AMPLIFIERS TRIAL MID-SEMESTER TEST

- This test is **closed** book, calculator permitted.
- Answer the questions in the spaces provided.
- Clearly label all currents, resistors and voltage drops in the circuits and state any assumptions in order to obtain a full mark
- When calculating values, clearly show all steps, starting with the formula, then substituting with numbers and finally show the measuring units of the obtained result. Otherwise **NO MARKS** are given
- It is permitted to use lecturer's approved formula sheet.
- Time permitted 1½ hours.
- **60 MARKS TOTAL (70% pass)**

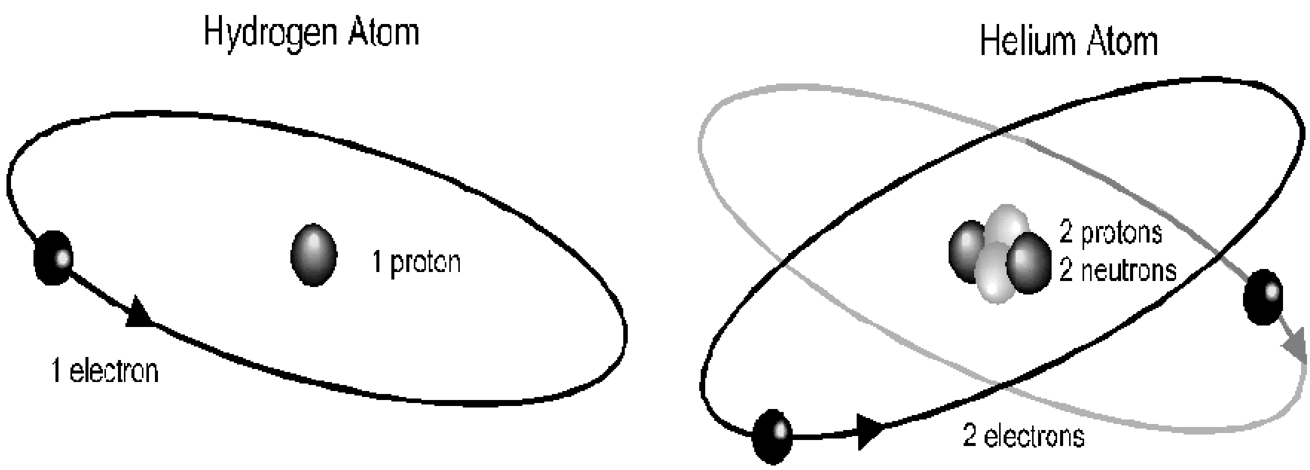
Q1) Electrons orbiting the nucleus of an atom are grouped into energy bands called: **[1 mark]**

a. Tunnels
b. Slots
c. Tracks
d. Shells

Q2) Which of the following statements is true? **[1 mark]**

a. Valence electrons possess the highest energy levels of all electrons orbiting around the nucleus.
b. Valence electrons possess the lowest energy levels of all electrons orbiting around the nucleus.
c. Valence electrons energy levels are the same as all the others electrons orbiting around the nucleus.
d. All of the above could be true, depending on the circumstances.

Q3) Sketch the Bohr model of an atom. **[1 mark]**



Q4) Define *atom.* **[1 marks]**

Answer. An atom is the smallest particle of an element that retains the characteristics of that element.

Q5). Define *electron,* according to the Bohr model of an atom. **[1 mark]**

Answer. An electron is a basic particle of an atom, which possesses a negative electrical charge. Electrons orbit around the nucleus.

Q6). Define *proton,* according to the Bohr model of an atom. **[1 mark]**

Answer. A proton is the basic particle of an atom, which possesses a positive electrical charge. Protons are located in the nucleus.

Q7). What is the nucleus of an atom composed of? **[1 mark]**

Answer. The nucleus of an atom consists of positively charged particles, called *protons* and uncharged particles, called *neutrons*.

Q8). Define *atomic number.* **[1 mark]**

Answer. The atomic number equals the number of the protons in the nucleus.

Q9). Define *balanced (or neutral) atom.* **[1 mark]**

Answer. A balanced atom has an equal number of protons and electrons. Its total net electrical charge is zero.

Q10). Define *valence electrons.* **[1 mark]**

Answer. The electrons, occupying the outermost shell (or energy band) are called valence electrons.

Q11) What is a *free electron*? **[1 mark]**

If a valance electron acquires sufficient additional energy, it can escape from the atom, thus becoming a free electron.

