A5. The circuit shown in Figure A5 uses silicon diodes. The current, I flowing in the diode is

$V_S = I.R_1 + IR_2 + 2V_D$

(a) 2.20 mA

(b) 2.43 mA

(c) 2.67 mA

(d) 3.30 mA

$I = \frac{V_S - 2V_D}{(R_1 + R_2)}$

$I = \frac{8 - 1.4}{3k}$

$I = 2.2mA$

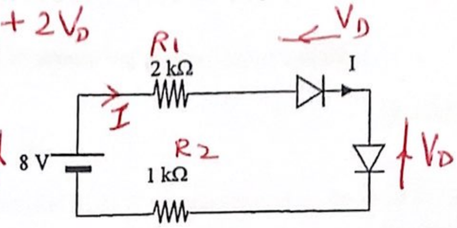


Figure A5

A6. Which one of the following sequences can be a correct order of a DC power supply?

(a) Step-up transformer, filter, rectifier and voltage regulator
(b) Step-up transformer, voltage regulator, filter and rectifier
(c) Step-down transformer, rectifier, filter and voltage regulator
(d) Step-down transformer, filter, rectifier and voltage regulator

A7. Which one of the following IC voltage regulators gives a DC output voltage of 24 V?

(a) 7918
(b) 7924
(c) 7818
(d) 7824

A8. In a PNP transistor which of the following layers have holes as the majority carrier?

(a) Emitter and base layers
(b) Collector and base layers
(c) Emitter and collector layers
(d) Emitter, collector and base layers

A9. The collector current of a NPN transistor is approximately proportional to the base current when it is operating in the ______ region.

(a) saturation
(b) avalanche breakdown
(c) active
(d) cut-off

A10. Which one of the following devices is NOT a transducer?

(a) Photodiode
(b) Zener diode
(c) Moisture sensor
(d) Light dependent resistor

SECTION B (14 marks each)

B1. (a) Explain the process of doping in producing n-type semiconductors.

[2 marks]

(b) For the circuit shown in Figure B1,

(i) state with reason whether the LED is reverse-biased or forward biased. [2 marks]

(ii) calculate the currents flowing through resistors R_1 and R_2. Indicate the direction of both currents. [9 marks]

(iii) calculate the current flowing through the LED. [1 mark]

Assume the LED used in the circuit has a forward voltage drop of 1.9 V.

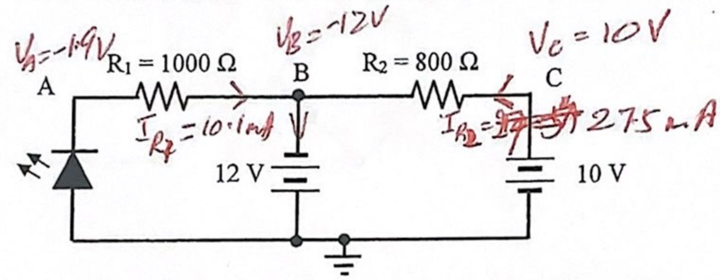


Figure B1

B2. The circuit shown in Figure B2 is a Zener diode regulator circuit. Given $V_{ZT} = 6.1$ V at $I_{ZT} = 55$ mA; $Z_Z = 10\ \Omega$; and $V_{ZM} = 6.7$ V.

$Z_Z = \frac{V_{ZM} - V_{ZT}}{I_{ZM} - I_{ZT}} \Rightarrow I_{ZM} = 115mA$

(a) Find I_{ZM} of the Zener diode. [5 marks]

(b) If I_{ZM} flows through the Zener diode, determine:

$I = \frac{10 - 6.7}{15} = 220mA$

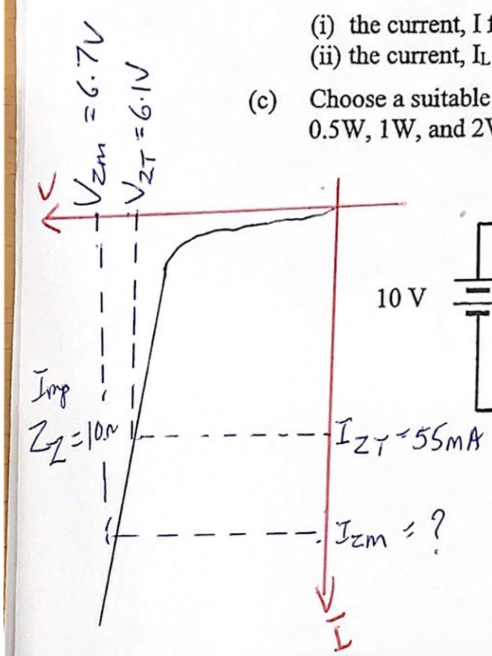
(i) the current, I flowing through the 15 Ω resistor. [3 marks]

