2024 - BE END SEMESTER EXAM

SOLUTION

SOL(1):

(a) For const current through 'a', op-amp must be in saturation.

Set-A:

For non-inverting op-amp,

$$V_o = \left(1 + \frac{R_F}{R_1}\right) V_{in}$$

$$\pm 12 = \left(1 + \frac{a}{1}\right) 2$$

$\therefore$ $a = 5\,K\Omega$ ✓, ~~$-7\,K\Omega$~~ ✗ → (2 POINT)

Hence, for const current through 'a', $a \leq 5\,K\Omega$

→ (2 POINT)

Set(B):

For non-inverting op-amp,

$$V_o = \left(1 + \frac{R_F}{R_1}\right) V_{in}$$

$$\pm 15 = \left(1 + \frac{a}{1}\right) 3$$

$\therefore$ $a = 4\,K\Omega$ ✓, ~~$-6\,K\Omega$~~ ✗ → (2 POINT)

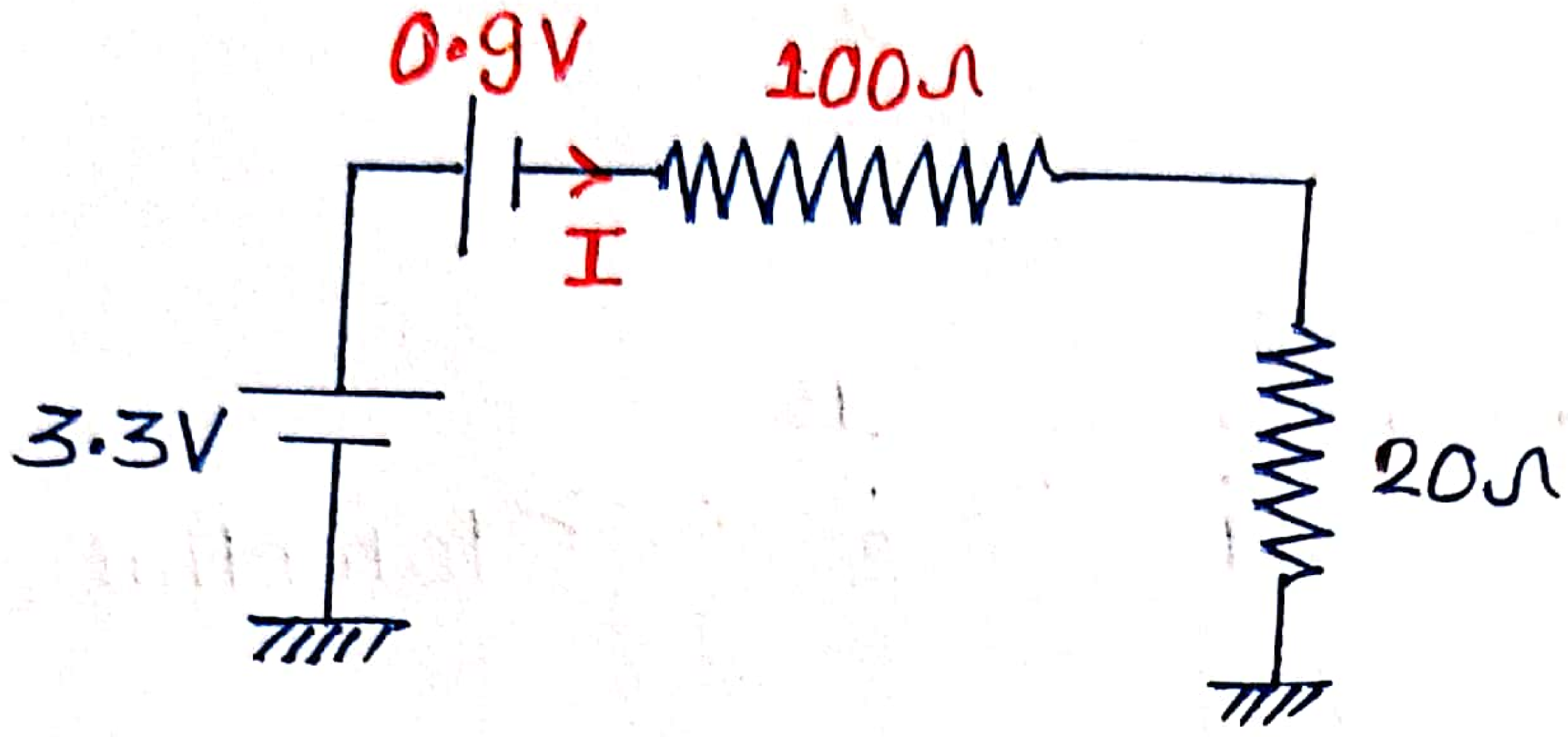
Hence, for const current through 'a', $a \leq 4\,K\Omega$

→ (2 POINT)

Set(B):-

Forward Voltage (V_f) & Forward resistance (R_f) will be same as Set(A).

Given circuit can be redrawn as–



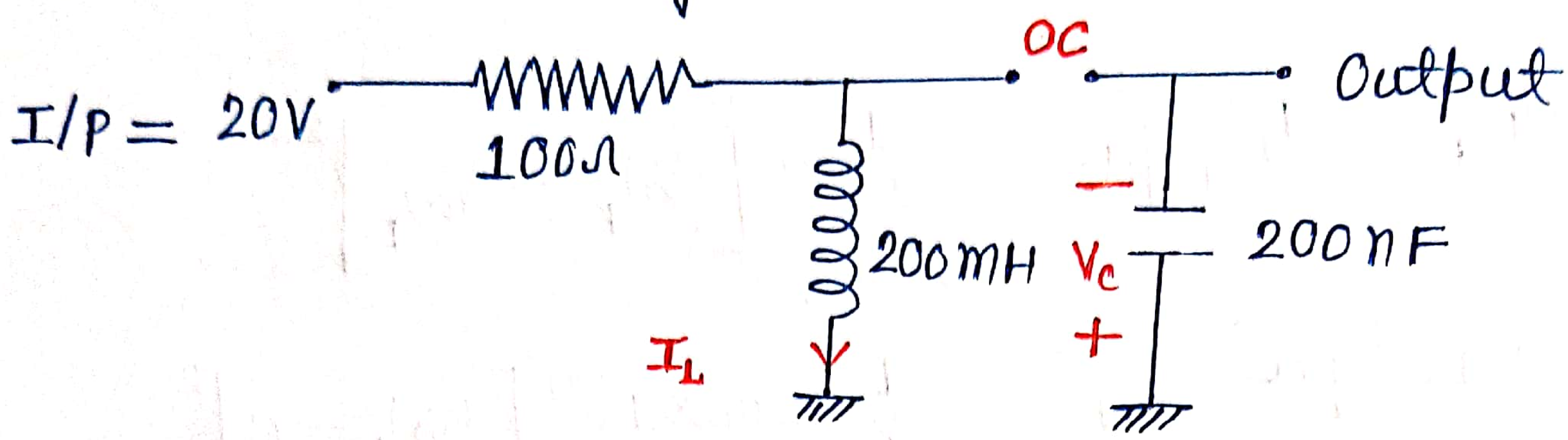
$\therefore$ Current, $I = \frac{(3.3-0.9)}{(100+20)} = 0.02\,A = 20\,mA$

→ (2 POINT)

SOL(5) :-

Set(A) :-

Case-I : When 20V voltage source applied at the input.

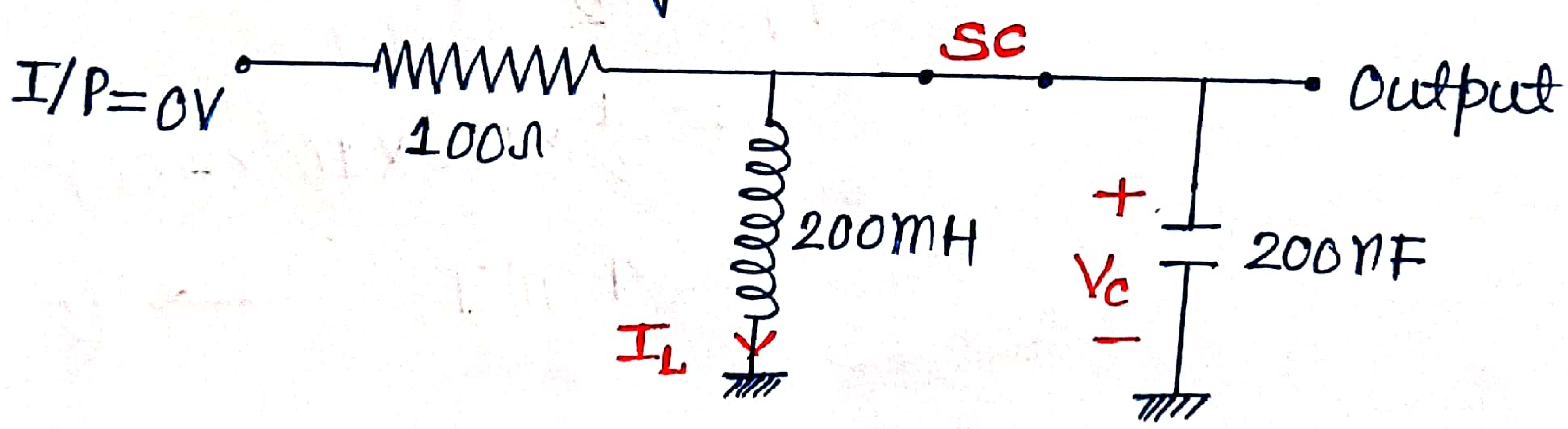


At Steady state –

Initial Current through inductor, $(I_L)_{initial} = \frac{20}{100} = 0.2A$

Initial voltage across capacitor, $(V_c)_{initial} = 0V$

Case-II : When suddenly source was removed



At steady state –

Final current through inductor, $(I_L)_{Final} = 0A$

Final voltage across capacitor, $(V_c)_{Final} = (V_c)_F$

NOTE: In Case-II, diode will work as short circuit, untill unless capacitor fully charged by the initial value of inductor current. After that diode will work as open circuit & there will be no flow of current. (apply for both sets)

