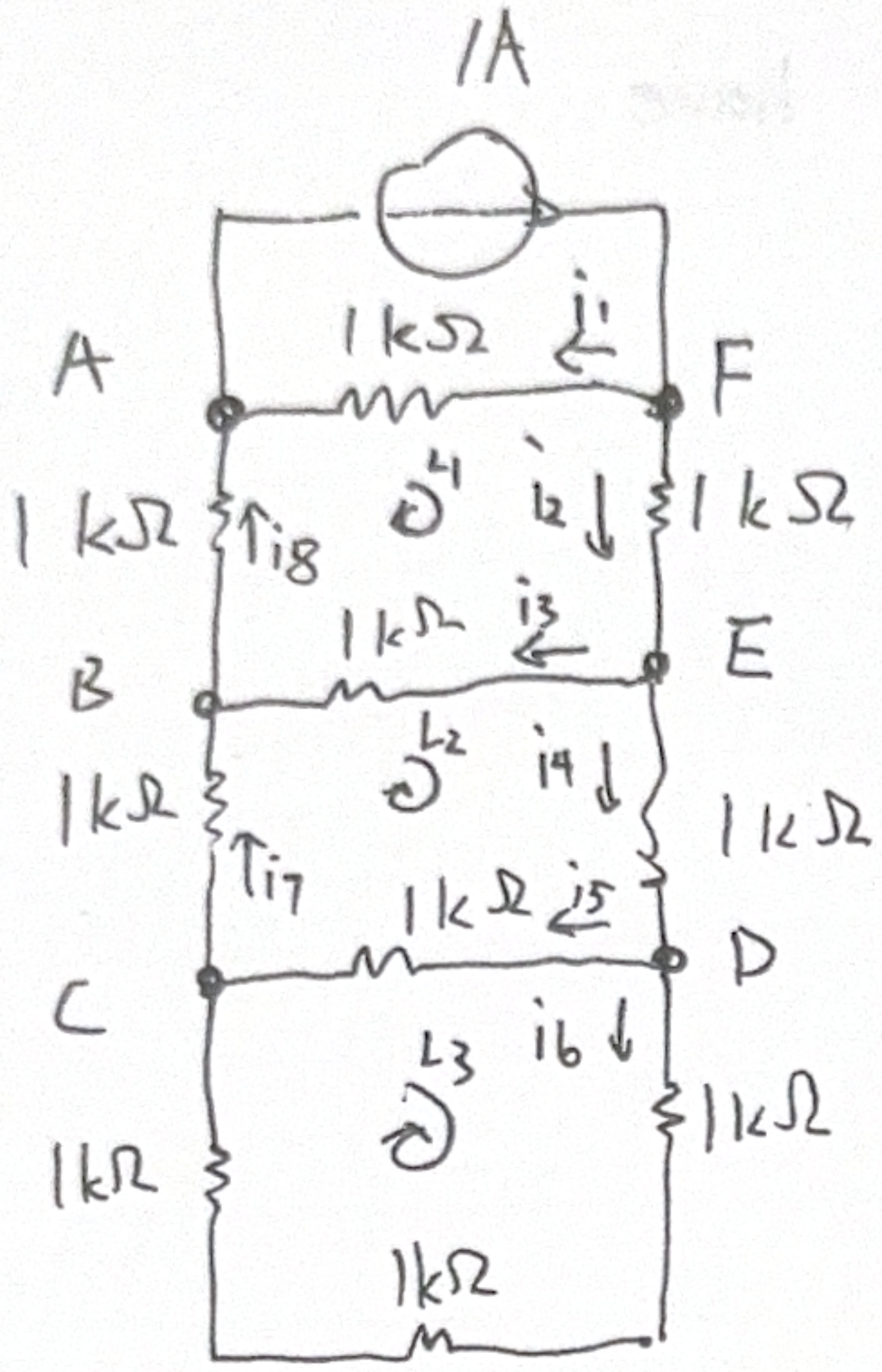
1.



