Department of Computer Science and Engineering (CSE)
BRAC University

Practice Problem Set 3.4

CSE251 - Electronic Devices and Circuits

DIODE RECTIFIERS

Haft Wave and Full Wave Rectifiers with and without Filter Capacitor, Average or DC Voltage, and Input Output Waveforms

Course Description, COs, and Policies

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Midterm and Final Questions

For any error or issues, contact purbayan.das@bracu.ac.bd

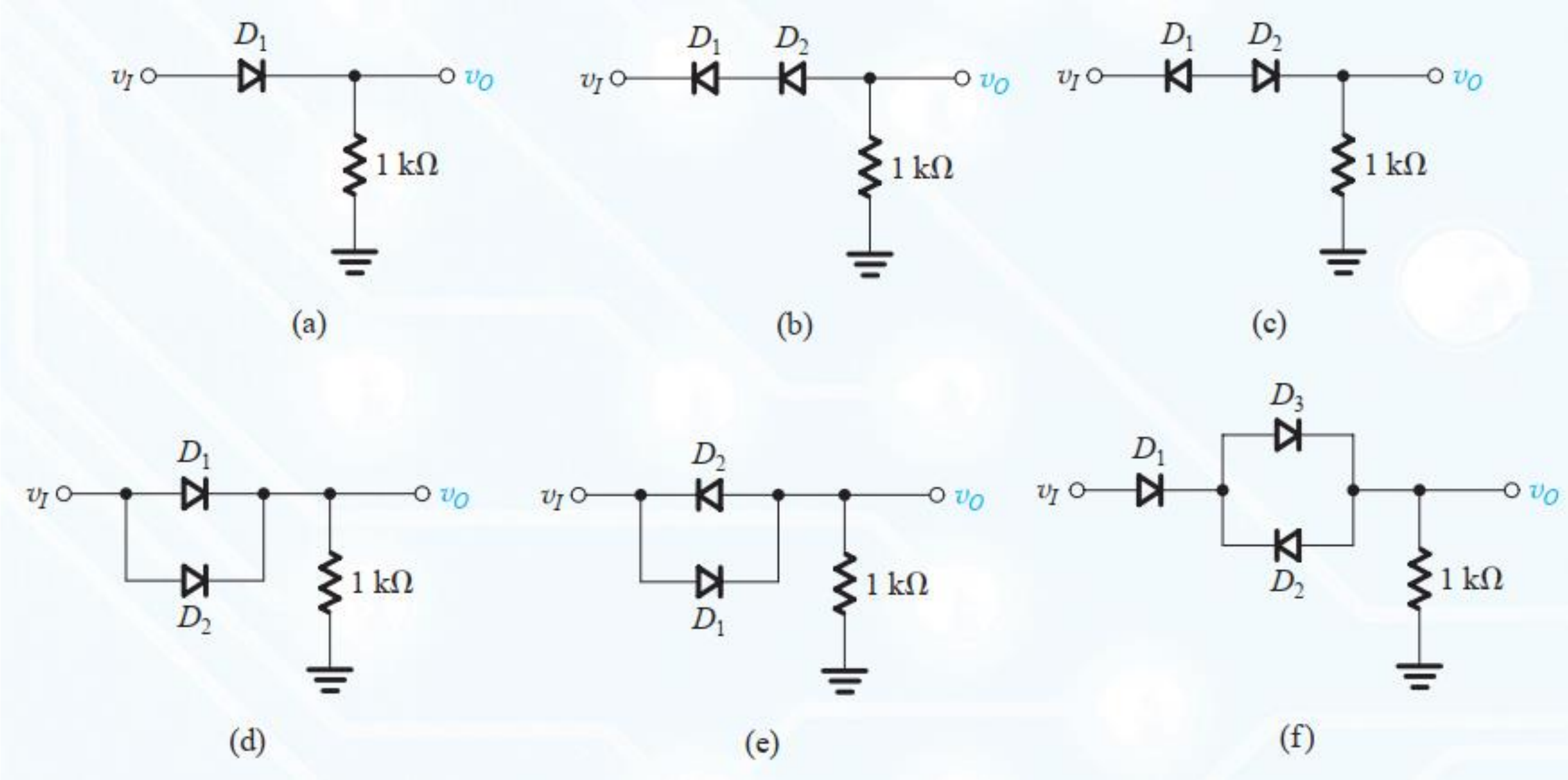
Input Voltage Parameters	Value
Peak	V_m
Frequency	f
Time period	$T = \frac{1}{f}$

Without Filter Capacitor	Output Voltage Frequency	Output Voltage Peak $(\boldsymbol{V_P})$	Average output voltage $(\boldsymbol{V_{DC}}$ or $\boldsymbol{V_{Avg}})$	Ripple Voltage $(\boldsymbol{V_r})$	Average Output Current $(\boldsymbol{I_{Avg}}$ or $\boldsymbol{I_{DC}})$
HW	f	$V_m - V_{D_o}$	$\frac{V_m}{\pi} - \frac{V_{D_o}}{2}$	V_P	V_{DC}/R
FW	$2f$	$V_m - 2V_{D_o}$	$\frac{2V_m}{\pi} - 2V_{D_o}$	V_P	V_{DC}/R

With Filter Capacitor	Output Voltage Frequency	Output Voltage Peak $(\boldsymbol{V_P})$	Average output voltage $(\boldsymbol{V_{DC}}$ or $\boldsymbol{V_{Avg}})$	Ripple Voltage $(\boldsymbol{V_r})$	Average Output Current $(\boldsymbol{I_{Avg}}$ or $\boldsymbol{I_{DC}})$
HW	f	$V_m - V_{D_o}$	$V_P - \frac{V_r}{2}$	$\frac{V_P}{fRC}$	V_{DC}/R
FW	$2f$	$V_m - 2V_{D_o}$	$V_P - \frac{V_r}{2}$	$\frac{V_P}{2fRC}$	V_{DC}/R

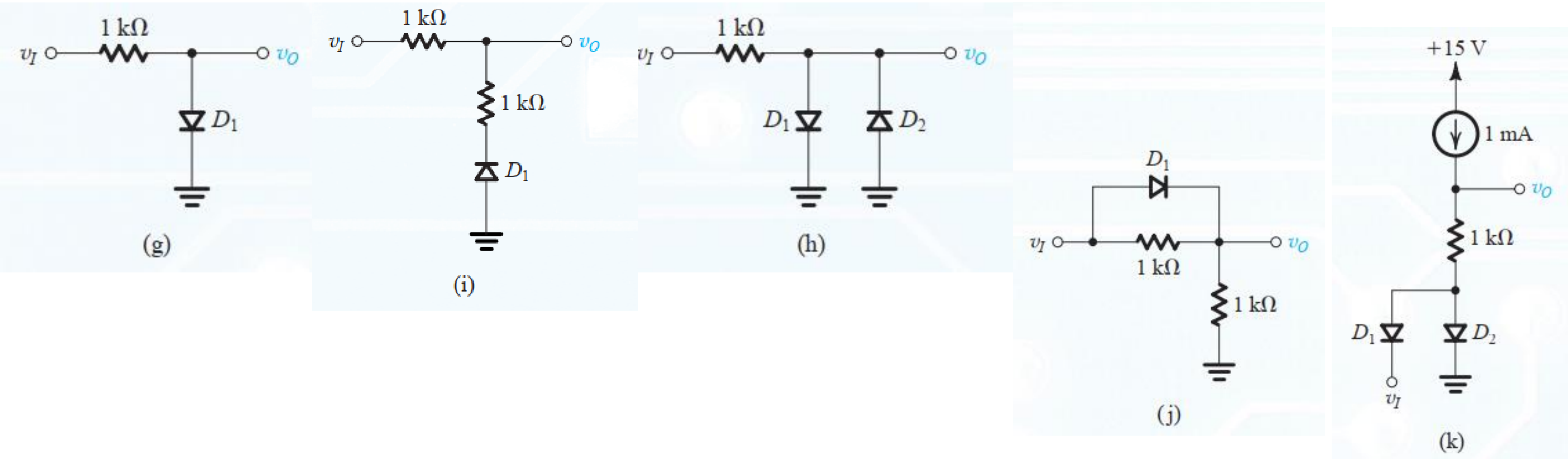
Problem 1.1

- In each of the ideal-diode circuits shown below, v_I is a $1\ kHz$, $10\ V$ peak sine wave. Sketch the waveform resulting at v_O. What are its positive and negative peak values?