Here,

$$\left(\begin{array}{c}\text{Energy transfer by} \\ \text{Inductor}\end{array}\right) = \left(\begin{array}{c}\text{Energy receive by} \\ \text{Capacitor}\end{array}\right)$$

$$\frac{1}{2} L \left[(I_L)_F - (I_L)_I\right]^2 = \frac{1}{2} C \left[(V_C)_F - (V_C)_I\right]^2$$

$$\frac{1}{2} \times 200 \times 10^{-3} \left[0 - 0.2\right]^2 = \frac{1}{2} \times 200 \times 10^{-9} \left[(V_C)_F - 0\right]^2$$

$$\therefore (V_C)_F = 200 \text{ Volt}$$

$\therefore$ Voltage at the output after longtime (steady state),

$= -(V_C)_F = (-200)$ Volt → (4 POINT)

$\therefore$ Amount of stored energy $= \frac{1}{2} C V^2$

$= \frac{1}{2} \times 200 \times 10^{-9} \times (200)^2$

$= 4 \text{ mJ}$ → (2 POINT)

Set(B):-

Case-I: When 10V voltage source applied at the input for long time.

At steady state,

Initial current through inductor, $(I_L)_I = \frac{10}{100} = 0.1\,A$

Initial voltage across capacitor, $(V_C)_I = 0\,V$

Case-II: When suddenly source was removed.

At steady state,

Final current through inductor, $(I_L)_F = 0\,A$

Final voltage across capacitor, $(V_C)_F = ?$

Here,

$$\begin{pmatrix}\text{Energy transfer by} \\ \text{Inductor}\end{pmatrix} = \begin{pmatrix}\text{Energy receive by} \\ \text{Capacitor}\end{pmatrix}$$

$$\frac{1}{2}L\left[(I_L)_F - (I_L)_I\right]^2 = \frac{1}{2}C\left[(V_C)_F - (V_C)_I\right]^2$$

$$\frac{1}{2}\times 200\times 10^{-3}\left[0-0.1\right]^2 = \frac{1}{2}\times 200\times 10^{-9}\left[(V_C)_F - 0\right]^2$$

$$\therefore (V_C)_F = 100\ \text{Volt}$$

$\therefore$ Voltage at the output after long time (Steady State),

$$= -(V_C)_F = -100\ \text{Volt}$$

→ (4 POINT)

$\therefore$ Amount of stored energy $= \frac{1}{2}CV^2$

$$= \frac{1}{2}\times 200\times 10^{-9}\times (100)^2$$

$$= 1\,mJ$$

→ (2 POINT)

SOL (6):

Each resistor is rated to a maximum of 250 mW. If the circuit allows this value to be exceeded, excessive heating will occour.

The max^m current the 100Ω resistor can tolerate is

$$\sqrt{\frac{P_{max}}{R}} = \sqrt{\frac{0.250}{100}} = 50\,mA$$

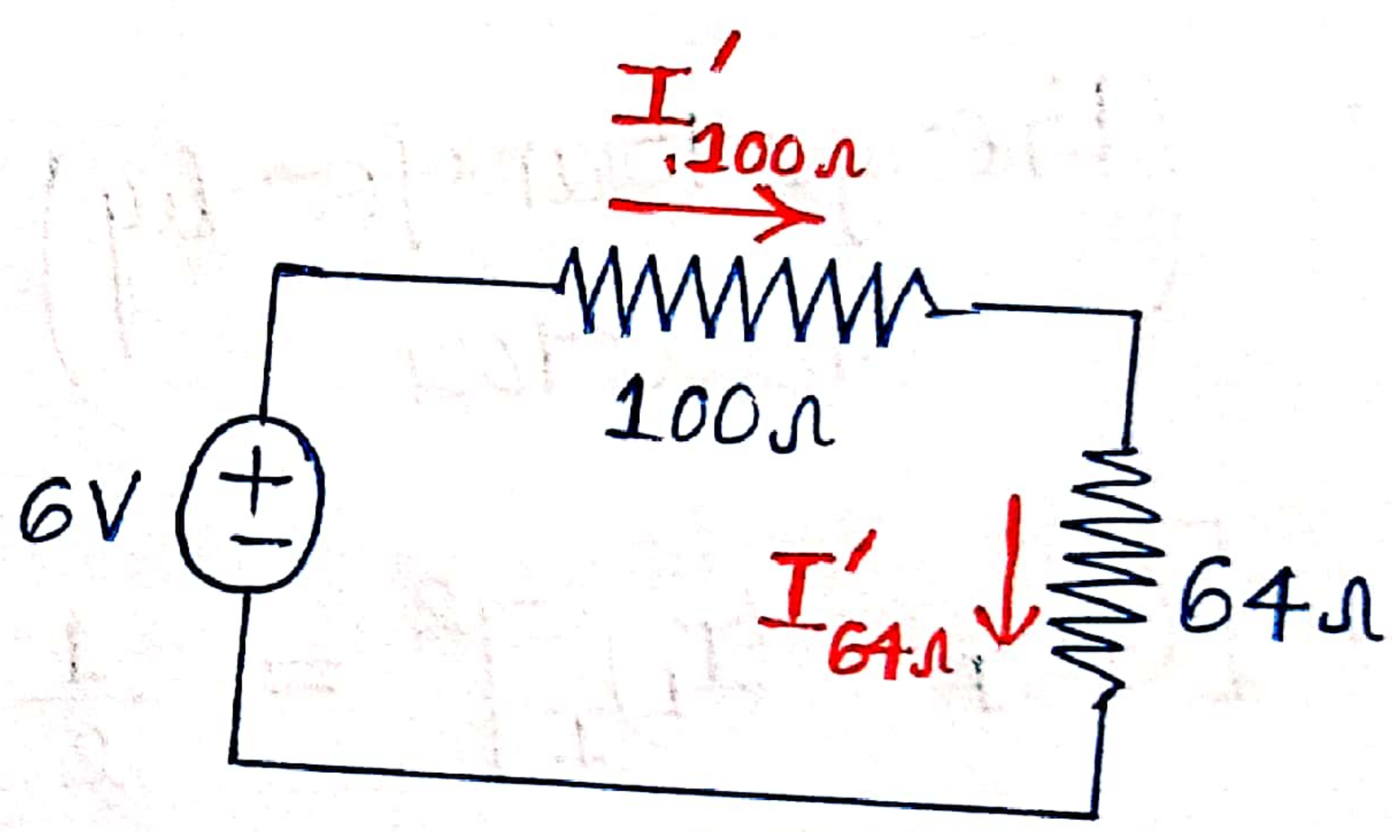
The max^m current the 64Ω resistor can tolerate is

$$\sqrt{\frac{P_{max}}{R}} = \sqrt{\frac{0.250}{64}} = 62.5\,mA$$

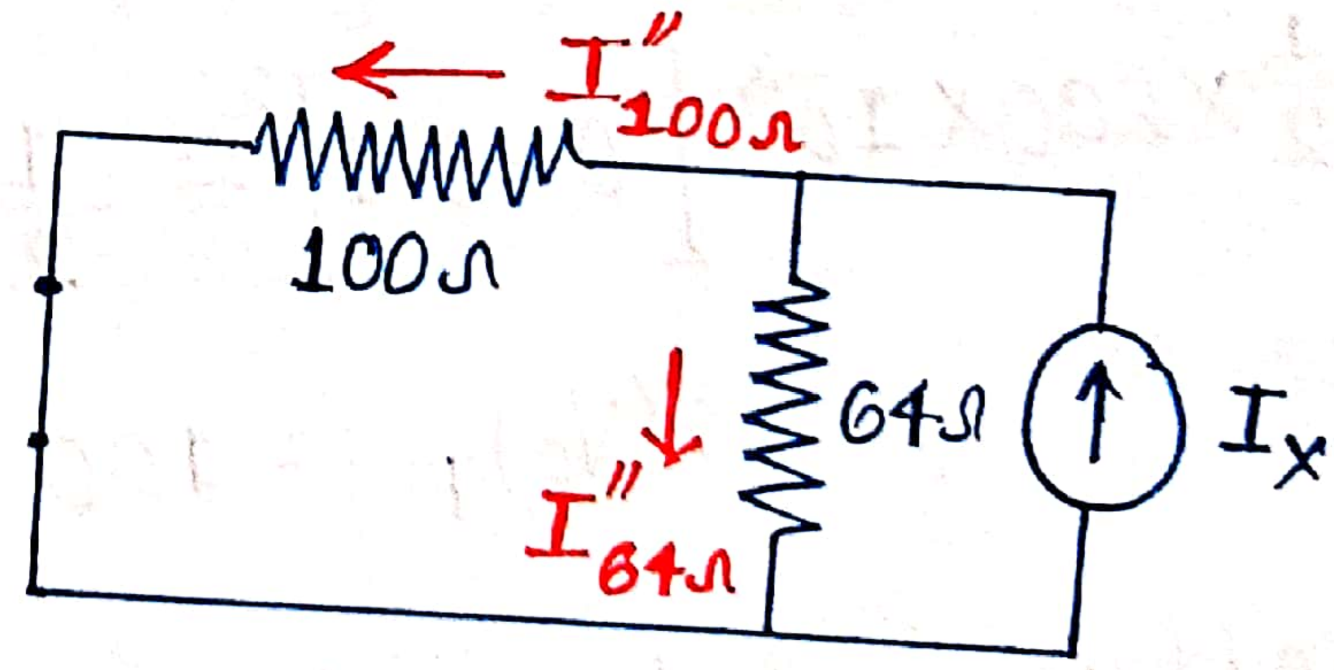
Using Superposition,

Consider only 6V source–

$$I'_{100\Omega} = I'_{64\Omega} = \frac{6}{100+64} = 36.59\,mA$$



Consider only I_x source–



We note that–

Current through 100Ω resistor $= (I'_{100\Omega} \sim I''_{100\Omega})$

Current through 64Ω resistor $= (I'_{64\Omega} + I''_{64\Omega})$

Therefore, I_x can safely contribute $(62.5 - 36.59)\,mA$ $= 25.91\,mA$ to the 64Ω resistor, and $(50+36.59)\,mA$

$= 86.59$ mA of current to the $100\,\Omega$ resistor.