(a) Equivalent resistance

$$R_{eq} = \cfrac{1}{\cfrac{1}{1000} + \cfrac{1}{2000 + \cfrac{1}{\cfrac{1}{1000} + \cfrac{1}{2000 + \cfrac{1}{\cfrac{1}{1000} + \cfrac{1}{3000}}}}}}$$

$$= \frac{41}{56} \times 1000\,\Omega \approx 732\,\Omega$$

(b) There are 6 nodes, denoted as A, B, C, D, E, F

There are 3 Loops, denoted as L_1, L_2, L_3

(FEBA) (EDCB) (D, C)

KCL:

F $1A = i_1 + i_2$

E $i_2 = i_3 + i_4$

D $i_4 = i_5 + i_6$

C $i_7 = i_5 + i_6$

B $i_8 = i_3 + i_7$

A $1A = i_1 + i_8$

KVL:

L_1 $i_1 \cdot 1k\Omega = i_2 \cdot 1k\Omega + i_3 \cdot 1k\Omega + i_8 \cdot 1k\Omega$

L_2 $i_3 \cdot 1k\Omega = i_4 \cdot 1k\Omega + i_5 \cdot 1k\Omega + i_7 \cdot 1k\Omega$

L_3 $i_5 \cdot 1k\Omega = i_6 \cdot 3k\Omega$

(1) Solve previous KCL and KVL, we have

$i_1 = 0.732\text{ A}$

$i_2 = i_8 = 0.268\text{A}$

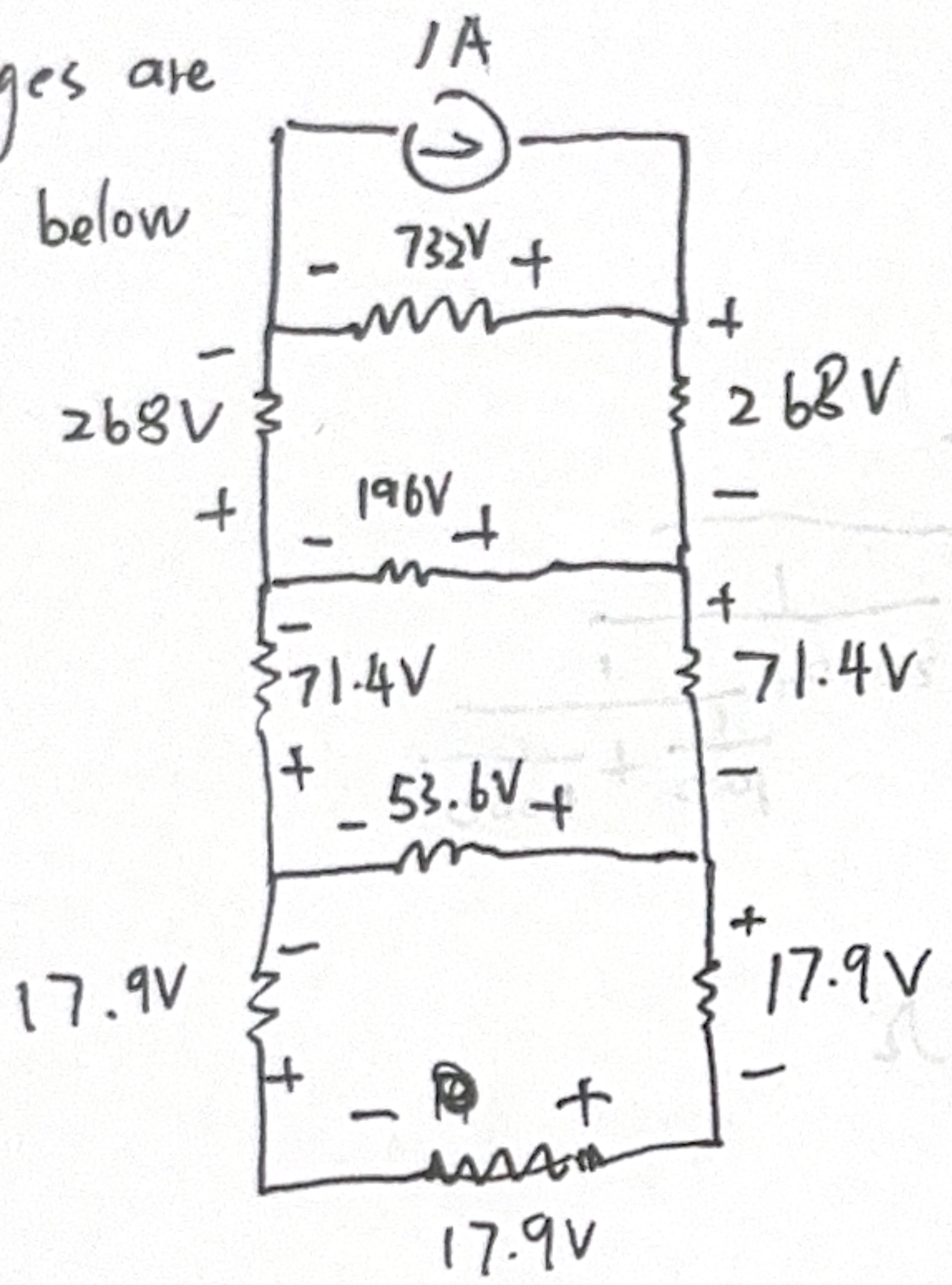
$i_3 = 0.196\text{ A}$