Q12) What is the maximum number of electrons permitted in the first shell? **[1 mark]**

a. 2
b. 8
c. 18
d. 32

Q13) What is the maximum number of electrons permitted in the second shell? **[1 mark]**

a. 2
b. 8
c. 18
d. 32

Q14) What is the maximum number of electrons permitted in the third shell? **[1 mark]**

a. 2
b. 8
c. 18
d. 32

Q15) What is the maximum number of electrons permitted in the fourth shell? **[1 mark]**

a. 2
b. 8
c. 18
d. 32

Q16) Describe the process of *ionization*. **[1 mark]**

Answer. The process of losing a valance electron is known as ionization. An atom which has lost a valance electron has a more positive total net charge and it is called a positive ion.

Q17) Describe the process of *recombination*. **[1 mark]**

Answer. When a free electron loses some of its energy, it can fill in the place of a previously lost valance electron in a positive ion. During this process, the positive ion is turned back again into a neutral atom. This process is called recombination.

Q18) What are the three main differences between the *Bohr model* of an atom and the more recent *Quantum model* of an atom? **[3 marks]**

a. The Bohr model of an atom regards electrons simply as particles. The Quantum model states that electrons have dual properties: they behave as particles **and** as waves.
b. The Quantum model is underpinned by the *uncertainty principle*. The more accurately the exact location of an electron can be determined, the less likely it is to obtain its exact velocity and vice versa.
c. The Bohr model does not take into account the repulsion between two or more electrons, orbiting in the same shell, while the Quantum model does.

Q19) Define *orbitals*, according to the Quantum model of an atom. **[2 marks]**

Answer. In the Quantum model each shell consists of up to four subshells, called orbitals, (which are designated with the letters *s*, *p*, *d* and *f*). These are based on mathematical models, which specify the three-dimensional regions where it is most likely to find an orbiting electron.

Q20) Define *conductors*. Give a few examples. **[2 marks]**

Answer. Conductors are materials, which practically do not oppose the flow of an electrical current. Their valence number is usually 1, 2 or 3. Examples: copper, silver, gold, tin, iron. Most metals and alloys are good conductors.

Q21) Define *insulators*. Give a few examples. **[2 marks]**

Answer. Insulators are materials that greatly oppose the flow of an electrical current. Current practically does not flow through them. Their valence number is 5, 6, 7 or more. Examples: rubber, glass, paper, mica, wood, plastic.

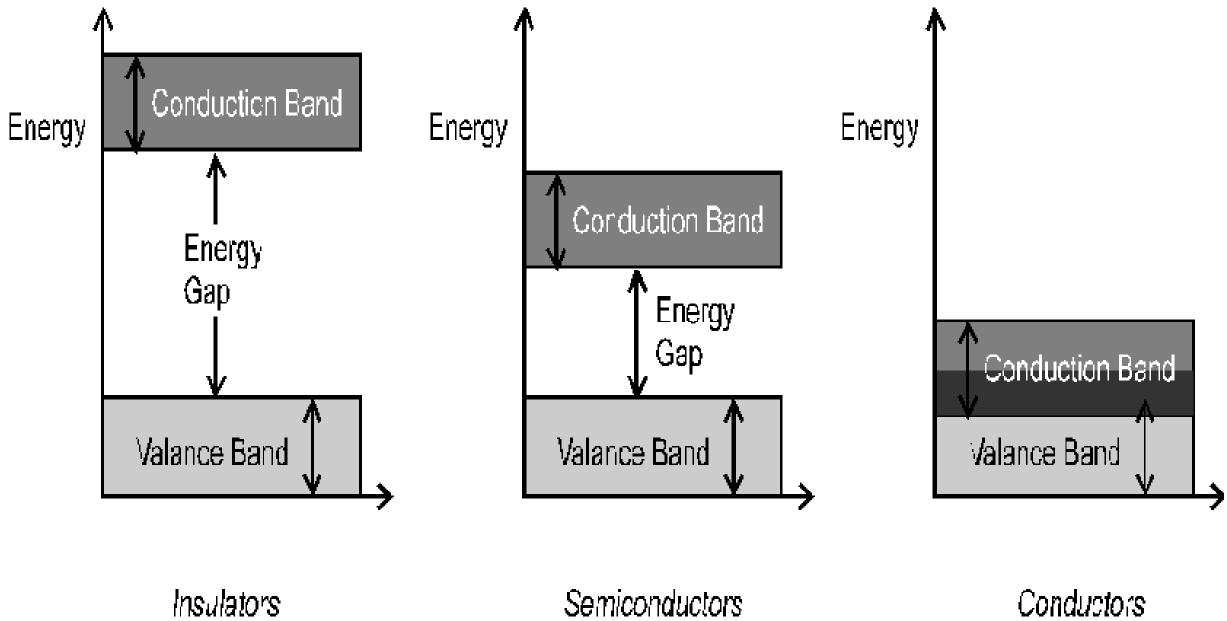
Q22) Define *semiconductors*. Give a few examples. **[2 marks]**

Answer. Semiconductors are materials, which electrical conductivity is somewhere in the middle between those of the conductors and the insulators. Their valence number is 4. The most used single-element semiconductor is silicon. Sometimes germanium is also used.