Problem 1.2

- In each of the ideal-diode circuits shown below, v_I is a $1\ kHz$, $10\ V$ peak sine wave. Sketch the waveform resulting at v_O. What are its positive and negative peak values?



Problem 2

- The diode in the adjacent circuit has a cut-in voltage of $1\,V$.

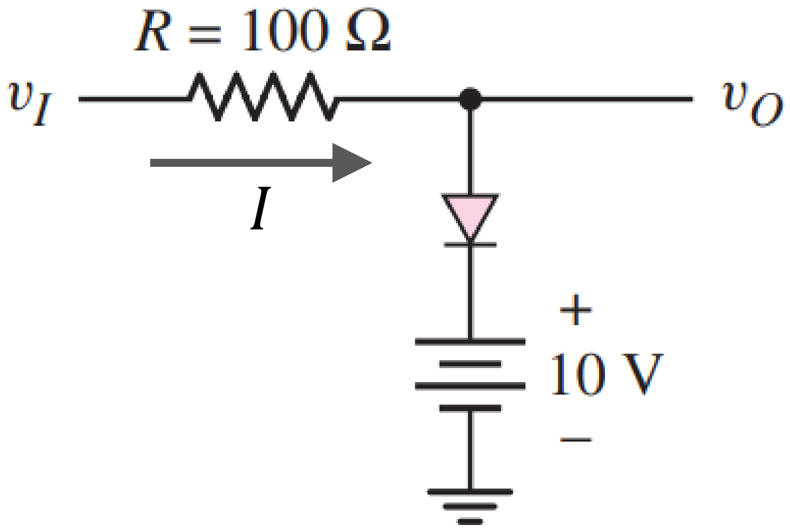
  a) For current to flow, v_I must be greater or smaller than what voltage?

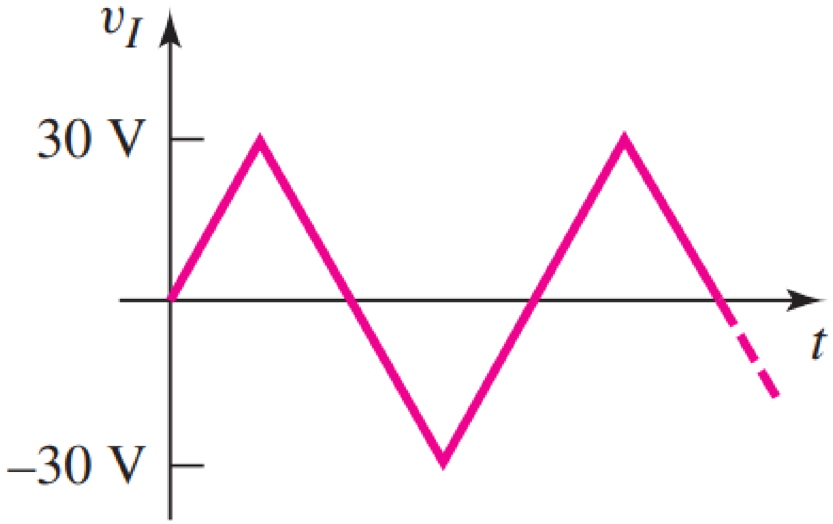
  [Hint: Assuming the diode is ON, use KCL/KVL to write an equation for the current I, then solve the inequality $I > 0$]

  b) If the condition in (a) is satisfied, and the diode is ON, what is the value of v_O?

  c) Write an equation for v_O in terms of v_I if the diode remains OFF.

  d) Using the answers in (b) and (c), and given that v_I is a triangular wave as shown, sketch $v_O(t)$.





Ans: (a) $> 11\,V$; (b) $11\,V$; (c) $v_O = v_I$

Problem 3

- The diode in the adjacent circuit has a cut-in voltage of $1\,V$.

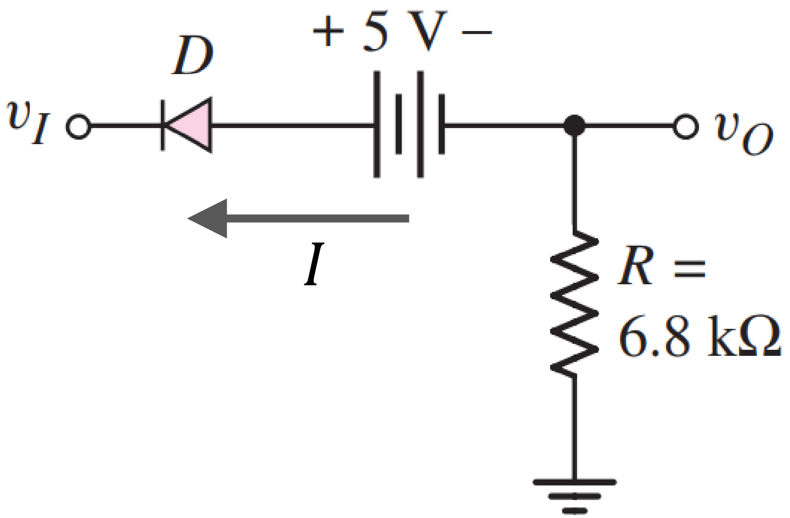
  a) For current to flow, v_I must be greater or smaller than what voltage?

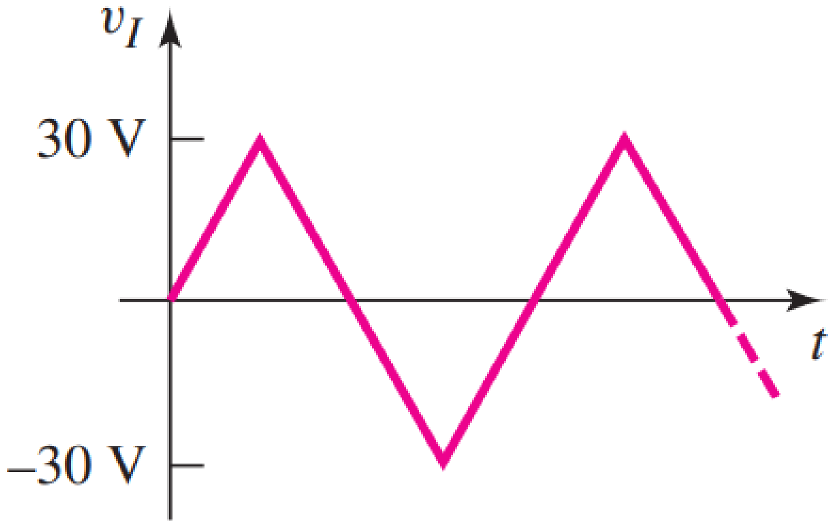
  [Hint: Assuming the diode is ON, use KCL/KVL to write an equation for the current I, then solve the inequality $I > 0$]

  b) If the condition in (a) is satisfied, and the diode is ON, write an equation for v_O in terms of v_I.

  c) What is the value of v_O if the diode remains OFF?

  d) Using the answers in (b) and (c), and given that v_I is a triangular wave as shown, sketch $v_O(t)$.





Ans: (a) $< 4\,V$; (b) $v_O = v_I - 4$; (c) $0\,V$

Problem 4

- The diode in the adjacent circuit has a cut-in voltage of $1\,V$.