$\therefore$ Constraint of I_x by $100\,\Omega$ resistor,

$$I_x < (86.59 \times 10^{-3}) \left(\frac{100+64}{64}\right)$$

$$I_x < 221.88 \text{ mA}$$

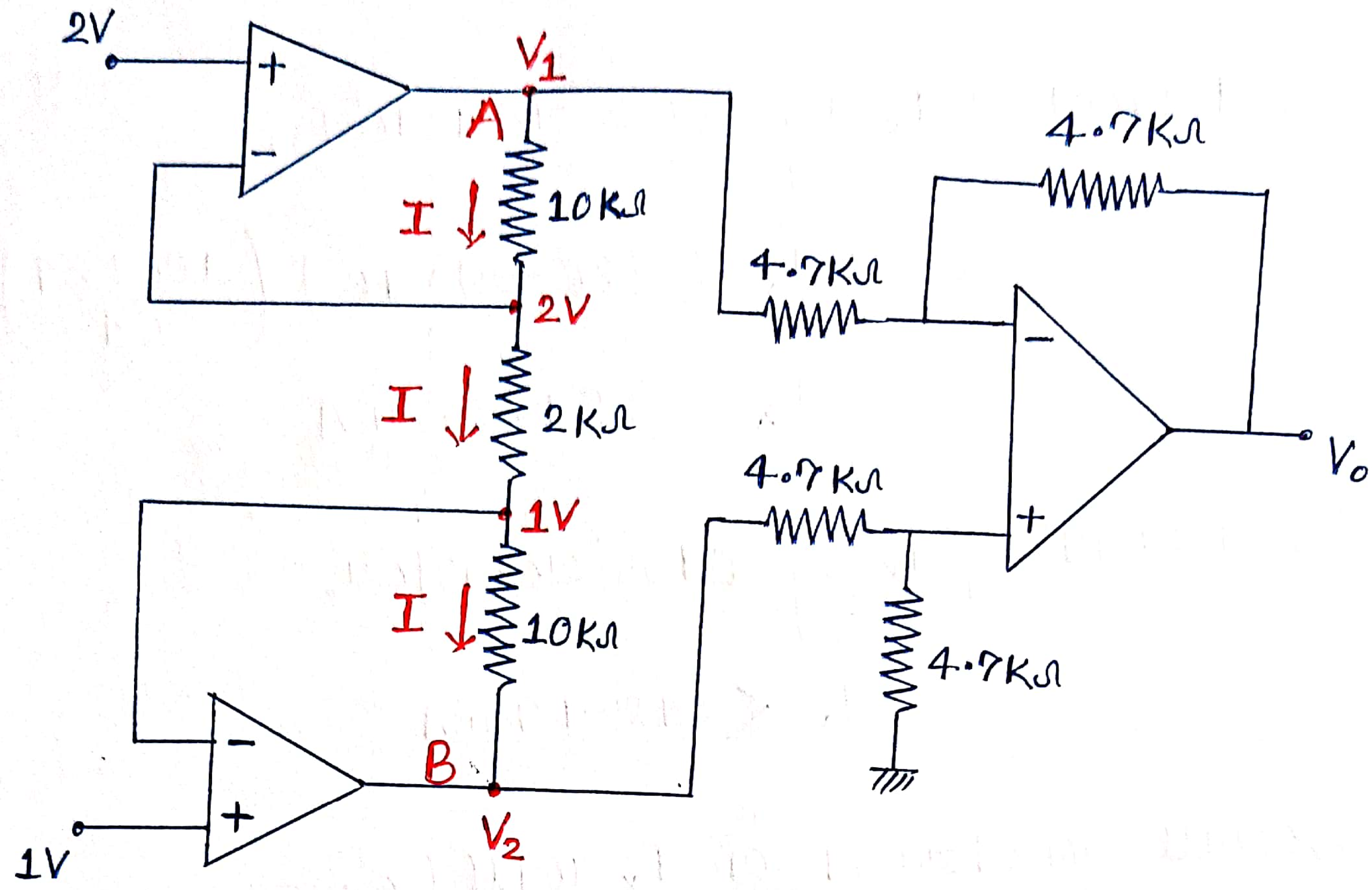
$\therefore$ Constraint of I_x by $64\,\Omega$ resistor,

$$I_x < 42.49 \text{ mA}$$

$\therefore$ Overall constraint on I_x will be —

$$I_x < 42.49 \text{ mA} \rightarrow \text{(6 POINT)}$$

SOL(7):



$$V_o = \left(-\frac{4.7}{4.7}\right)V_1 + \left(1+\frac{4.7}{4.7}\right)\left(\frac{4.7}{4.7+4.7}\right)V_2$$

$$V_o = -V_1 + 2 \times 0.5 V_2$$

$$V_o = -V_1 + V_2 \quad \text{——} \quad (1)$$

By given circuit — $I = \left(\frac{2-1}{2 \times 10^3}\right) = 0.5\,mA$

$$\frac{V_1 - 2}{10 \times 10^3} = I$$

$\therefore V_1 = 2 + 10^4 \times 0.5 \times 10^{-3} = 7$ Volt → (2 POINT)

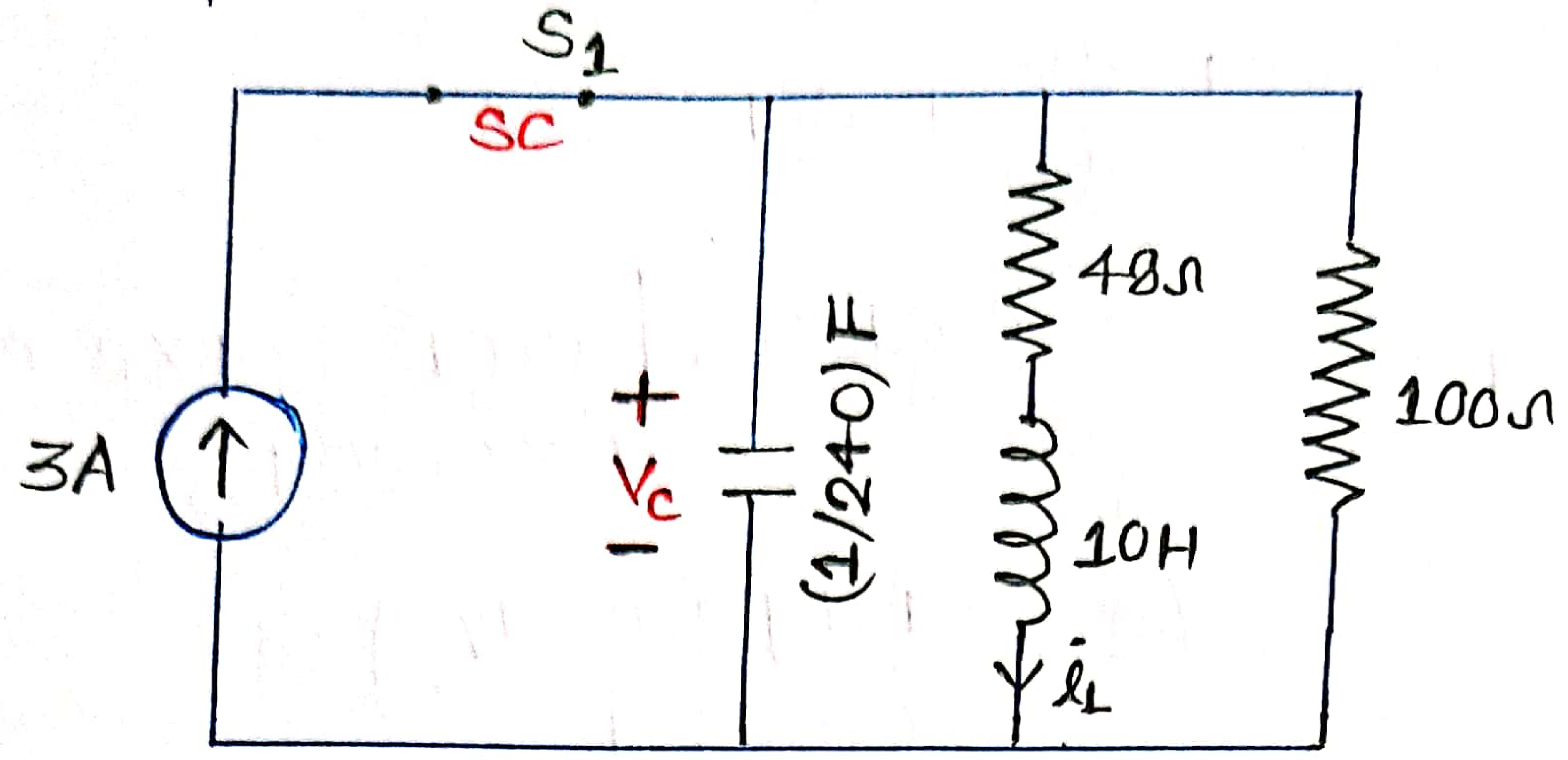
$$\frac{1 - V_2}{10 \times 10^3} = I$$

$\therefore V_2 = 1 - 10^4 \times 0.5 \times 10^{-3} = -4$ Volt → (2 POINT)