$I_L = I - I_{ZM} = 105mA$

(ii) the current, I_L flowing through the variable resistor R_L. [3 marks]

(c) Choose a suitable power rating of resistor R_L from the following list: 0.25W, 0.5W, 1W, and 2W. [3 marks]

KCL, $I = I_{ZM} + I_L$



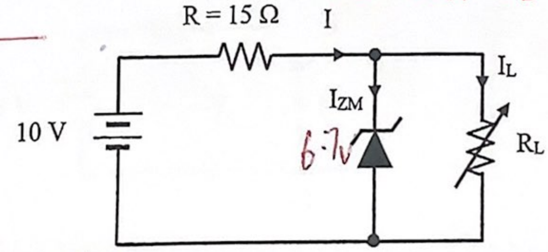


Figure B2

$P_{RL} = V_{ZM} \times I_L$
$= 6.7 \times 105mA$
$= 0.7035W$
use 1W.

B3. For the circuit shown in Figure B3,

a) FW Bridge Rectifier

b) $V_{p(sec)} = \frac{325}{10} = 32.5V$, $V_{p(out)} = V_{p(sec)} - 1.4$, $V_{p(out)} = 31.1V$

(a) state the type of rectifier circuit shown. [2 marks]

(b) calculate the peak voltage across the load resistor, R_L. [3 marks]

(c) calculate the average current flowing through each diode. [4 marks]

c) 2 diodes, $I_{avg} = \frac{2 I_{pout}}{\pi} = 9.9mA$ ∴ I_{ave} in each diode $= \frac{9.9mA}{2} = 4.95mA$

(d) calculate the PIV for each diode. $PIV = 31.8V$ [3 marks]

(e) sketch the voltage waveform across the load resistor, R_L. [2 marks]

Assume the diodes used are silicon diodes.

V_{out} 31.1V, 0V, π, 2π

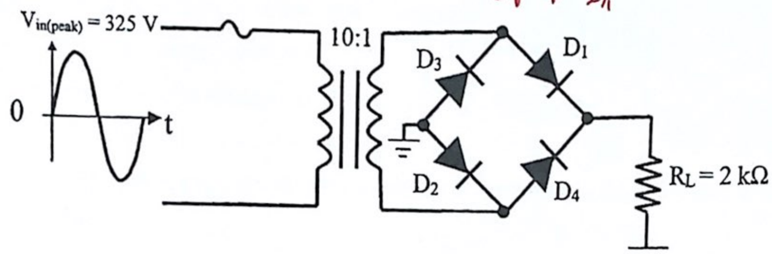


Figure B3

B4. For the transistor circuit shown in Figure B4 if the voltage across R_C is 3V, calculate

(a) the emitter current, I_E — $I_B = 0.13mA$, $I_C = 0.03A$, $I_E = I_B + I_C = 30.13mA$ [6 marks]

(b) the voltage across the transistor, V_{CE} $= 2V$ [2 marks]

(c) the current gains, β_{DC} and α_{DC} $\beta = \frac{I_C}{I_B} = 230.8$, $\alpha_{DC} = \frac{I_C}{I_E} = 0.996$ [4 marks]

(d) the saturation current $I_{C(sat)}$ taking $V_{CE(sat)} = 0.2$ V [2 marks]

$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C} = \frac{5-0.2}{100} = 48mA$

c) $\beta = \frac{I_C}{I_B} = \frac{30}{0.13} = 230.8$

$\alpha = \frac{I_C}{I_E} = \frac{30}{30.13} = 0.996$

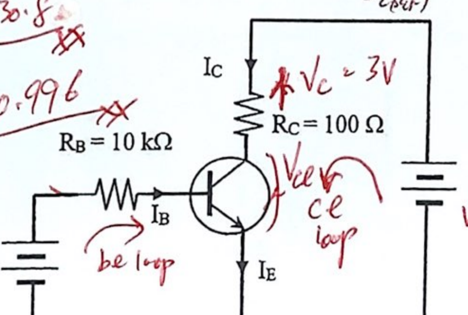


Figure B4

be-loop Eqn.

a) $V_{BB} = I_B R_B + V_{BE}$

$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{2 - 0.7}{10k}$

$I_B = 0.13mA$

$I_C = \frac{V_C}{R_C} = \frac{3}{100} = 30mA$

$I_E = I_B + I_C$

$I_E = 0.13 + 30 = 30.13mA$

b) ce loop Eqn,

$V_{CC} = V_C + V_{ce}$

∴ $V_{ce} = V_{CC} - V_C$

$= 5 - 3$

$V_{ce} = 2V$

d) ce loop.