$i_4 = i_7 = 0.0714\text{A}$

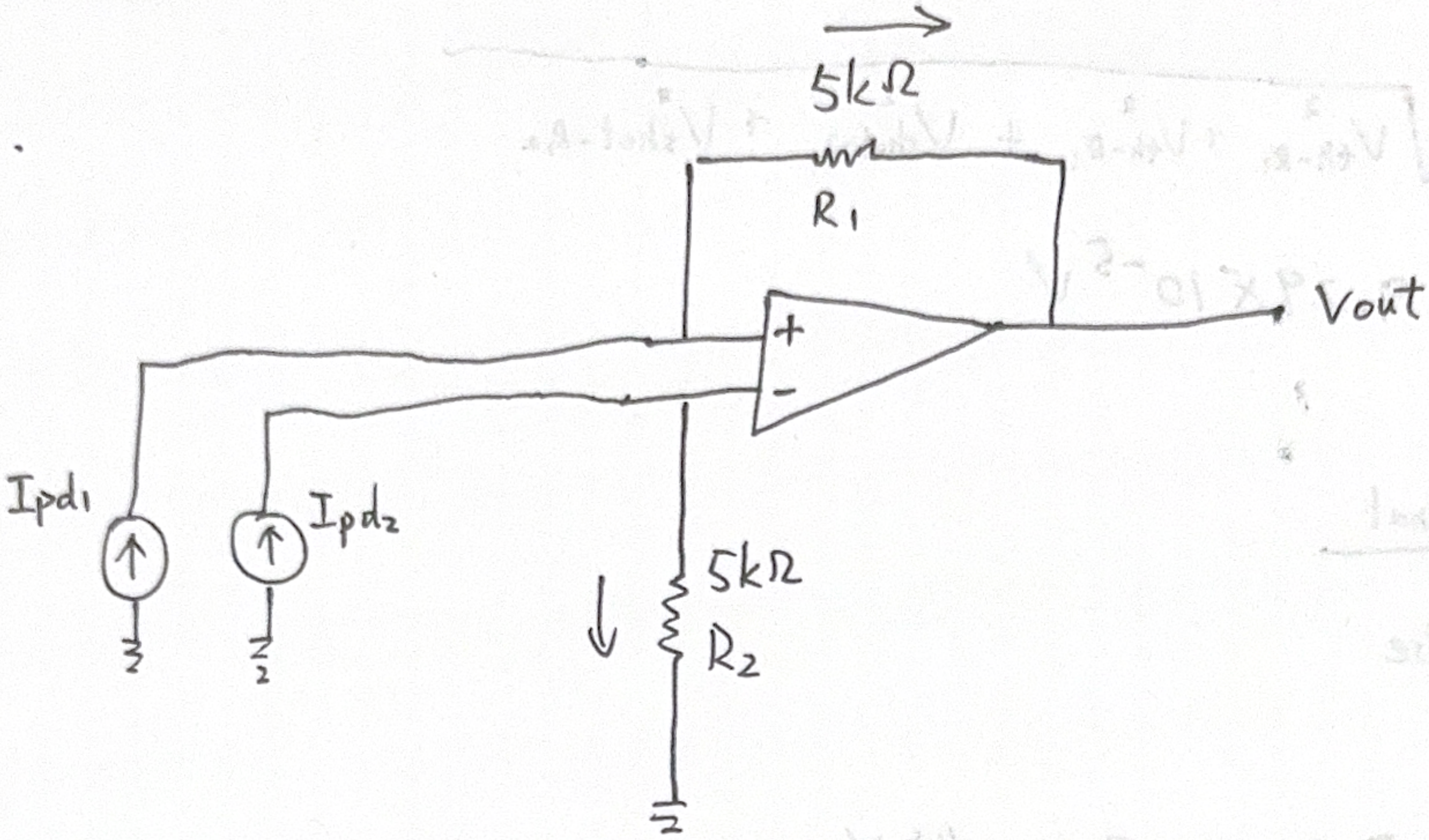
$i_5 = 0.0536\text{A}$

$i_6 = 0.0179\text{ A}$

Voltages are shown below



2.



(a) $V^+ = V^-$

$I_{R_1} = I_{pd1}$

$I_{R_2} = I_{pd2}$

$V_{out} + I_{pd1} \cdot 5k\Omega = 0V + I_{pd2} \cdot 5k\Omega$

$V_{out} = (I_{pd2} - I_{pd1}) \cdot 5k\Omega$

(b) Resistor thermal voltage $\qquad k_B = 1.38 \times 10^{-23}\ J/k$

$V_{noise} = \sqrt{4 k_B T R \Delta f} = 2.88 \times 10^{-6}\ V$ on R1 & R2 respectively

PD shot noise $\qquad q_e = 1.60 \times 10^{-19}\ C$

$I_{pd1\text{-}noise} = \sqrt{2 q_e I_{pd1} \Delta f}$

$= 1.79 \times 10^{-8}\ A$

$I_{pd2\text{-}noise} = 5.66 \times 10^{-9}\ A$

Effective on R_1 and R_2

$V_{shot\text{-}noise\text{-}R_1} = I_{pd1\text{-}noise} \times 5k\Omega = 8.94 \times 10^{-5}\ V$

$V_{shot\text{-}noise\text{-}R_2} = I_{pd2\text{-}noise} \times 5k\Omega = 2.83 \times 10^{-5}\ V$