By eq^n(1), $V_o = -7 - 4 = -11$ Volt → (2 POINT)

SOL(8):-

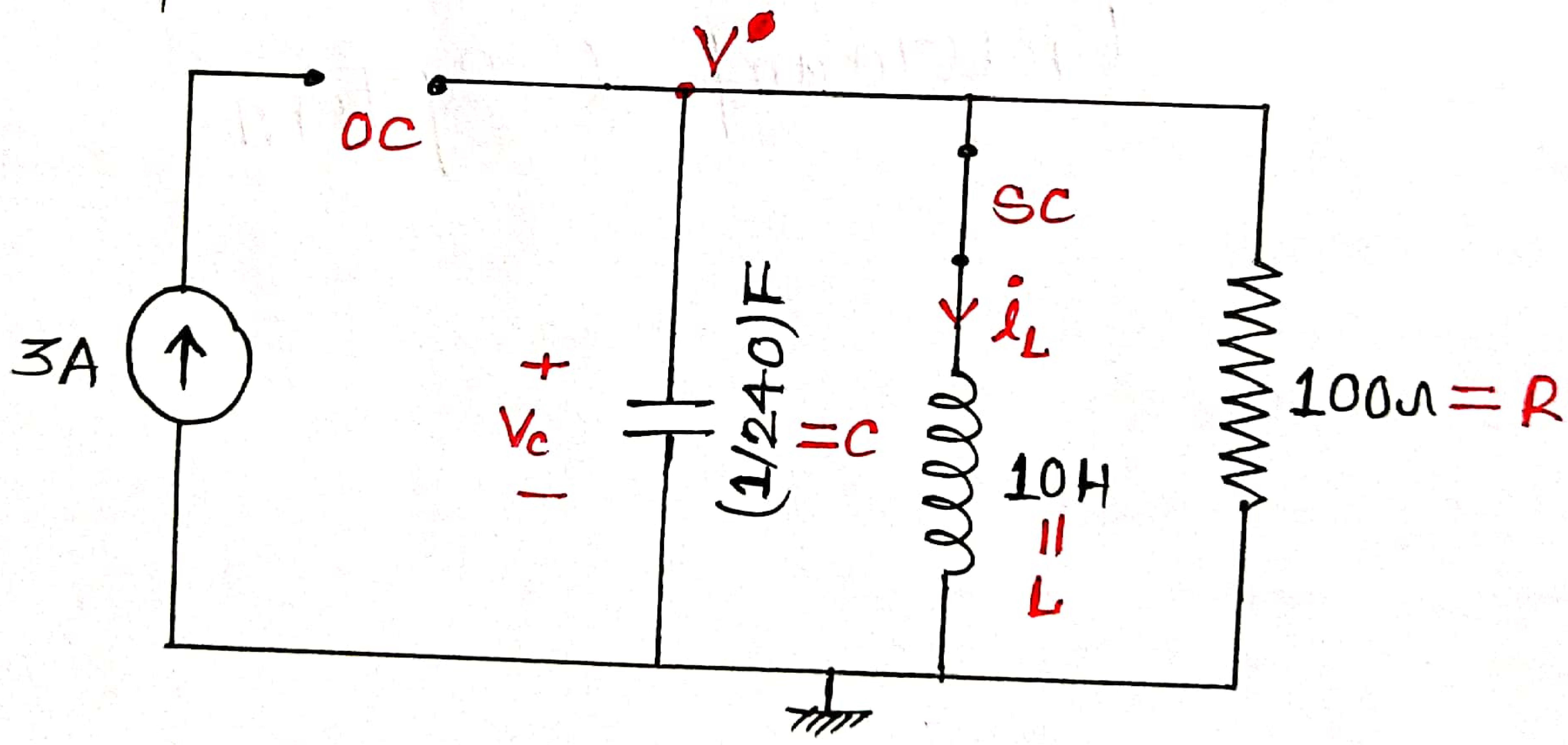
Circuit analysis at $t<0$



at steady state—
$$i_L(0^-) = \left(\frac{100}{100+48}\right)3 = 2.02\ A$$
→ (0.5 POINT)

$$V_c(0^-) = 97.29\ V$$

Circuit analysis at $t>0$



By nodal analysis, we can write—

$$\frac{V}{R} + \frac{1}{L}\int_0^t V\,dt - i_L(0) + C\frac{dV}{dt} = 0 \quad \text{—— (1)}$$

Here, $V = V_L = L\frac{di_L}{dt}$ —— (2)

By eqn(1) & eqn(2), we can write —

$$\frac{L}{R}\frac{di_L}{dt} + \frac{1}{L}\times L\, i_L - i_L(0) + LC\frac{d^2 i_L}{dt^2} = 0$$

$$LC\frac{d^2 i_L}{dt^2} + \frac{L}{R}\frac{di_L}{dt} + i_L = i_L(0)$$

$$0.042\frac{d^2 i_L}{dt^2} + 0.1\frac{di_L}{dt} + i_L = 2.02$$ → (4 POINT)

$$\text{Roots, } S_{1,2} = \frac{-0.1 \pm \sqrt{0.1^2 - 4\times 0.042 \times 1}}{2\times 0.042}$$

$$= \frac{-0.1 \pm j\,0.40}{0.084}$$

$$= (-1.19 \pm j4.76)$$

⇓

Roots are purely imaginary

⇓

Underdamped system → (1.5 POINT)

Case

(b)

Set(A):

$$V_o = \left(1+\frac{R_F}{R_1}\right)V_{in}$$

$$= \left(1+\frac{2}{1}\right)2 = 6V$$

Hence, current flowing through resistor 'a' will be

$$= \left(\frac{6-2}{2}\right) = 2mA$$

→ (2 POINT)

Set(B):

$$V_o = \left(1+\frac{R_F}{R_1}\right)V_{in}$$

$$= \left(1+\frac{2}{1}\right)3 = 9V$$

Hence, current flowing through resistor 'a' will be –

$$= \left(\frac{9-3}{2}\right) = 3mA$$

→ (2 POINT)

SOL(2):

According to given characteristic of diode,

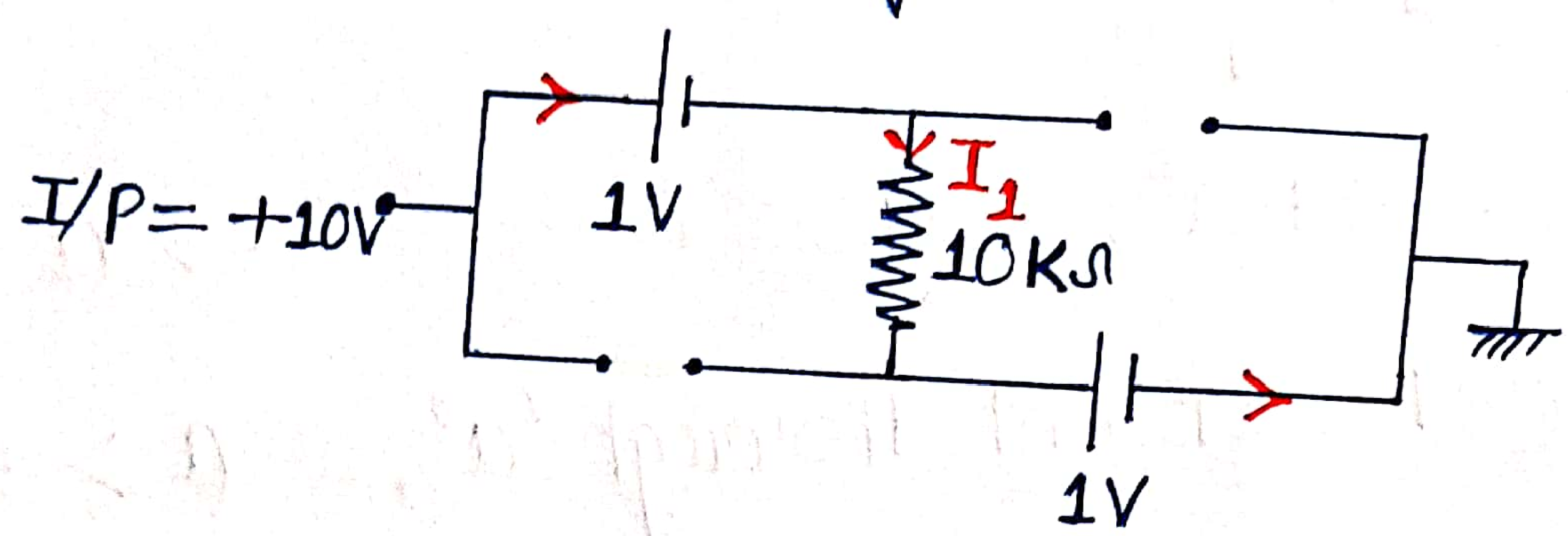
Forward voltage drop across diode/ cut-in voltage,

$V_\gamma = 1$ Volt

Forward resistance, $R_f = 0$

Set(A):