$V_{CC} = I_{C(sat)} R_C + V_{ce(sat)}$

$I_{C(sat)} = \frac{V_{CC} - V_{ce(sat)}}{R_C} = \frac{5 - 0.2}{100} = 48mA$

B5. The moisture sensor circuit shown in Figure B5 is used to detect rain drops. The LED will light up when the sensor gets wet. The circuit has the following parameters:

Resistance of the moisture sensor when it is wet, $R_{M(wet)} = 0\ \Omega$ (close-circuited)
Resistance of the moisture sensor when it is dry, $R_{M(dry)} = \infty\ \Omega$ (open-circuited)
$V_{LED} = 2.1$ V when it is forward biased and conducting
The current gain of the transistor, $\beta_{DC} = 180$ and $V_{CE(sat)} = 0.2V$

(a) What is the voltage across R_2 when the moisture sensor is dry? 0V [2 marks]

(b) When the moisture sensor is wet, calculate

(i) the voltage across R_2. $V_{R2} = \frac{R_2}{R_1+R_2} \times V_{cc} = 7.13V$. [4 marks]

(ii) the base current, I_B. $= \frac{V_{R2} - 0.7}{R_B} = 0.238mA$ [2 marks]

(iii) the saturated collector current, $I_{C(sat)}$. $= \frac{V_{cc} - V_{CE} - V_{LED}}{R_C} = 23.3mA$ [3 marks]

(c) State with reason whether the transistor is operating in the saturation or active region. [3 marks]

$I_{B(min)} > I_{B(sat)}$

$0.238mA > 0.1296mA$

$I_{B(sat)} = \frac{I_{C(sat)}}{\beta} = \frac{23.3}{180} = 0.1296mA$

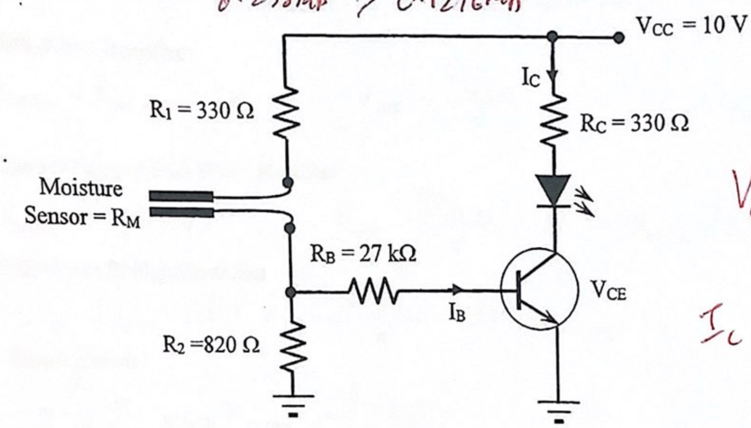


Figure B5

OR alternative.

$V_{ce} = V_{cc} - I_cR_c - V_{LED}$

$= \cancel{10}$

$I_c = \beta . I_B \quad I_B = 0.238mA$

$= 180 \times 0.238$

$I_c = 42.84mA$

$\therefore V_{ce} = 10 - (42.8m \times 330) - 2.1$

$= 10 - 14.14 - 2.1$

$= -6.24V$

$V_{ce} \approx -6.24V$

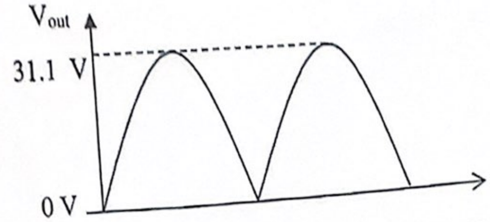
Since $V_{ce(sat)} \not< 0.2V$ as calculated, ∴ Transistor saturated.

- End of Paper –

SECTION B (5 × 14 = 70 marks)

No.	SOLUTION	MARKS	TOTAL MARKS
B1			
(a)	To produce n-type semiconductors pentavalent impurities are added to pure semiconductor materials. This will result in more free electrons.	2	
(b) (i)	With the LED removed from the circuit	1	
	$V_A = V_B = -12$ V		
	Since V_A is less than -1.9V the LED will be forward biased.	1	
(ii)	With the LED in the circuit.	1	
	$V_A = -1.9$ V	1	
	$V_B = -12$ V		
	$I_{AB} = I_{R1} = \frac{(-1.9-(-12))}{1000} = 10.1$ mA	2 1	
	$V_C = 10$ V		
	$I_{CB} = I_{R2} = \frac{(10-(-12))}{800} = 27.5$ mA	2 1	
	Direction of I_{R1} from A to B Direction of I_{R2} from C to B	1	
(iii)	$I_{LED} = I_{R1} = 10.1\ mA$	1	14