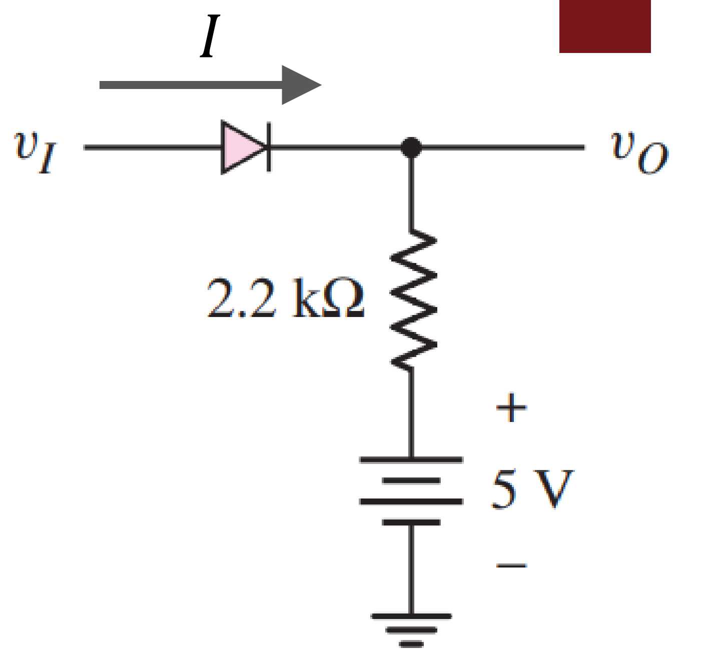
  a) For current to flow, v_I must be greater or smaller than what voltage?

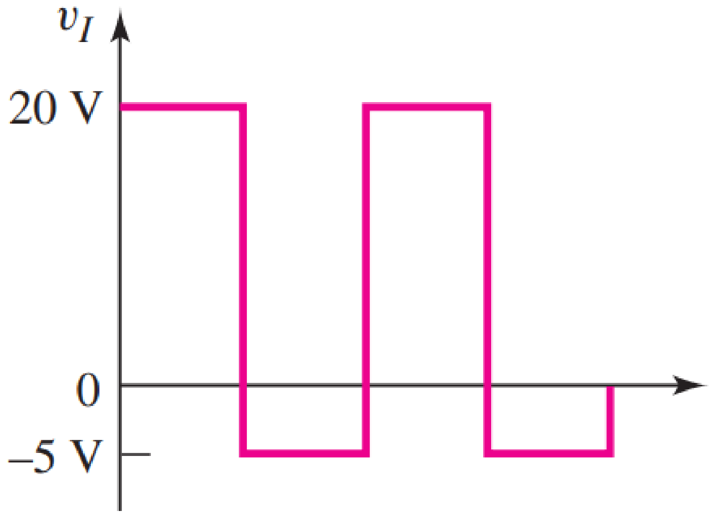
  [Hint: Assuming the diode is ON, use KCL/KVL to write an equation for the current I, then solve the inequality $I > 0$]

  b) If the condition in (a) is satisfied, and the diode is ON, write an equation for v_O in terms of v_I.

  c) What is the value of v_O if the diode remains OFF?

  d) Using the answers in (b) and (c), and given that v_I is a square wave as shown, sketch $v_O(t)$.





Ans: $(a) > 6\,V$; $(b)\ v_O = v_I - 1$; $(c)\ 5\,V$

Problem 5

- The diode in the adjacent circuit has a cut-in voltage of $1\,V$.

  a) For current to flow, v_I must be greater or smaller than what voltage?

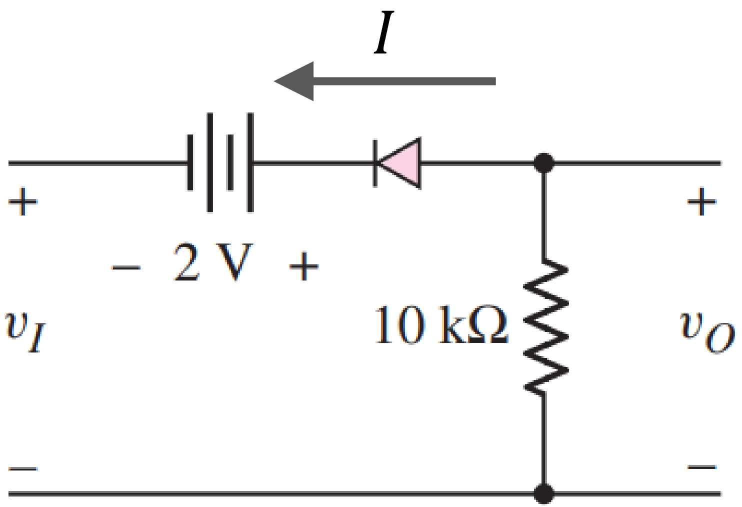
  [Hint: Assuming the diode is ON, use KCL/KVL to write an equation for the current I, then solve the inequality $I > 0$]

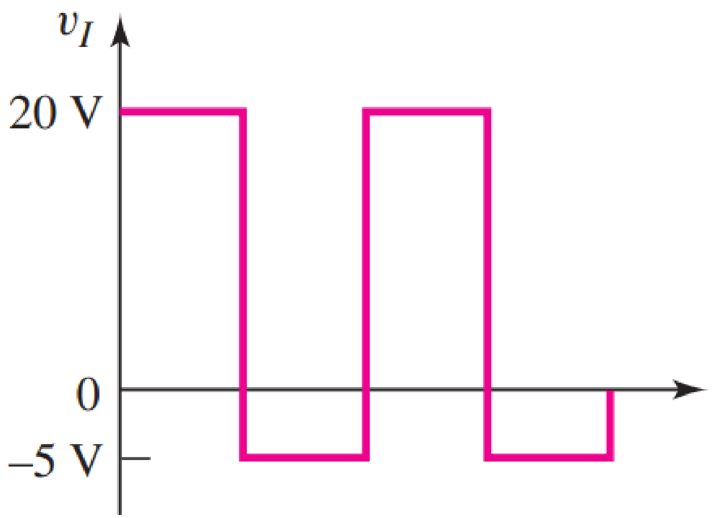
  b) If the condition in (a) is satisfied and the diode is ON, write an equation for v_O in terms of v_I.

  c) What is the value of v_O if the diode remains OFF?

  d) Using the answers in (b) and (c), and given that v_I is a square wave as shown, sketch $v_O(t)$.

Ans: (a) $< -3\,V$; (b) $v_O = v_I + 3$; (c) $0\,V$

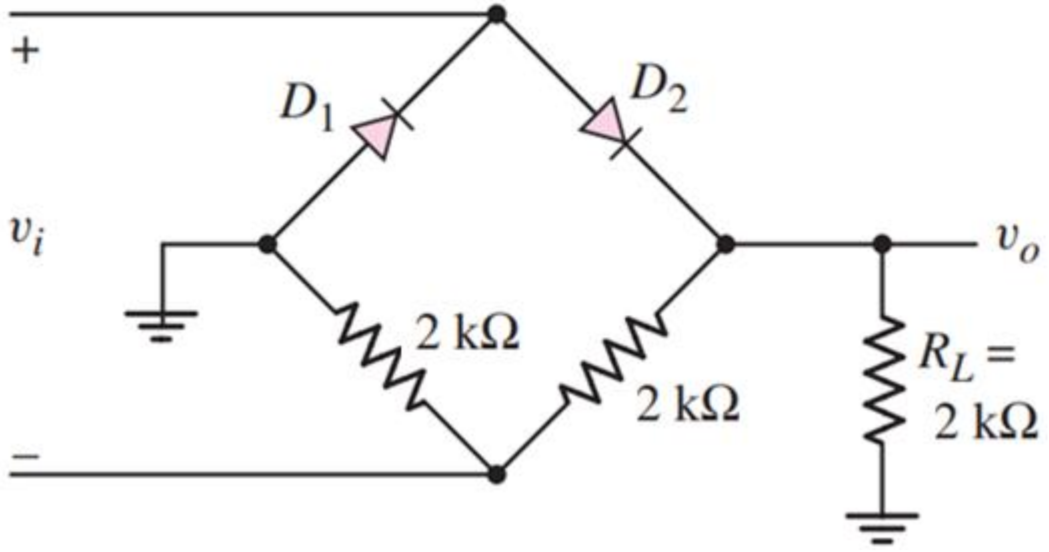


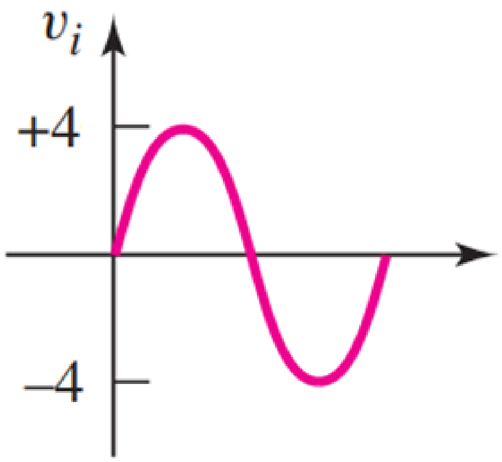


Problem 6**

- The circuit below rectifies an ac voltage into dc. The two diodes are ideal and identical. It can be shown that during each half cycle, only one diode remains ON: D_2 in '+' half cycles and D_1 in '−'s.
  - a) Derive the voltage transfer characteristics (VTC), that is, an expression relating v_O and v_i.