Case(I): When input voltage = +10V

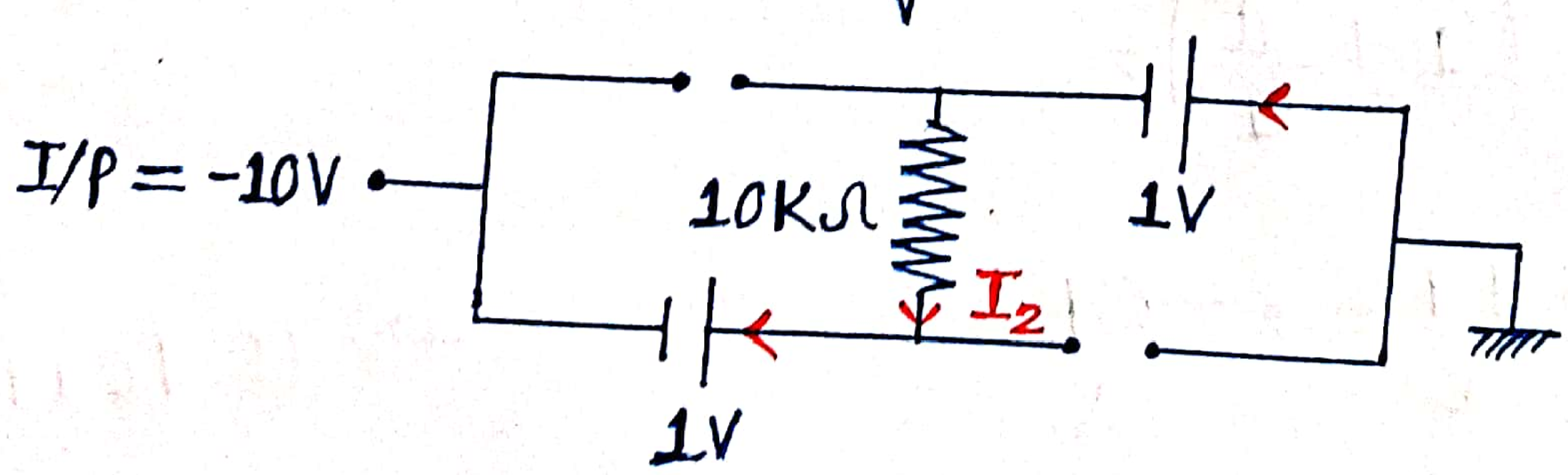


∴ Current, $I_1 = \left(\frac{10-1-1}{10 \times 10^3}\right) = 0.8$ mA → (1 POINT)

∴ Power used by diodes = Voltage drop x Current

$= (1+1) \times 0.8 = 1.6$ mW → (1.5 POINT)

Case(II): When input Voltage = −10 V



∴ Current, $I_2 = \left(\frac{10-1-1}{10 \times 10^3}\right) = 0.8$ mA → (1 POINT)

∴ Power used by diodes = voltage drop x Current

$= (1+1) \times 0.8 = 1.6$ mW → (1.5 POINT)

Conclusion: We can see that power used over one time period is constant & it will remain same for all time period.

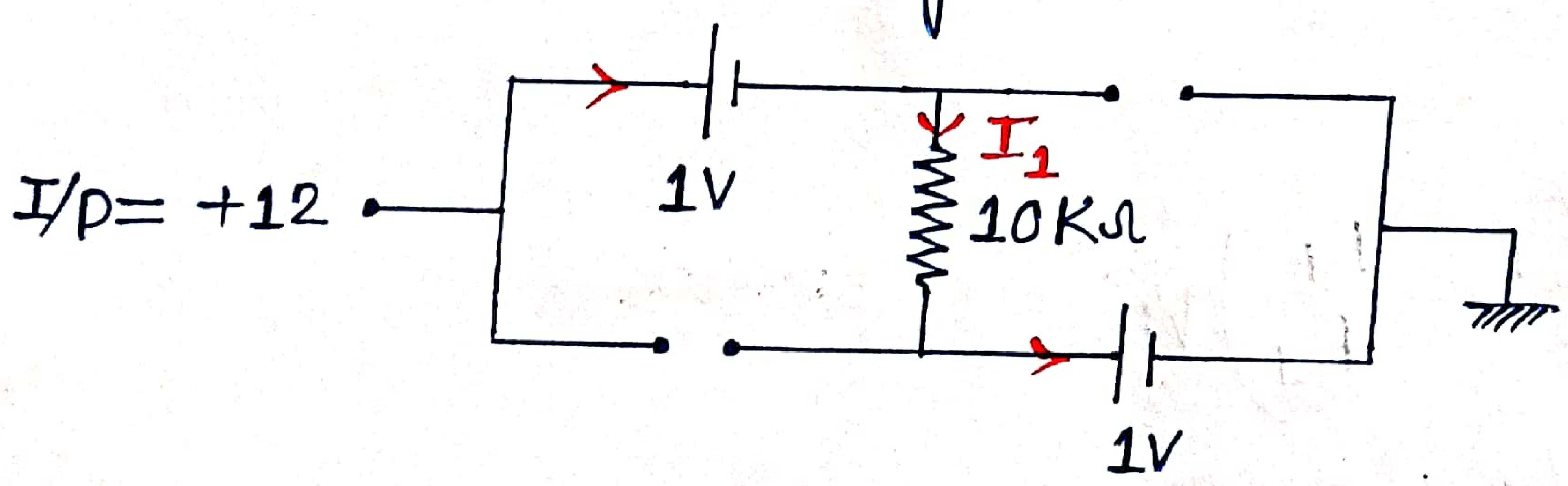
$\therefore$ Amount of energy used in one second $= P \times t$

$= 1.6 \times 1$

$= 1.6\ mJ$ → (1 POINT)

Set(B):

Case(I): When input voltage $= +12V$

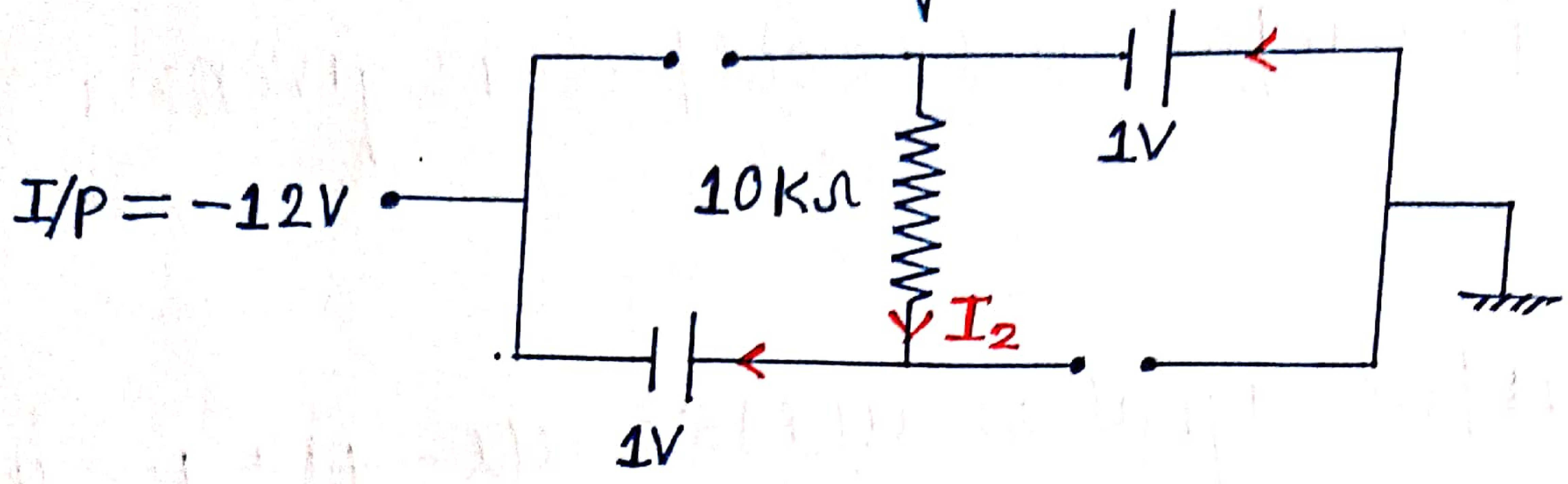


$\therefore$ Current, $I_1 = \left(\frac{12-1-1}{10 \times 10^3}\right) = 1\ mA$ → (1 POINT)

$\therefore$ Power used by diodes $=$ voltage drop $\times$ Current

$= (1+1) \times 1 = 2\ mW$ → (1.5 POINT)

Case(II): When input voltage = −12V



∴ Current, $I_2 = \left(\frac{12-1-1}{10\times10^3}\right) = 1mA$ → (1 POINT)

∴ Power used by diodes = Voltage drop × Current
$= (1+1)\times1 = 2mW$ → (1.5 POINT)

Conclusion:- We can see that power used over one time period is constant & it will remain same for all time period.