Q23) What is meant by the term *intrinsic* crystal? **[1 mark]**

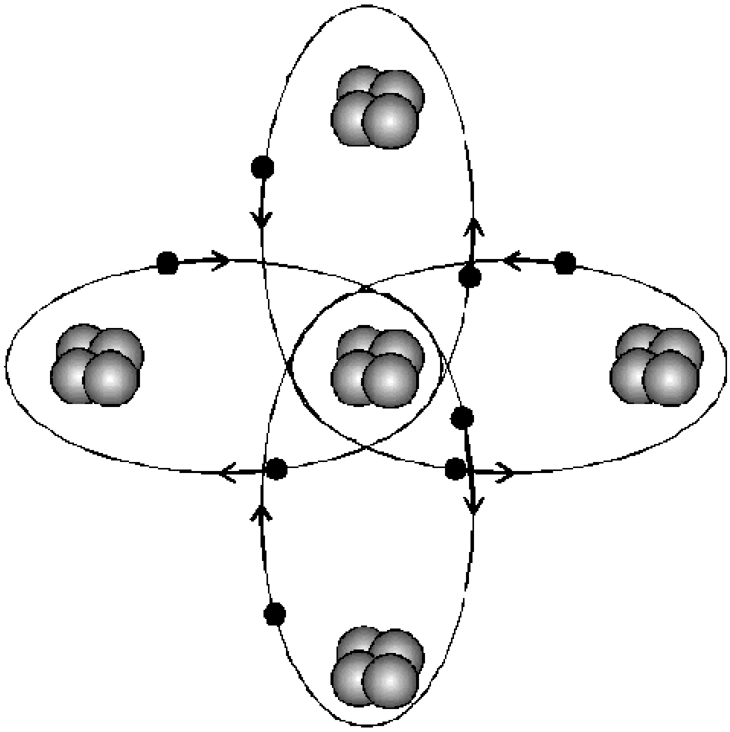
Answer. An intrinsic crystal has no impurities.

Q24) Sketch the energy diagrams for conductors, insulators and semiconductors. **[2 marks]**



Q25) Define *covalent bonds* in a silicon crystal. **[1 mark]**

Answer. Each silicon atom positions itself with four adjacent atoms to form a crystal. Each of the four valance electrons are then shared between the four respective adjacent atoms. A pair of valance electrons, shared between two adjacent atoms is called a covalent bond.



Q26) Which of the following statements is true? **[1 mark]**

a. At 0 Kelvin the intrinsic silicon crystal behaves as an ideal conductor.
b. At 0 Kelvin the intrinsic silicon crystal behaves as an ideal insulator.
c. The temperature does not affect the conductivity of the intrinsic silicon crystal.
d. None of the above.

Q27) Where are the free electrons located? **[1 mark]**

a. In the valance band.
b. In the conduction band.
c. In the band closest to the nucleus.
d. They are free. It is impossible to tell.

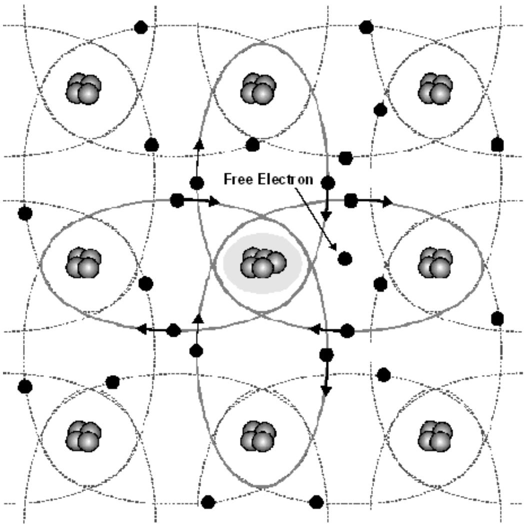
Q28) What is a *hole*? **[1 mark]**

When a valance electron jumps to the conduction band, it leaves behind a vacancy, which is called a hole.

Q29) What does the process of *doping* involve? **[1 mark]**

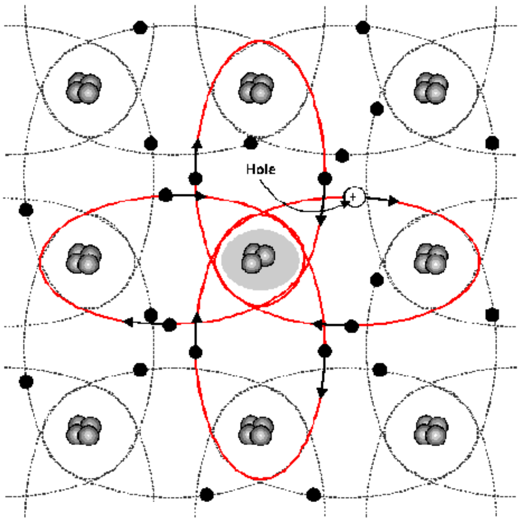
The process of doping involves the controlled addition of impurities into the intrinsic semiconductor crystal. It significantly increases the number of current carriers. As a result, the conductivity of the semiconductors is greatly improved.