    [Hint: Analyze separately for '+' and '−' half cycles and you should get the same relationship.]
  - a) Plot the VTC derived in (a).





Ans: $(\boldsymbol{a})\ \boldsymbol{v_O} = \pm\, {}^{\boldsymbol{v_i}}/_{\boldsymbol{2}}$

Note: Problems marked with an asterisk (**) are a bit more advanced for this course. However, attempting them can help you develop a stronger grasp of the topic.

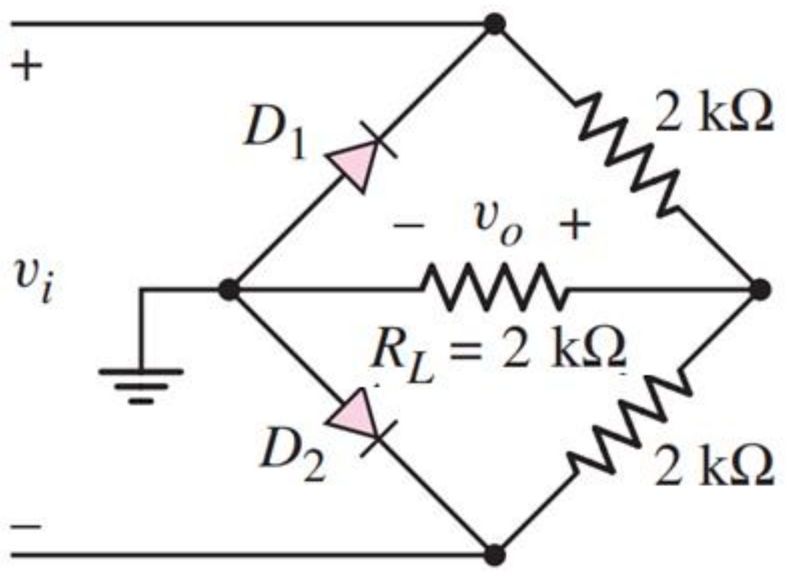
Problem 7**

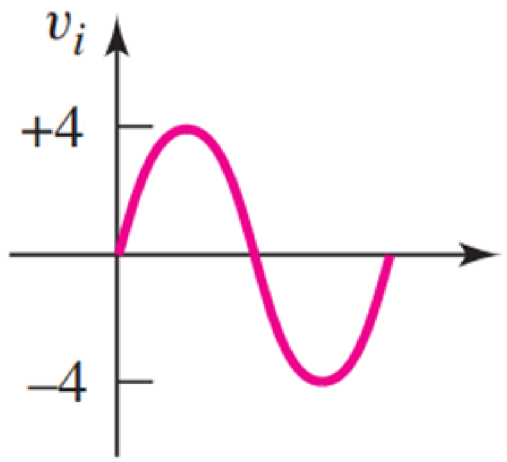
- The circuit below rectifies an ac voltage into dc. The two diodes are ideal and identical. It can be shown that during each half cycle, only one diode remains ON: D_2 in '+' half cycles and D_1 in '−'s.

    a) Derive the voltage transfer characteristics (VTC), that is, an expression relating v_O and v_i.

    [Hint: Analyze separately for '+' and '−' half cycles and you should get the same relationship.]

    a) Plot the VTC derived in (a).





Ans: $(a)\ v_O = \pm {}^{v_i}/_3$

Note: Problems marked with an asterisk (**) are a bit more advanced for this course. However, attempting them can help you develop a stronger grasp of the topic.

Problem 8

- Assuming a cut-in voltage $1\ V$ for diode(s), draw the VTC plot for
  a) Half-wave rectifier
  b) Full-wave rectifier

Problem 9

- The input voltage to a half wave rectifier is $75\sin(120\pi t)\,V$. The voltage drop across the diode is negligible compared to the input voltage. The ripple voltage is to be no more than $4\ V$. If the filter capacitor is $50\ \mu F$, determine the minimum load resistance that can be connected to the output.

Ans: $\mathbf{6.25\ k\Omega}$

Problem 10

- The output voltage of a full wave bridge rectifier has been filtered with two $2.5\ \mu F$ capacitors in parallel. The peak, average, and frequency of the output voltage are $4.3\ V$, $4\ V$, and $300\ Hz$ respectively. Determine the load resistance.

Ans: $\mathbf{4.78\ k\Omega}$

Problem 11

- Assume that the input signal to a rectifier circuit has a peak value of $12\ V$ and is at a frequency $50\ Hz$. Assume the load has a resistance of $2\ k\Omega$ and the ripple voltage is to be limited to $0.5\ V$. Determine the value of capacitance required to yield this specification for (a) half wave rectifier and (b) full wave bridge rectifier. Assume a $0.5\ V$ cut-in voltage for each diode.

Ans: $(\mathbf{a})\ \mathbf{230}\ \boldsymbol{\mu F};\ (\mathbf{b})\ \mathbf{220}\ \boldsymbol{\mu F}$

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Problem 12

- A $24\,V$ peak to peak $50\,Hz$ sine wave ac voltage is to be rectified with a full wave bridge rectifier circuit without filter capacitor. Determine the portion of the output voltage cycle during which each diode conducts. Also, calculate the average output voltage. Assume all the diodes are identical with a cut-in voltage $V_{D_o} = 0.6\,V$.

Ans: $\mathbf{93.62\%}$; $\boldsymbol{V_{avg} = 6.44\,V}$

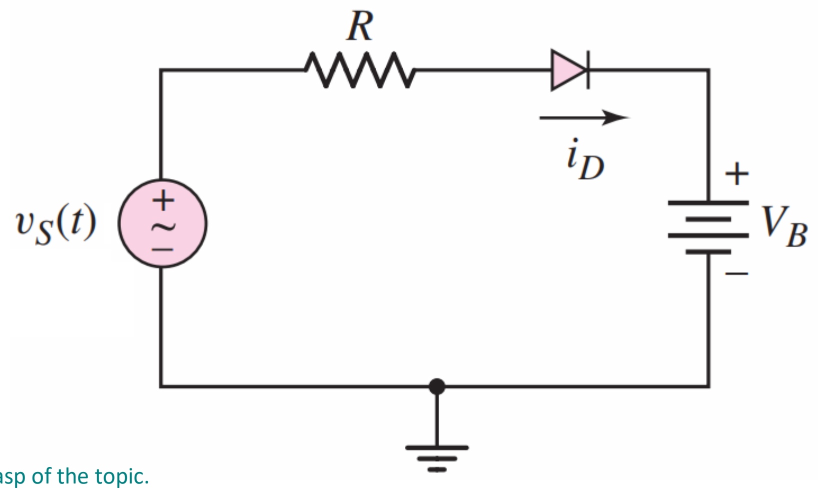
Problem 13

- A full wave bridge rectifier is to be designed to produce a peak output voltage of $12\ V$, deliver peak $120\ mA$ to the load, and produce an output with a ripple of not more than 5%. An input line voltage of $9.9\sqrt{2}\ V\ (peak)$, $2\ kHz$ is available. Specify the diode voltage and value of the capacitance you require.