∴ Amount of energy used in one second $= P\times t = 2\times1$
$= 2mJ$

→ (1 POINT)

SOL(3):-

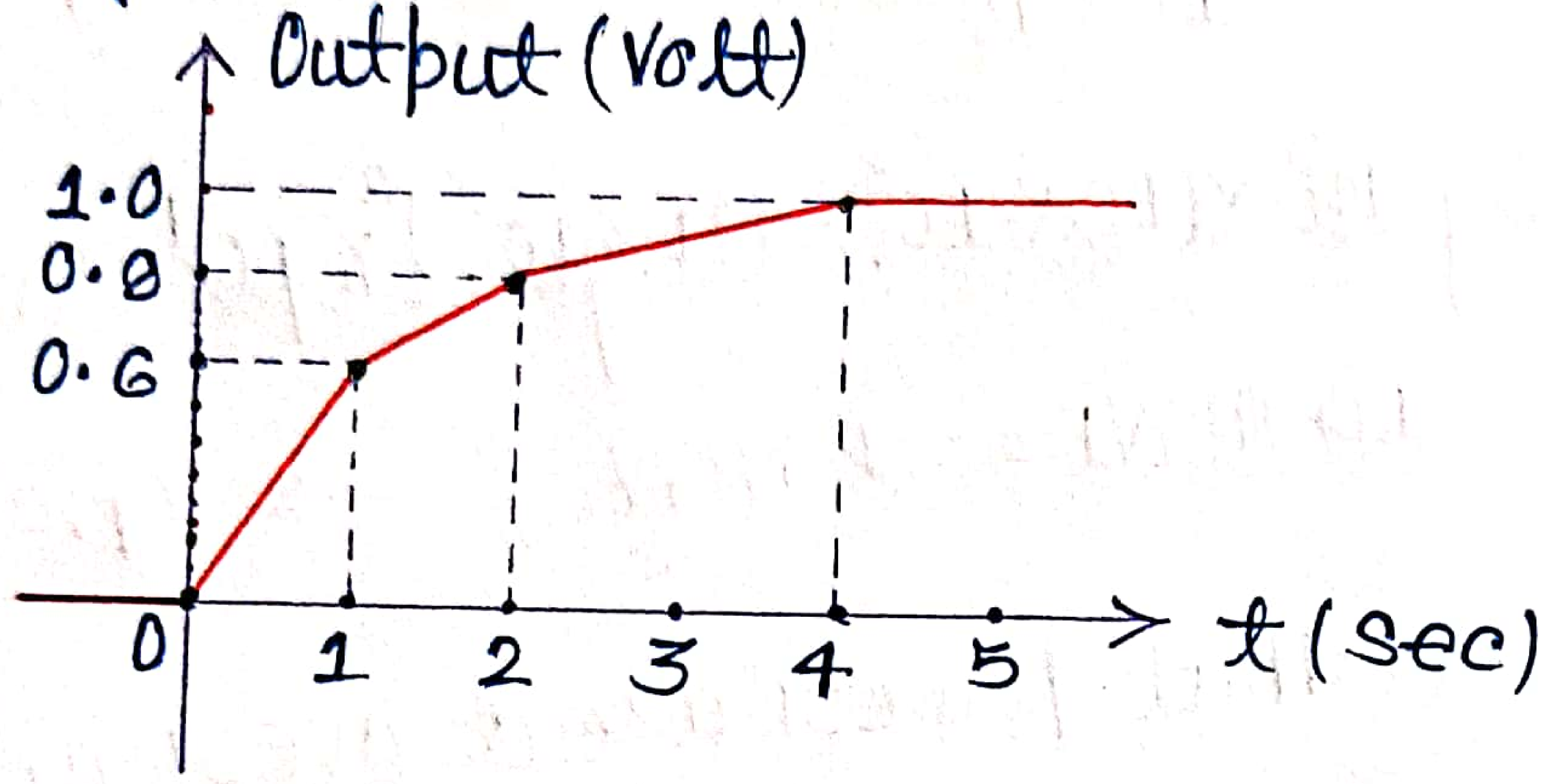
By question, for input $u(t)$, output is given.