No.	SOLUTION	MARKS	TOTAL MARKS
B2.			
(a)	Change of voltage: $\triangle V = (6.7 - 6.1)\ V = 0.6\ V$ Corresponding change of current: $\triangle I = \triangle V / Z_Z$ $\triangle I = 0.6 / 10 = 0.06\ A = 60\ mA$ $I_{ZM} = (I_{ZT} + \triangle I)\ mA = (55 + 60)\ mA = 115\ mA$	1 1 1 2	
(b)			
(i)	The total current that flows through R is $I = \frac{V_{IN} - V_Z}{R} = \frac{10 - 6.7}{15} = 220\ mA$	3	
(ii)	Since I_{ZM} is flowing through the Zener diode, load current I_L $I_L = I - I_{ZM} = 220 - 115\ mA = 105\ mA$	3	
(c)	Power $P_L = I_L V_L = 105m \times 6.7$ $= 703.5\ mW = 0.7035\ W$ Select resistor with power rating of 1 W	2 1	
			14
B3			
(a)	Full wave bridge rectifier	2	
(b)	$V_{sec(p)} = \frac{325}{10} = 32.5\ V$ $V_{out(p)} = V_{sec(p)} - 1.4$ $= 32.5 - 1.4 = 31.1\ V$	1 2	
(c)	$I_{out(p)} = \frac{31.1}{2k} = 15.55\ mA$ $I_{out(avg)} = \frac{2I_{out(p)}}{\pi} = \frac{2x15.55}{\pi} = 9.9\ mA$ I_{avg} in each diode = 9.9/2 = 4.95 mA	2 1 1	 4
(d)	PIV = $V_{out(p)} + 0.7 = 31.1 + 0.7 = 31.8\ V$	3	

No.	SOLUTION	MARKS	TOTAL MARKS
(e)		2	14
B4		2	
(a)	$I_B = \frac{V_{BB}-0.7}{R_B} = \frac{2-0.7}{10k} = 0.13\text{ mA}$ $I_C = \frac{V_C}{R_C} = \frac{3}{100} = 0.03\text{ A}$ $I_E = I_B + I_C = 0.13 + 30\, mA = 30.13\text{ mA}$	2 2	
(b)	$V_{CC} = V_{CE} + I_C R_C$ $5 = V_{CE} + 3$ $V_{CE} = 5 - 3 = 2\text{ V}$	2	
(c)	$\beta_{DC} = \frac{I_C}{I_B} = \frac{30}{0.13} = 230.8$ $\alpha_{DC} = \frac{I_C}{I_E} = \frac{30}{30.13} = 0.996$	2 2	
(d)	$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C} = \frac{5-0.2}{100} = 0.048\, A = 48\, mA$	2	14

No.	SOLUTION	MARKS	TOTAL MARKS
B5			
(a)	$V_{R2} = 0$	2	
(b) (i)	When wet $R_m = 0$ $V_{R2} = \frac{V_{cc}R_2}{R_1 + R_2}$ $V_{R2} = \frac{10X820}{330+820} = 7.13\text{ V}$	2 2	4
(ii)	$I_B = \frac{V_{R2} - 0.7}{R_B} = \frac{7.13 - 0.7}{27k} = 0.238\, mA$	2	
(iii)	$V_{CC} = V_{CE} + I_{C(sat)}R_C + V_{LED}$ $I_{C(sat)}R_C = V_{CC} - V_{CE} - V_{LED}$ $I_{C(sat)} = (10 - 0.2 - 2.1)/330$ $= 23.33\text{ mA}$	1 1 1	3
(c)	$\beta_{DC} = \frac{I_{C(sat)}}{I_{B(min)}}$ $I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}} = \frac{23.33}{180} = 0.1296\, mA$ Since $I_B = 0.238$ mA is more than the minimum base current, 0.1296 mA for saturation to occur, the transistor is operating in the saturation region.	1 1 1	3
	Alternative solutions for (c) $\beta_{DC} = \frac{I_C}{I_B}$ $I_C = \beta_{DC} I_B = 0.238\, mX\ 180 = 42.84\, mA$ Since I_C is greater than $I_{C(sat)}$ the transistor is operating in the saturation region.	1 1 1	3
	Alternative solutions for (c) $V_{CE} = Vcc - IcRc - V_{LED}$ $= 10 - 42.84m330 - 2.1 = -6.24\text{ V}$ Since V_{CE} is less than $V_{CE(sat)}$ the transistor is operating in the saturation region.	2 1	3
			14