(c) $V_{noise-total} = \sqrt{V_{th-R_1}^2 + V_{th-R_1}^2 + V_{shot-R_1}^2 + V_{shot-R_2}^2}$

$= 9.39 \times 10^{-5} V$

(d) $SNR = \dfrac{V_{signal}^2}{V_{noise}^2}$

$V_{out} = (I_{pd_2} - I_{pd_1}) \times 5k\Omega = -45V$

$SNR = \dfrac{(-45V)^2}{(9.39\times10^{-5})V^2} = 2.30 \times 10^{11}$

Alternatively

$SNR = 20 \cdot (\log_{10}(|V_{out}|) - \log_{10}(V_{noise})) = 113.6 dB$

Q3: $I = I_0\left(e^{\frac{qV}{nKT}} - 1\right) \Rightarrow$

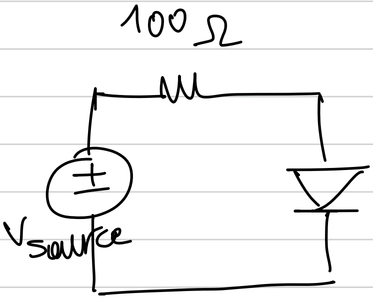
$I_{min} = 0 \Rightarrow e^{\frac{qV}{nKT}} = 1 \Rightarrow \frac{qV}{nKT} = \ln(1) = 0 \Rightarrow V_{min} = 0$

$I_{max} = 10 \times 10^{-3} = 1 \times 10^{-21} \times e^{\frac{qV}{nKT}} \Rightarrow$

$e^{\frac{qV}{nKT}} = 10^{19} \Rightarrow \frac{qV}{nKT} = 19\ln(10) = 43.74$

$\Rightarrow V = 2 \times 1.38 \times 10^{-23} \times 300 \times 43.74 \times \frac{1}{1.6 \times 10^{-19}} \Rightarrow$