Ans: $\mathbf{1}\ \boldsymbol{V}$; $\mathbf{50}\ \boldsymbol{\mu F}$

Problem 14

- A battery V_B is charged though a half wave rectifier circuit as shown below. The voltage V_B of the battery at the time of charging is $4.5\,V$. The resistance R is $250\ \Omega$. $v_S(t)$ is a $24\,V$ peak to peak sine wave. Cut-in voltage for the diode is $V_{D_o} = 0.6\,V$.
  I. What is the required value of $v_S(t)$ for the diode to conduct?
  II. Determine the peak diode current, maximum reverse-bias diode voltage, and the fraction of the cycle over which the diode is conducting.
  III. **Determine the average voltage of the voltage across the resistor. *[Hint: note that, the average formula we derived will not work here. You have to integrate with the exact limits.]*

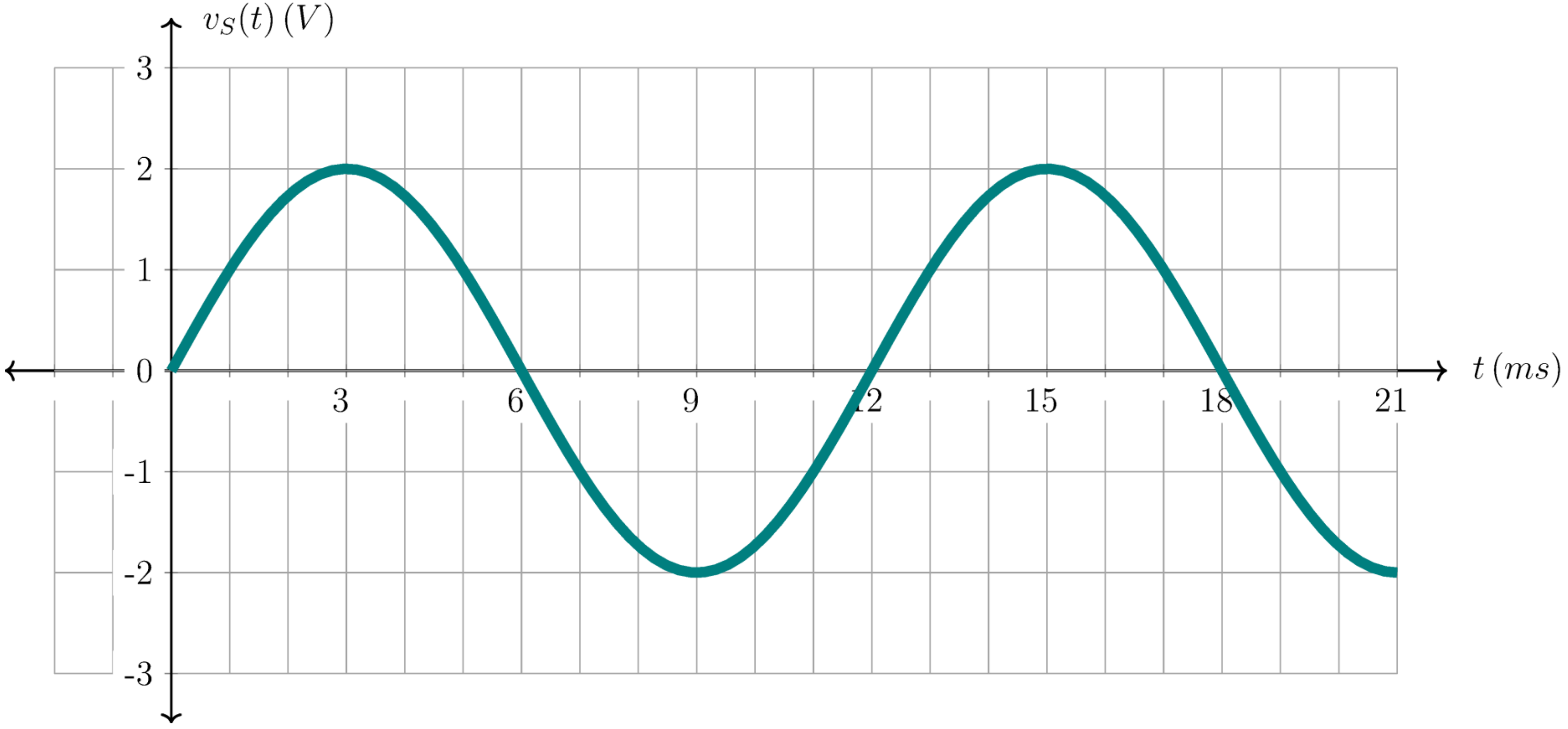


Ans: $\mathrm{I.}\ \mathbf{5.1\ V}$; $\mathrm{II.}\ \mathbf{27.6\ mA, 16.5\ V, 36\%}$; $\mathrm{III.}\ \boldsymbol{V_{avg} = 3.47\ V}$

Note: Problems marked with an asterisk (**) are a bit more advanced for this course. However, attempting them can help you develop a stronger grasp of the topic.

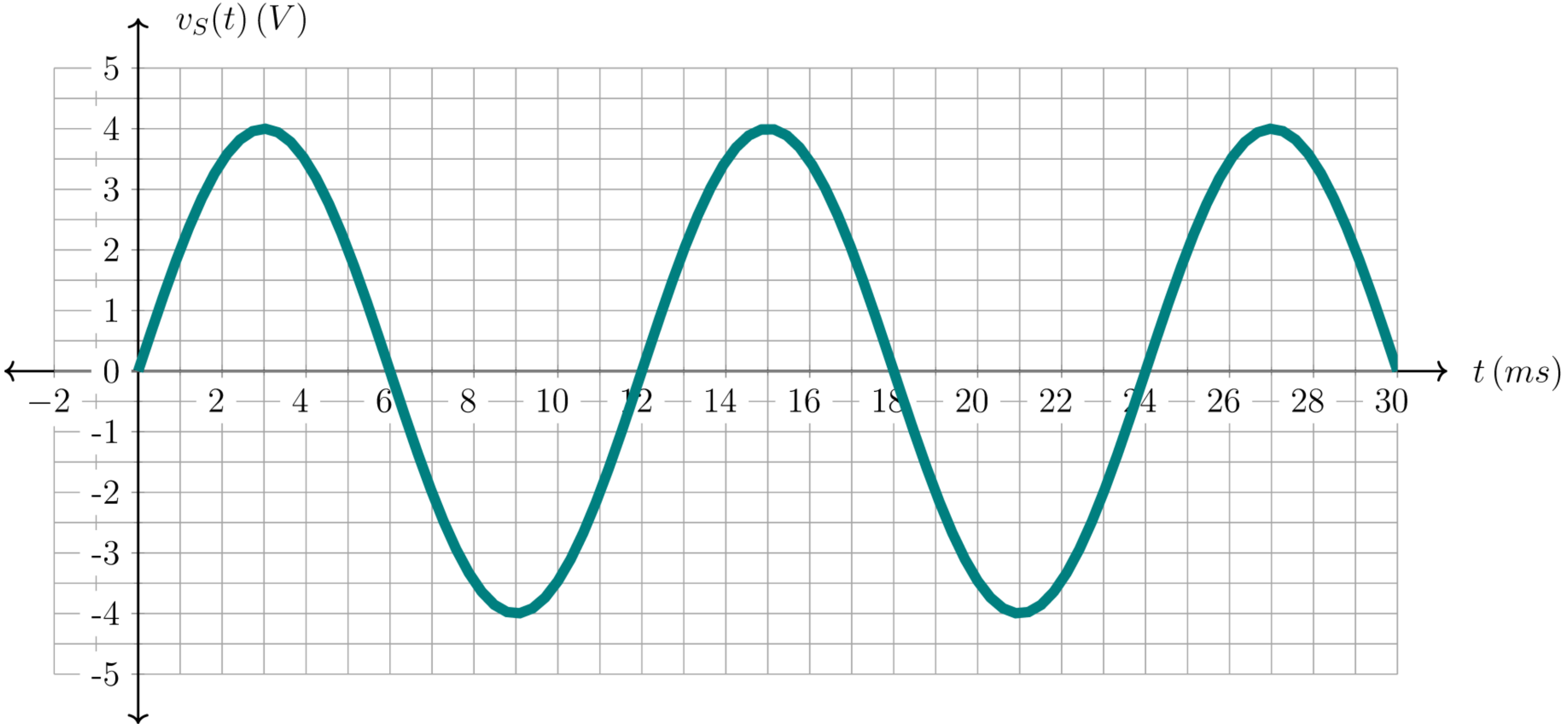
Problem 15

- The following is the input voltage to a half wave rectifier without filter capacitor. Draw the output waveform on the same grid. Assume a cut-in voltage $V_{D_o} = 1.0\ V$ for the diode.



