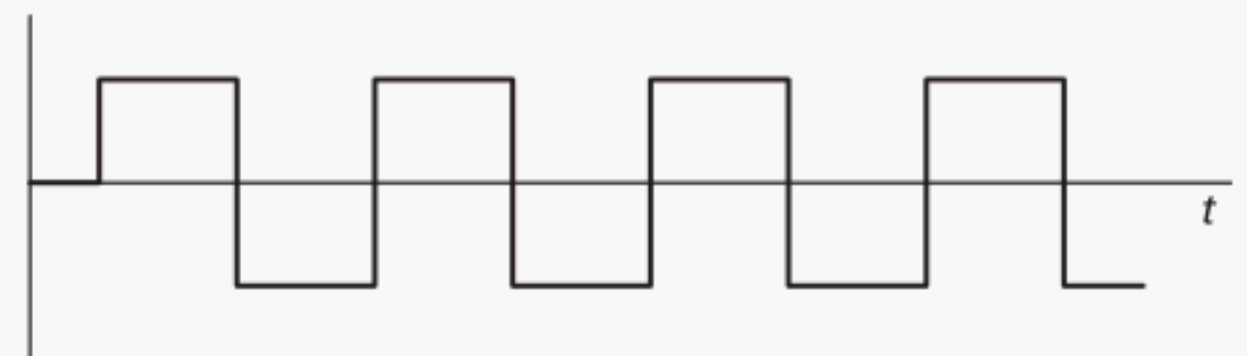
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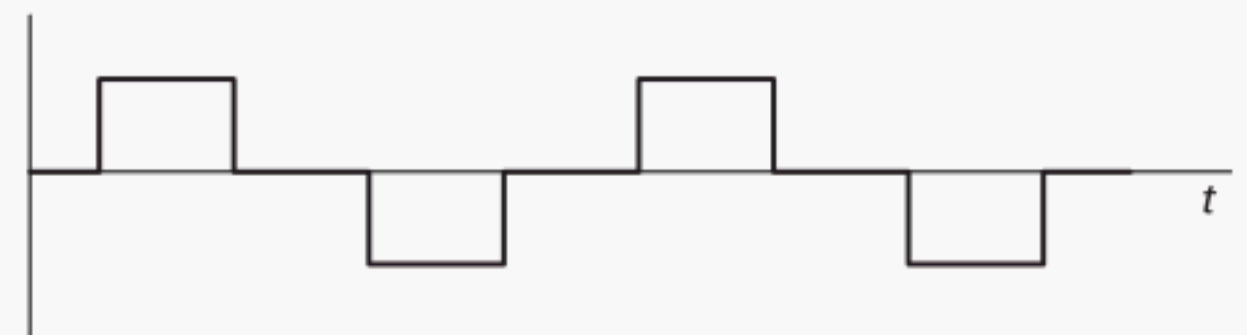
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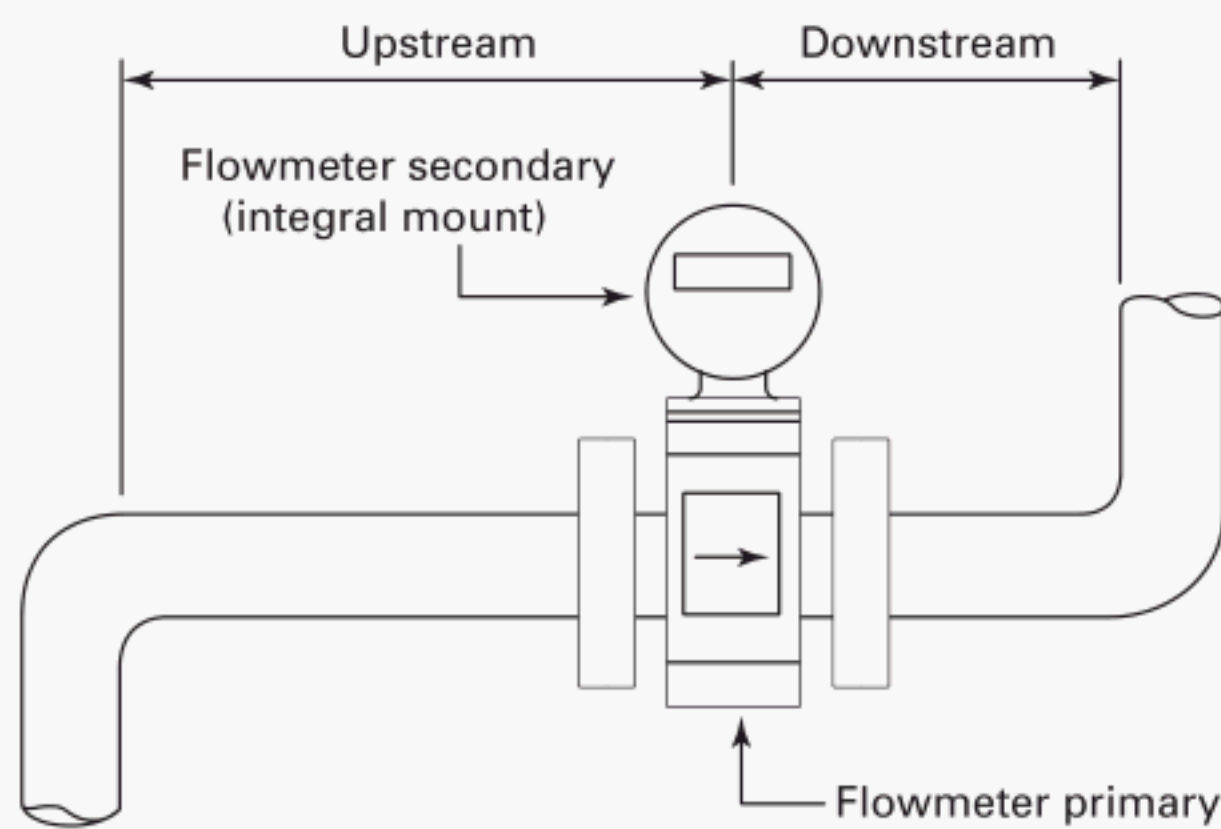


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