$V_{LED} = 2.26 \times 10^{4} \times 10^{-23} \times 10^{19} = 2.26\,V$



$V_{source} = V_R + V_{LED} \Rightarrow$

$V_R = R \times I = 100 \times 10 \times 10^{-3} = 1\,V$

$V_{source_{max}} = 1 + 2.26 = 3.26$

$V_{source_{min}} = 0$

b) Photon Energy: $E = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{532 \times 10^{-9}} = 3.73 \times 10^{-19}\,J$

electrons per second: $I = nq \Rightarrow n = \frac{10 \times 10^{-3}}{1.6 \times 10^{-19}} = 6.25 \times 10^{16}\ \frac{elec}{s}$

photons per second: $n_{photon} = \eta \times n_{electron} = 0.215 \times 6.25 \times 10^{16}$

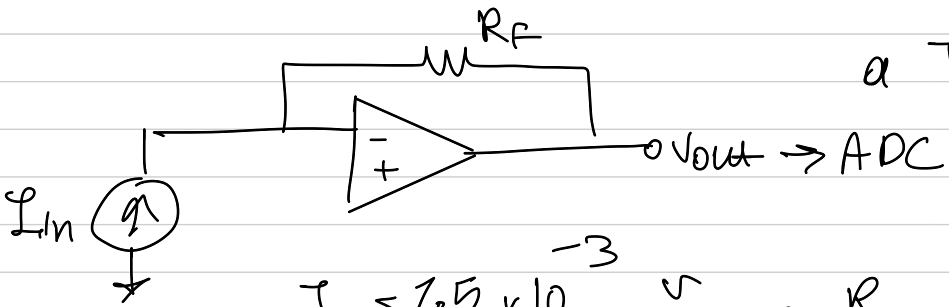
$= 1.34 \times 10^{16}\ \frac{photons}{s}$

optical power $\Rightarrow P = n_{photon} \times E = 1.34 \times 10^{16} \times 3.73 \times 10^{-19} = 5.012 \ mW$

$I_{photodiode} = R_\lambda \times P_{optical} \rightarrow$ based on the curve $R_\lambda \cong 0.3 \frac{A}{W}$

$I_{ph} = 0.3 \times 5.012 \times 10^{-3} = 0.0015 = 1.5mA$

Now we need to convert this current to 10 v using a Transimpedance Amplifier.



$$I = 1.5 \times 10^{-3} = \frac{v}{R} \Rightarrow R = \frac{10}{1.5 \times 10^{-3}} = 6.6 \ K\Omega$$

we need $R_F = 6.6 \ K\Omega$ but we want to design our circuit using 100 Ω resistors so we need 66, 100 Ω resistors in series.

Q4:

500 x 128 = 64000

128 x 64 = 8192

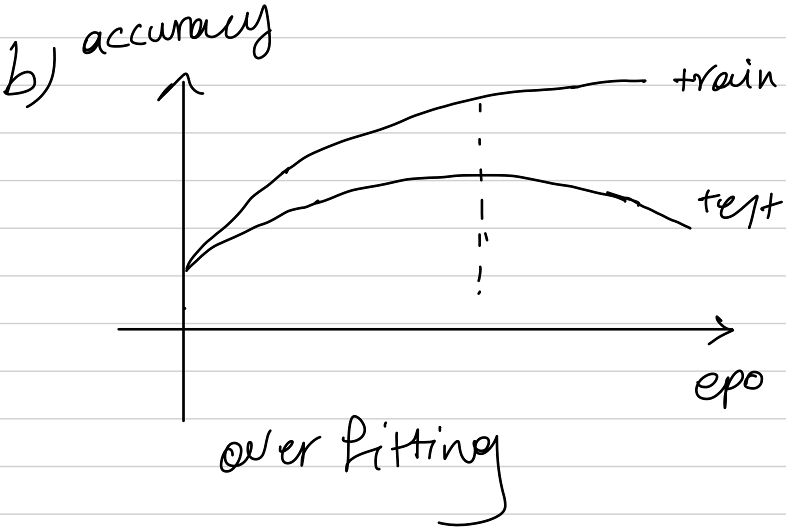
64 x 32 = 2048

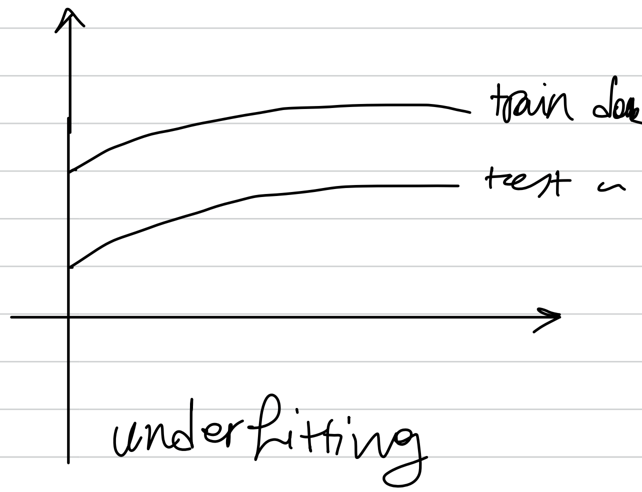
32 x 10 = 320

sum => 74560 MAC operation

FLOPS = 74560 x 2 = 149120

b)





c) The rule is:

$$Y = f(x_1 w_1 + x_2 w_2 + \dots + \text{bias}) \text{ or } \sum_{i=1}^{n} x_i w_i + b$$

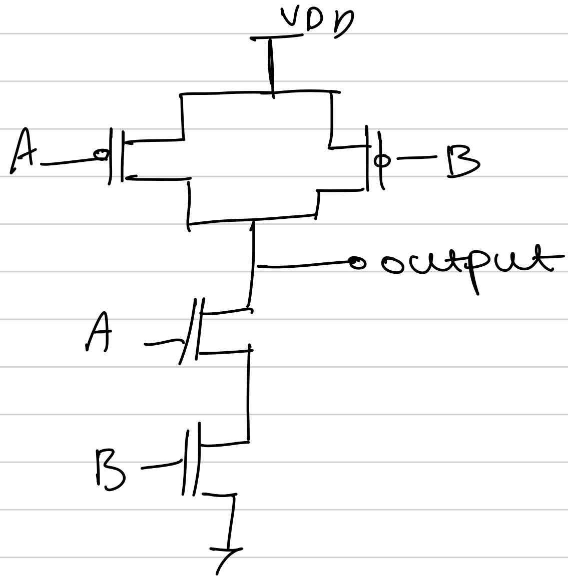
f is a step function or an activation function

d) perceptrons can only solve linearly separable problems, they cannot handle non linearly separable datasets.

They use step function as activation function so which prevents them from using gradient based methods.