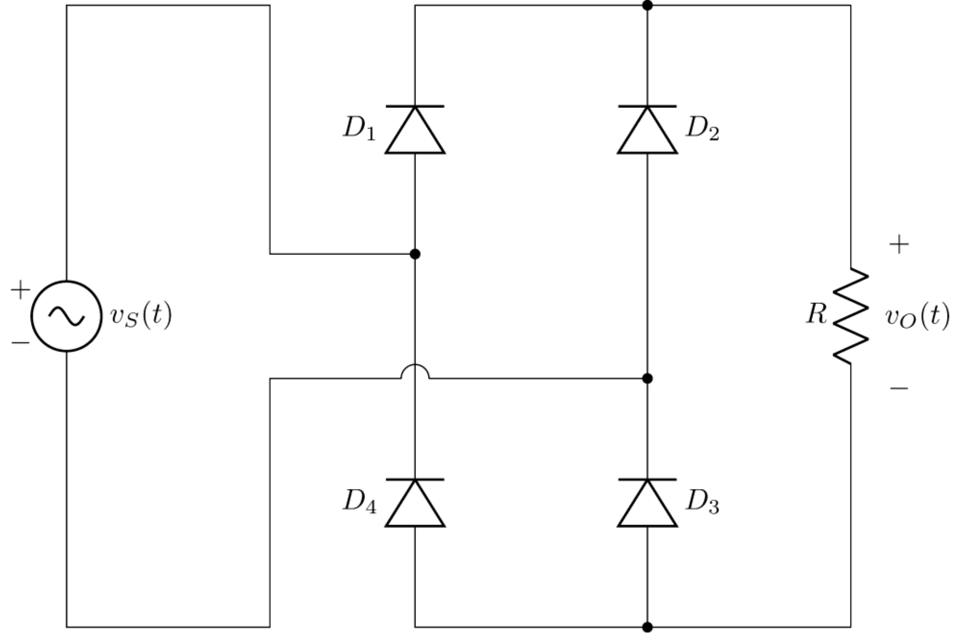
Problem 16

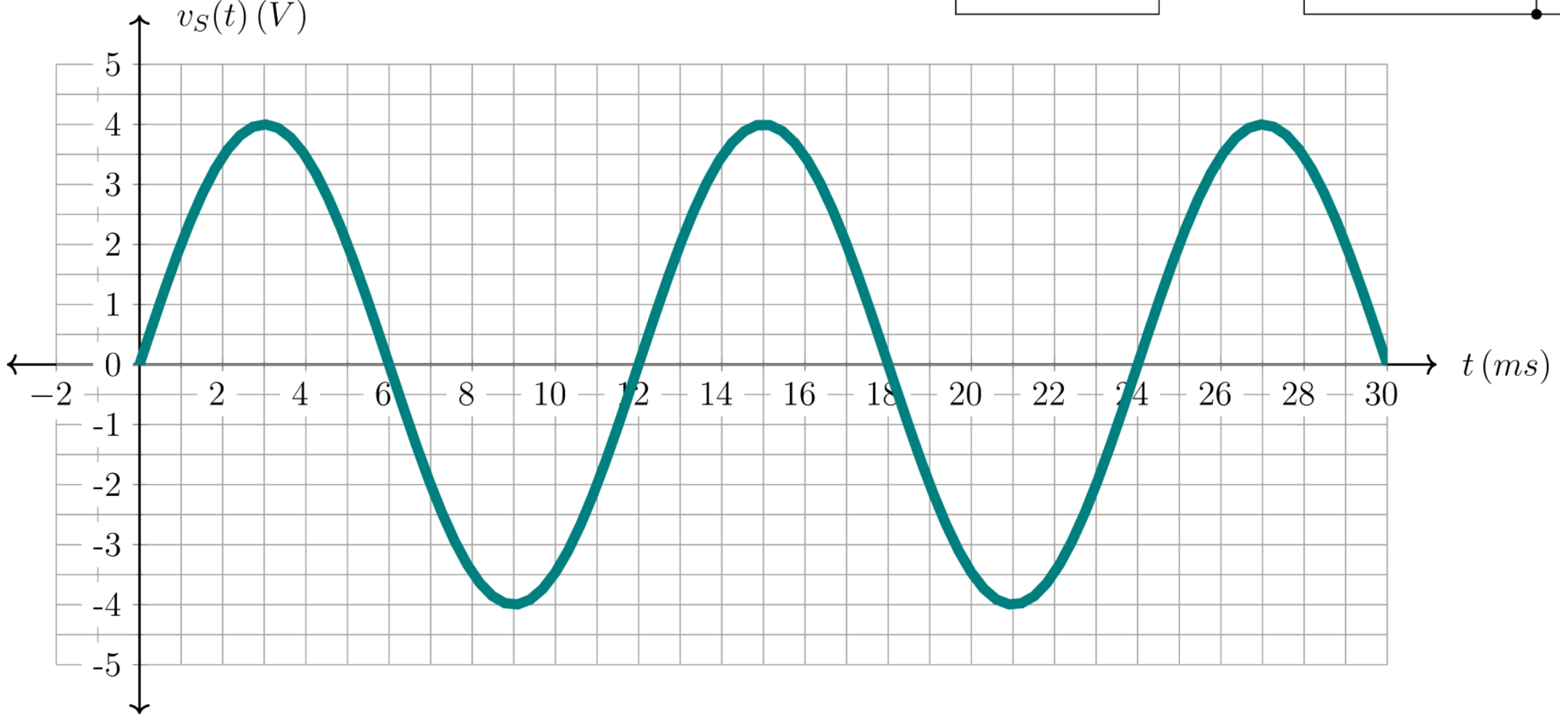
- The following is the input voltage to a full wave bridge rectifier without filter capacitor. Draw the output waveform on the same grid. Assume all the diodes are identical with a cut-in voltage $V_{D_o} = 1\,V$.