Set(A):-

New applied input signal $= u(t) - 2u(t-4) + 1.8u(t-5)$

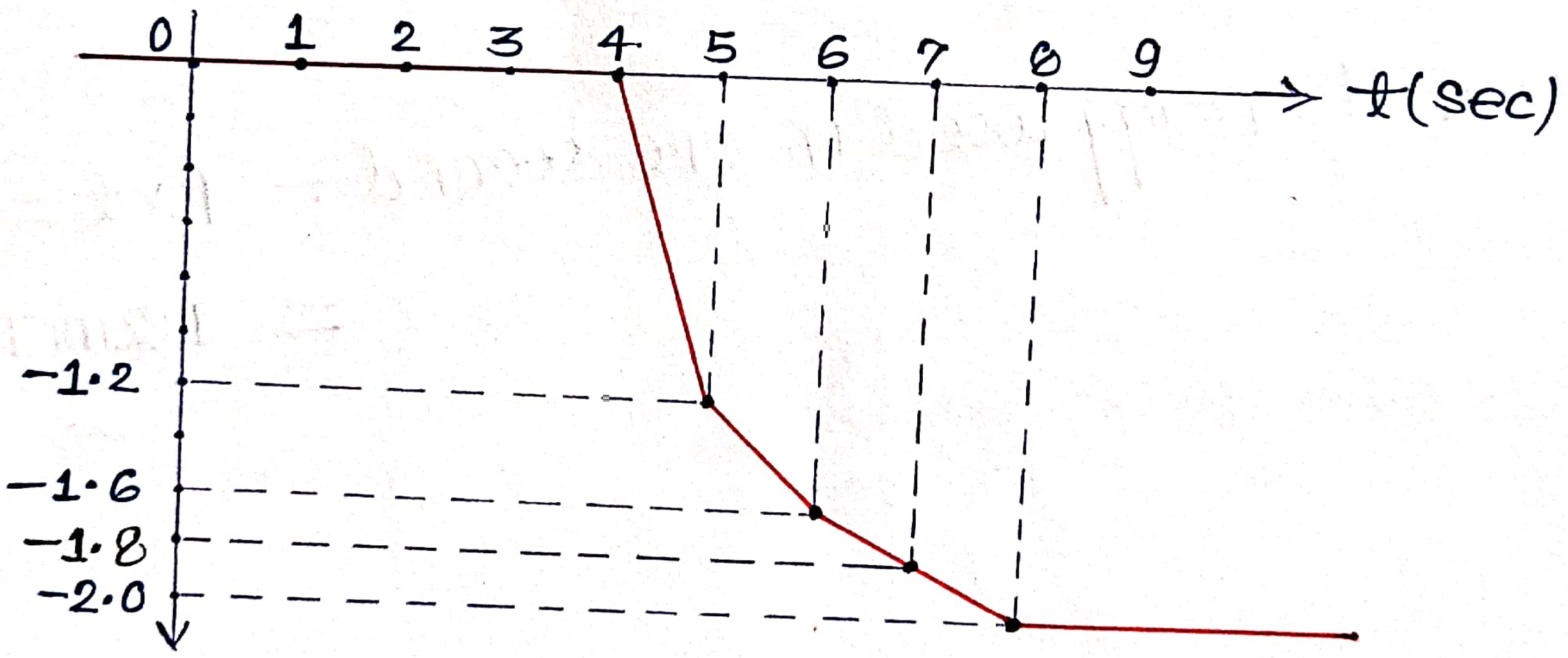
Case(I)-

Output signal for input $u(t)$,



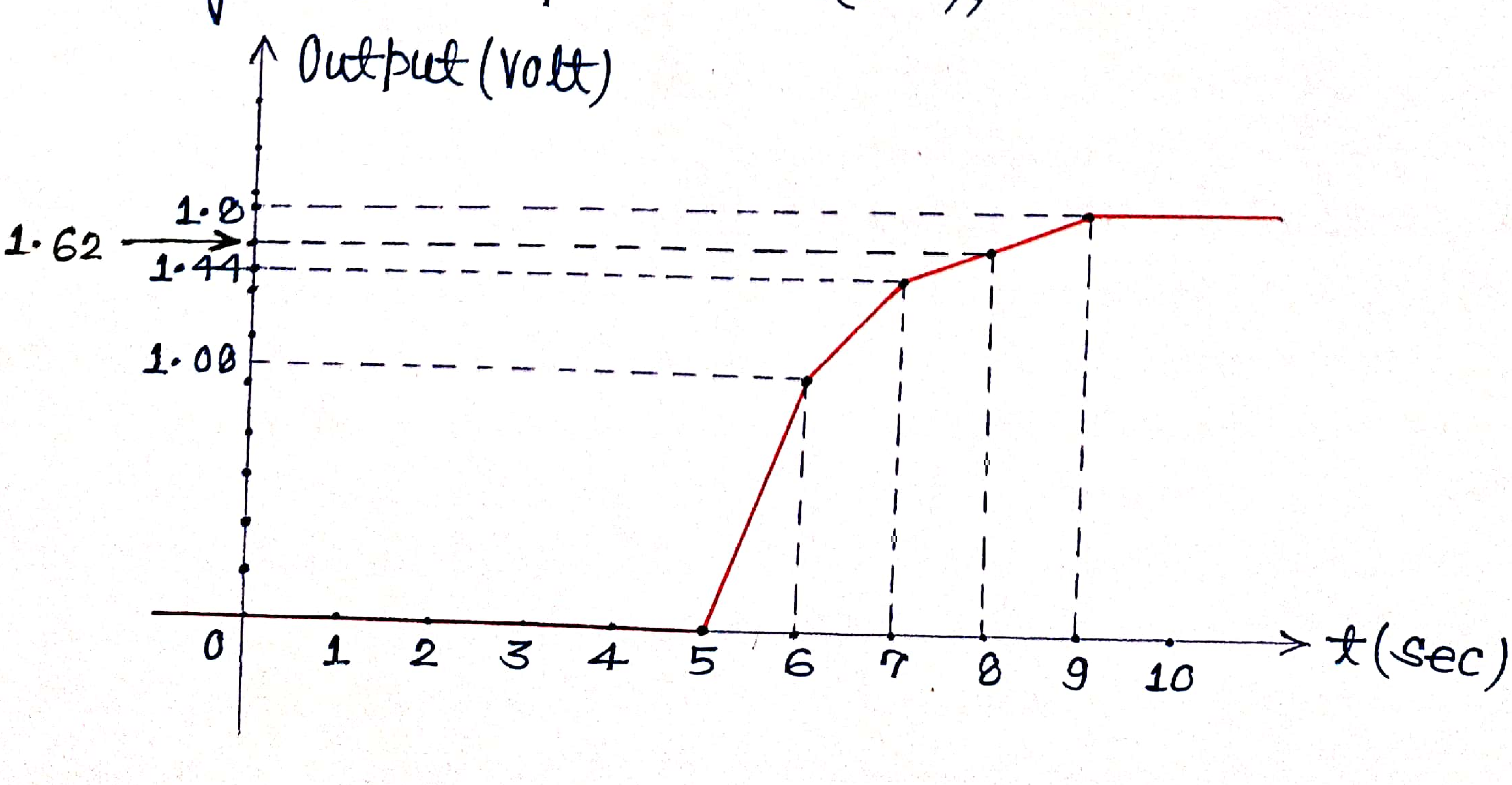
Case(II)-

Output signal for input $-2u(t-4)$,

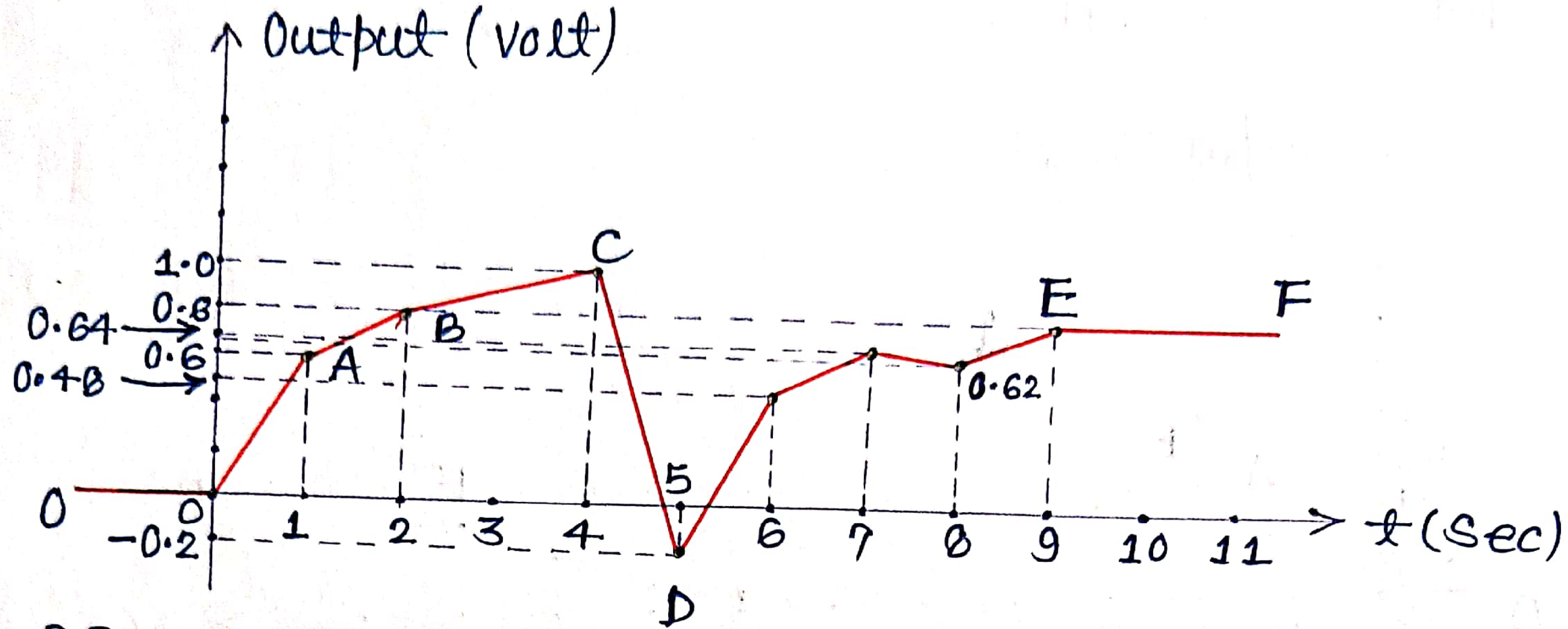


Case(III)-

Output signal for input $1.8u(t-5)$,



By using the property of linearity, resultant signal for the input signal $u(t)-2u(t-4)+1.8\,u(t-5)$ will be-



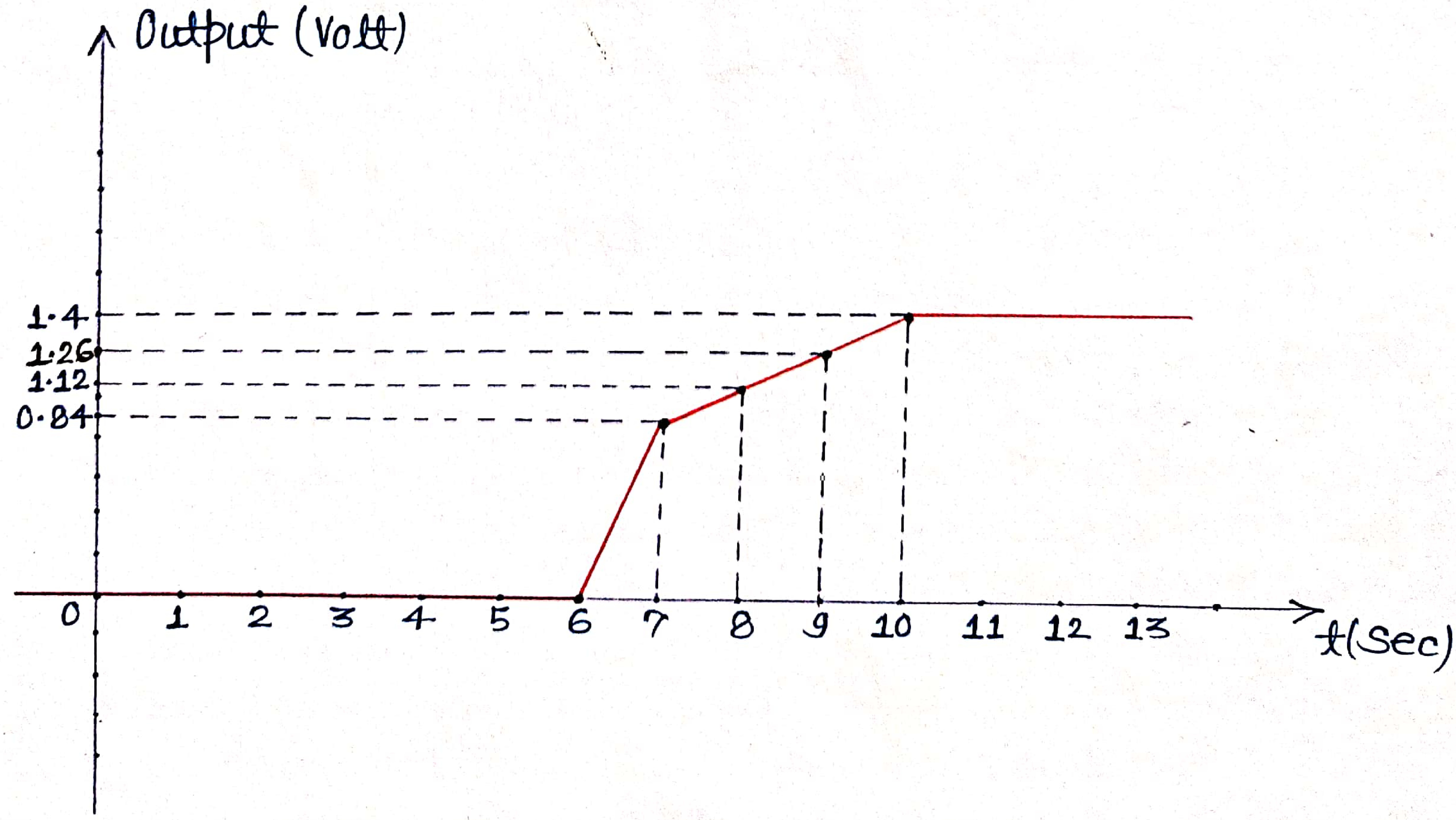
(OA, AB, BC, CD, DE, EF) × 1 POINT → (6 POINT)