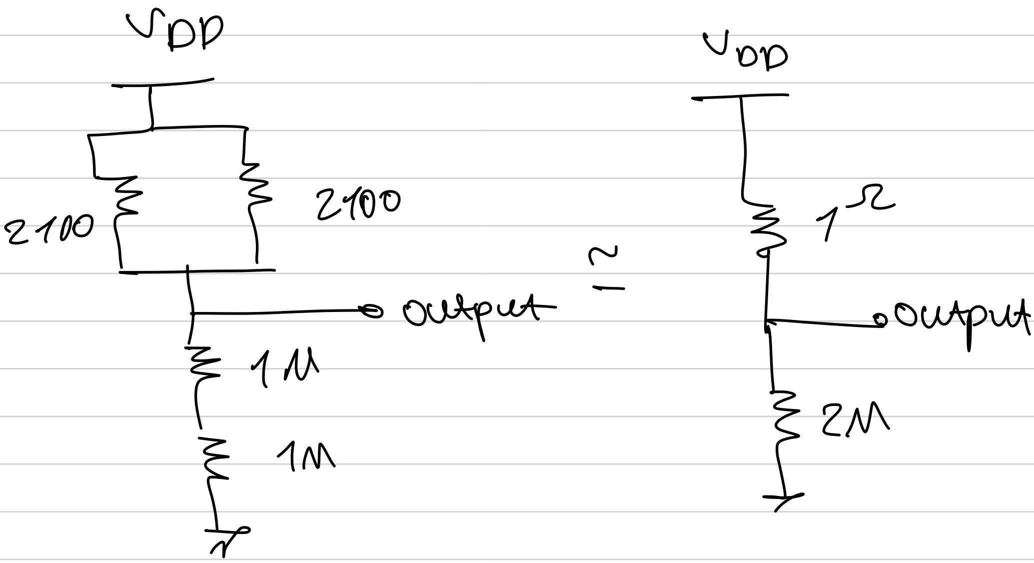
Q5 8

a) NAND Gate



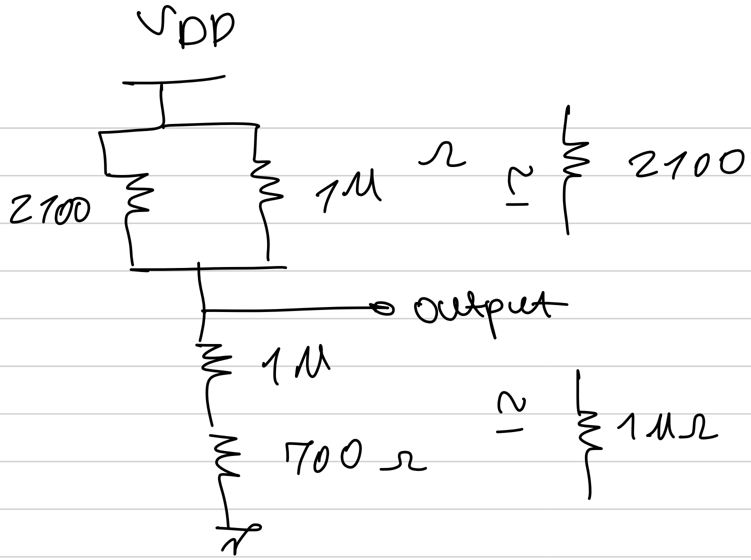
b)

A	B
0	0



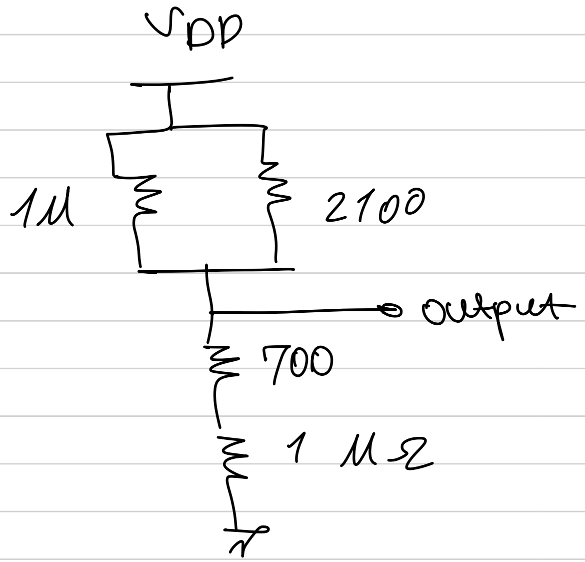
output = $\frac{2 \times 2M}{2M} \simeq 2V$

A	B
0	1



$$output \cong 2 \times \frac{1M}{1M} \cong 2$$

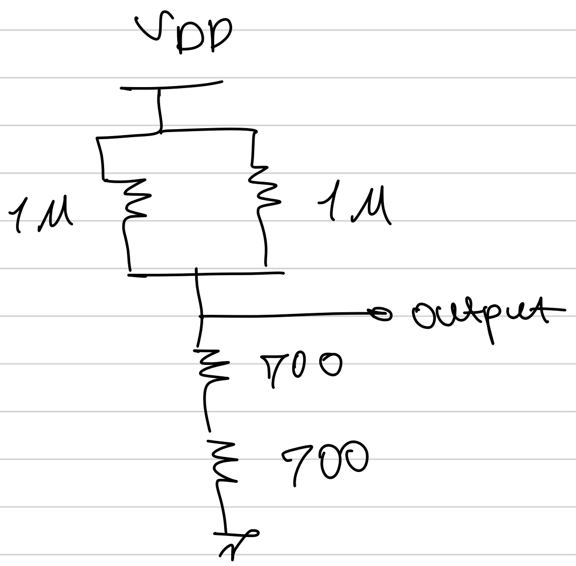
A	B
1	0



Voutput
2
2
2
0.005

output ≅ 2v

A	B
1	1



$$Output \cong 2 \times \frac{1400}{\cong 0.5 \times 10^{6}} = 5600 \times 10^{-6} = 0.005$$