Problem 17

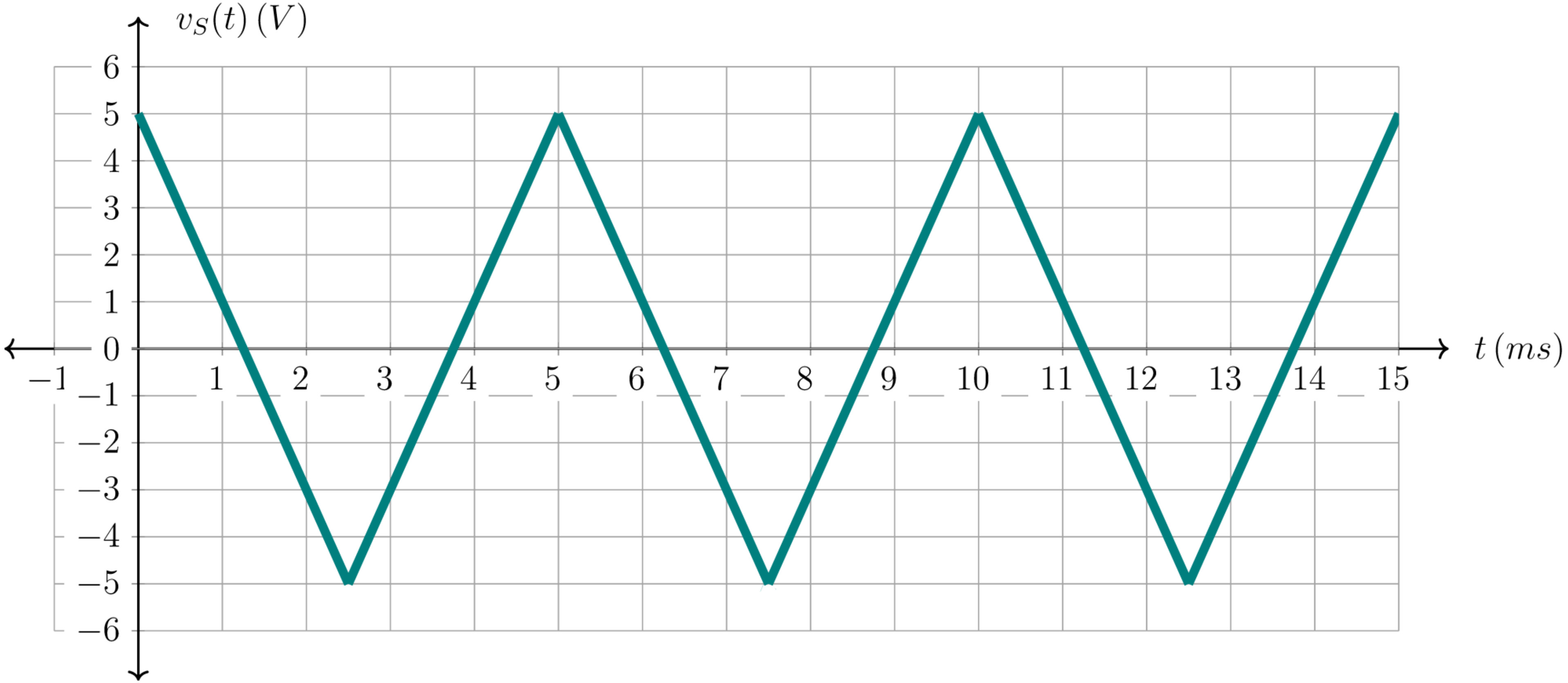
- The following is the input voltage to a full wave bridge rectifier without filter capacitor. Draw the output waveform on the same grid. Assume $V_{D_{o_1}} = 1.2\,V$, $V_{D_{o_2}} = 0.55\,V$, $V_{D_{o_3}} = 0.8\,V$, and $V_{D_{o_4}} = 0.45\,V$.





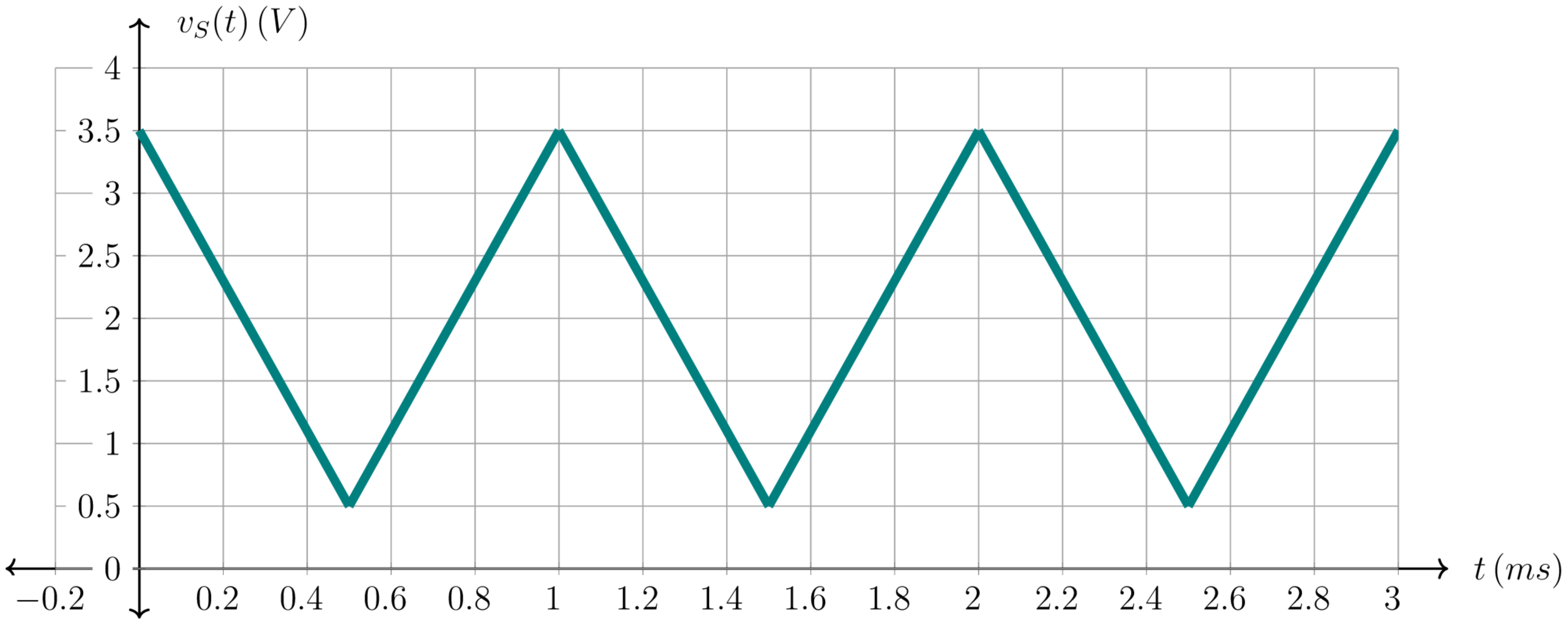
Problem 18

- Draw the output voltage waveforms if the following is the input voltage to a (i) half wave rectifier and (ii) full wave bridge rectifier, both without filter capacitor. Assume all the diodes are identical with a cut-in voltage $V_{D_o} = 1\ V$.



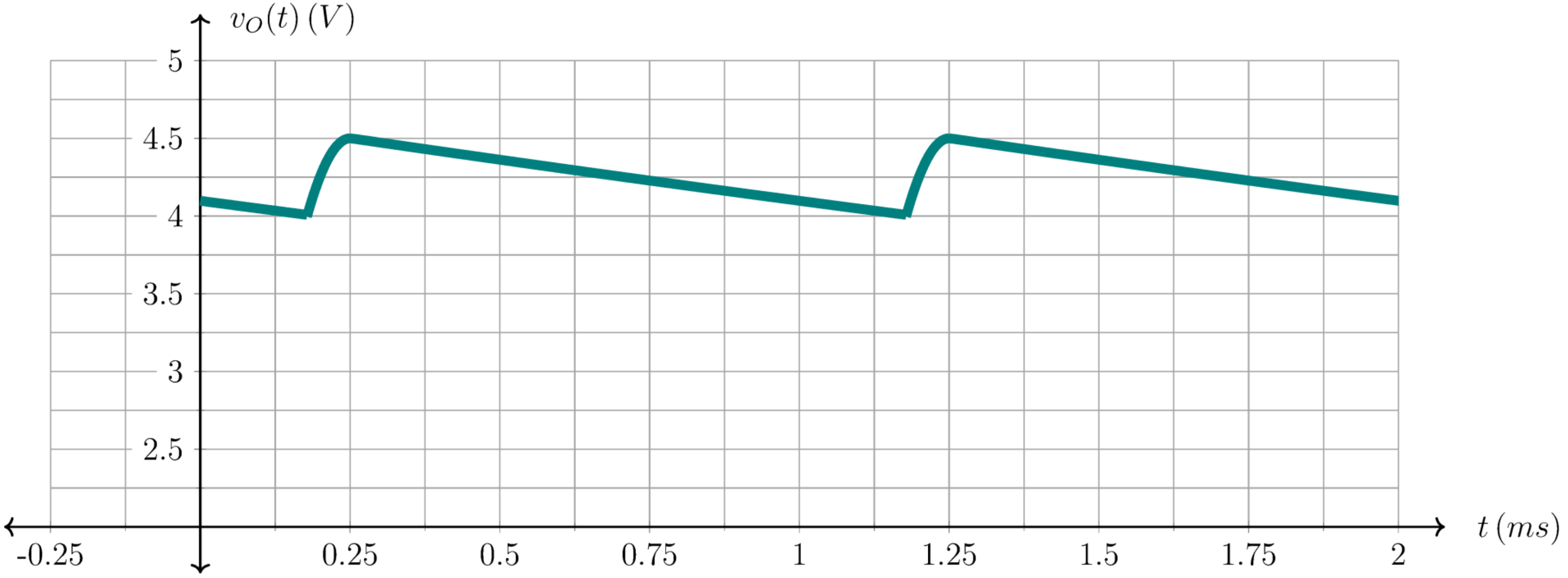
Problem 19

- The following is the input voltage to a full wave bridge rectifier without filter capacitor. Draw the output waveform on the same grid. Assume all the diodes are identical with a cut-in voltage $V_{D_o} = 0.5\,V$.