Set (B):-

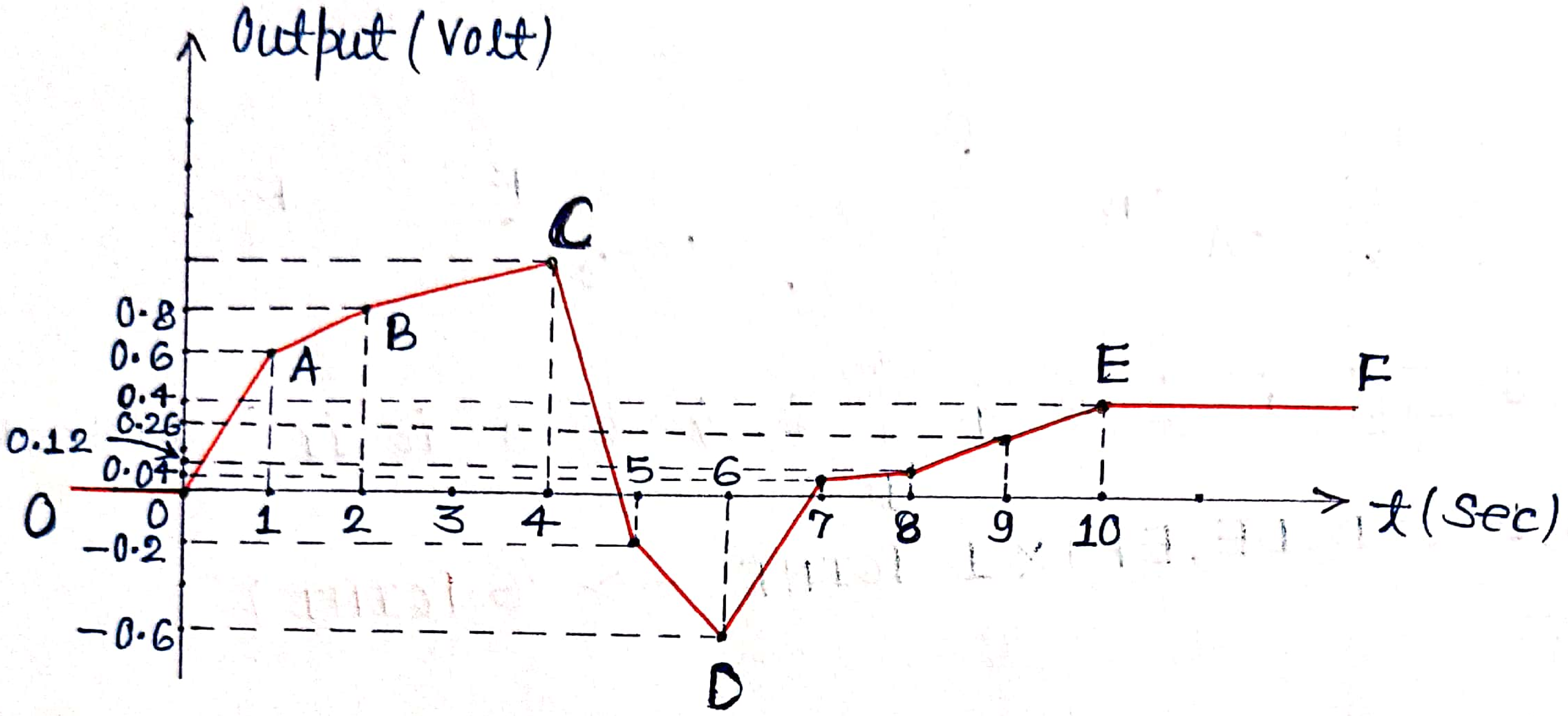
New applied input signal $= u(t)-2u(t-4)+1.4\,u(t-6)$

Case(I) & Case(II) will be same as Set(A).

Case (III)– Output signal for input $1.4\,u(t-6)$,



By using the property of linearity, resultant output signal for the given input signal, $u(t) - 2u(t-4) + 1.4u(t-6)$ will be —

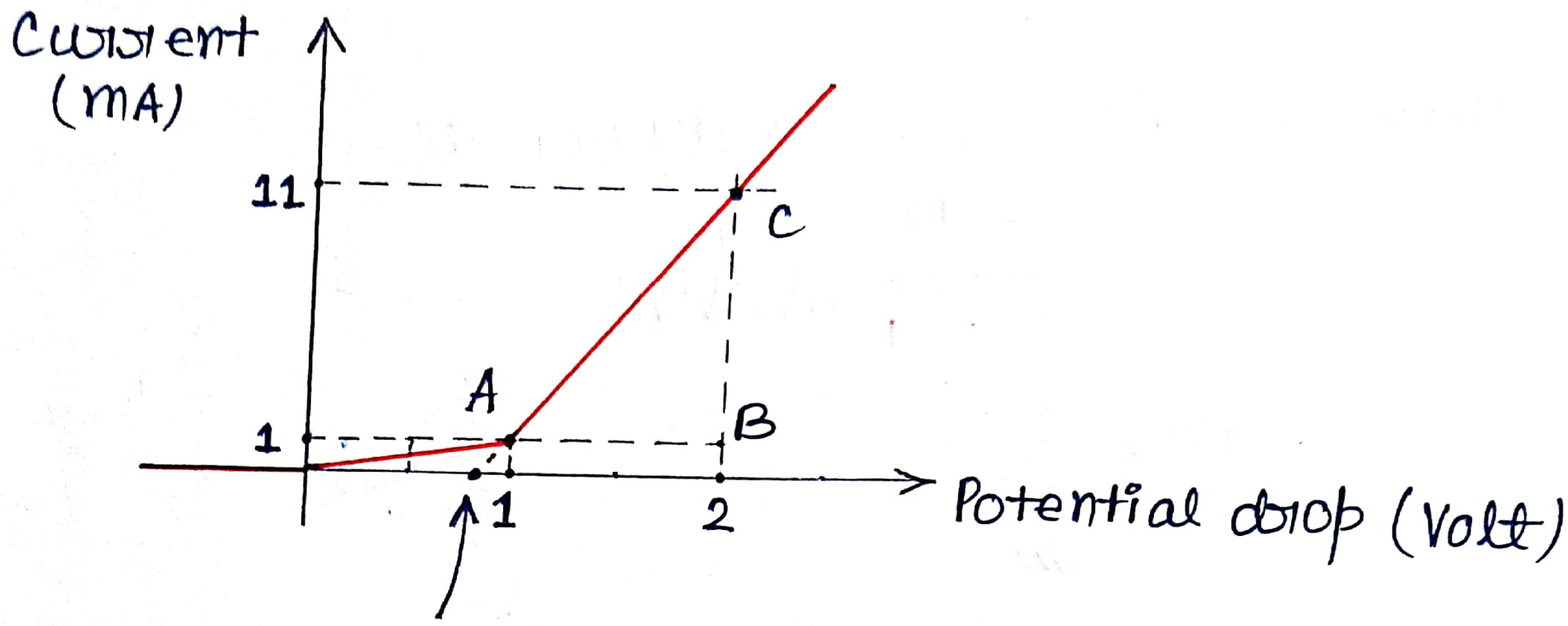


(OA, AB, BC, CD, DE, EF) X 1 → (6 POINT)

SOL (4) :-

Set (A) :-

Given V-I characteristic of diode—



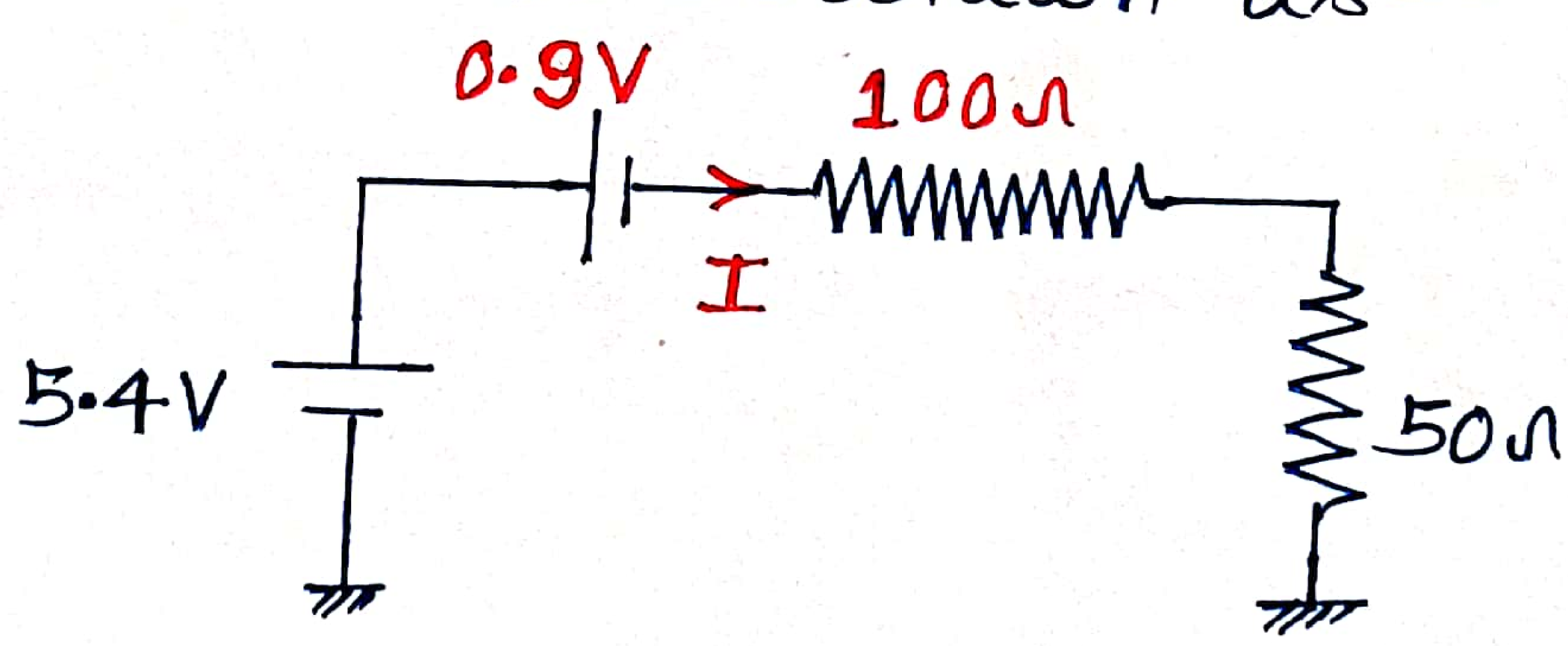
Forward Voltage Drop / Cut-in Voltage (V_γ)

$= 0.9$ Volt → (2 POINT)

Internal resistance of diode / Forward Resistance

$$(R_f) = \left(\frac{2-1}{11-1}\right) k\Omega = \frac{1}{10} k\Omega = 100\Omega$$ → (2 POINT)

Given circuit can be redrawn as—



$$\therefore \text{Curren, } I = \frac{(5.4-0.9)}{(100+50)} = 0.03A = 30mA$$

→ (2 POINT)