Problem 20

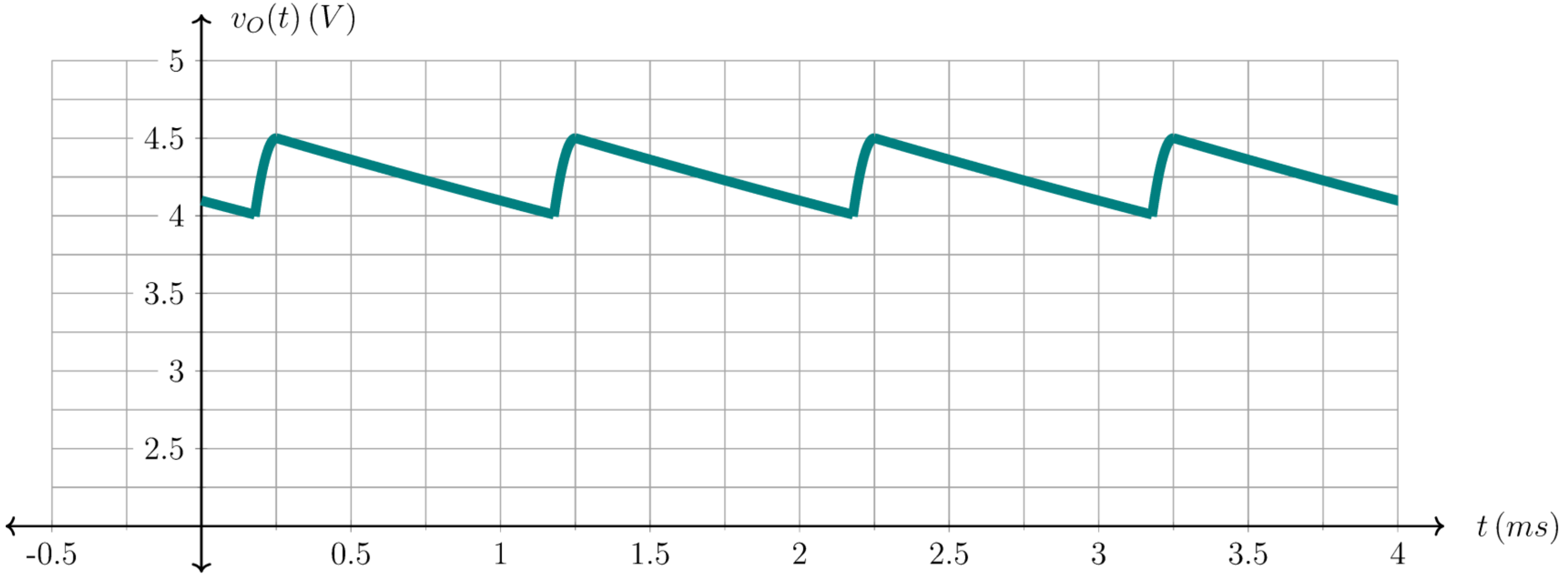
- The following is the rectified output of an ac sinusoidal voltage at $1\,kHz$ frequency, provided to a load of $4.5\,k\Omega$. The diode(s) used in the rectifier had a cut-in voltage of $0.5\,V$.
  - I. What type of rectifier was utilized?
  - II. What capacitance was used in the rectifier's design?
  - III. What was the amplitude of the sinusoidal ac voltage applied to the rectifier?



Ans: II. $2\,\mu F$; III. $5\,V$

Problem 21

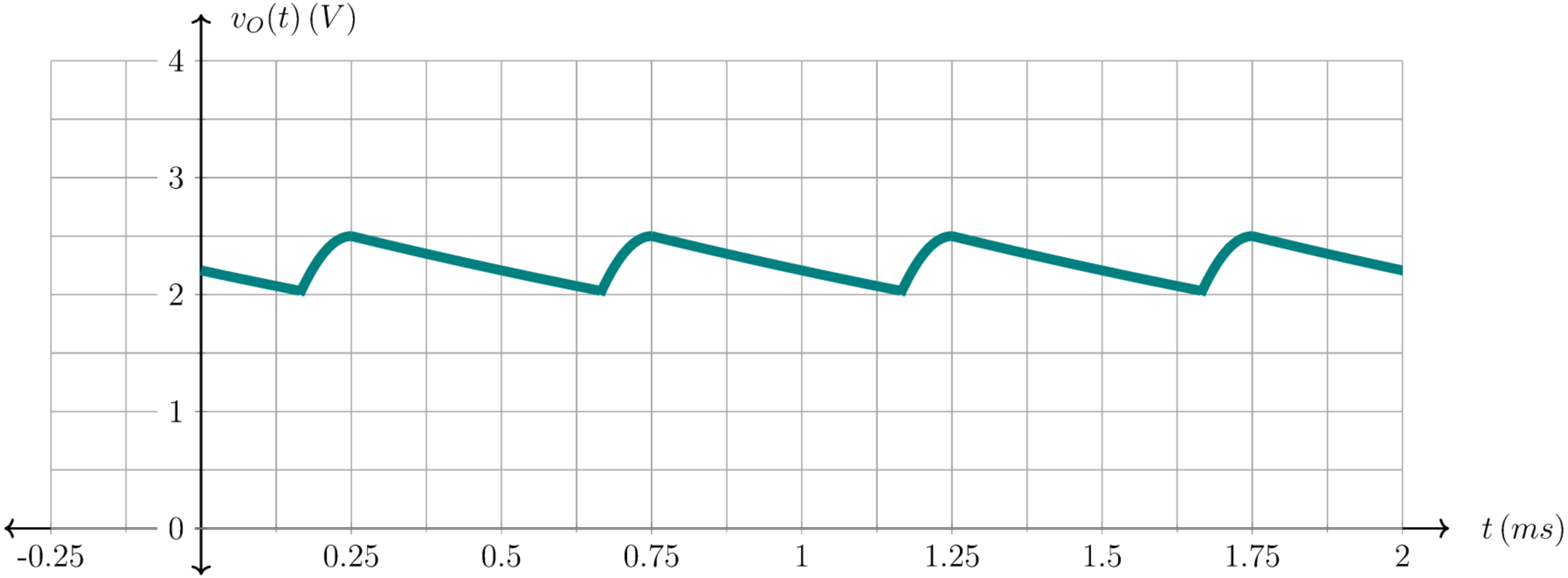
- The following is the rectified output of an ac sinusoidal voltage at $500\ Hz$ frequency, provided to a load of $18\ k\Omega$. The diode(s) used in the rectifier had a cut-in voltage of $0.5\ V$.
  - I. What type of rectifier was utilized?
  - II. What capacitance was used in the rectifier's design?
  - III. Write an expression as a function of time for the input voltage?
  - IV. Draw the circuit diagram of the rectifier.



Ans: II. $\mathbf{0.5\ \mu F}$; III. $\frac{11}{2}\boldsymbol{sin(1000\pi t)\ V}$

Problem 22

- The following is the rectified output of an ac sinusoidal voltage at $1\,kHz$ frequency, provided to a load of $5\,k\Omega$. The diode(s) used in the rectifier had a cut-in voltage of $0.5\,V$.
  I. What type of rectifier was utilized?
  II. What capacitance was used in the rectifier's design?
  III. Write an expression as a function of time for the input voltage?
  IV. Draw the circuit diagram of the rectifier.



Ans: II. $\mathbf{0.5\ \mu F}$; III. $\frac{7}{2}\boldsymbol{sin(2000\pi t)}\ \boldsymbol{V}$