Q30) How is an *n-type* semiconductor formed? Sketch a diagram and explain. **[2 marks]**



The intrinsic semiconductor crystal is infused with pentavalent atoms (valance of 5), such as antimony (Sb), arsenic (As), phosphorus (P) or bismuth (Bi). In this case, the doped semiconductor will have an excess of free electrons.

Q31) How is an *p-type* semiconductor formed? Sketch a diagram and explain. **[2 marks]**



The intrinsic semiconductor crystal is infused with trivalent atoms (valance of 3), such as boron (B), indium (In), and gallium (Ga). In this case, the doped semiconductor will have an excess of holes (unfilled spaces, where valance electrons are supposed to be orbiting).

Q32) What is a *p-n junction*? **[1 mark]**

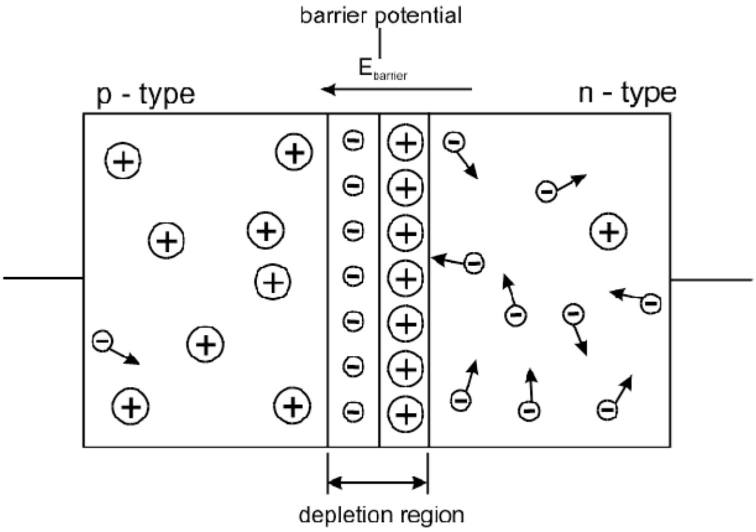
If a piece of intrinsic semiconductor is doped in such a way that one part of it is p-type and the other part is n-type, then a p-n junction is formed on the boundary between the two regions.

Q33) Describe the *depletion region*. **[1 mark]**

At the initial instant when the p-n junction is formed, some electrons from the n-region diffuse across into the p-region and some of the holes of the p-region diffuse across into the n-region. After this initial surge of carriers, equilibrium is reached and no further diffusion is possible. Thus, the region around the p-n junction becomes depleted of charge carriers (electrons and holes) and this is why it is called a depletion region.

Q34) What is *barrier potential*? Sketch a diagram and explain. **[1 mark]**

When electrons and holes diffuse across the p-n junction they create a potential difference across it. This potential difference is called a barrier potential. It is about 0.7 V for silicon and about 0.3 V for germanium at 25ºC. Sketch a diagram.

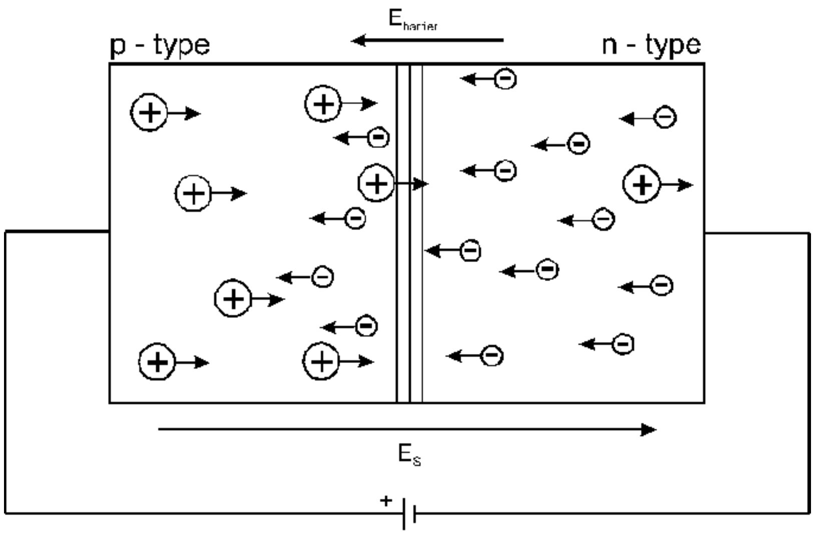


Q35) What is *a diode*? **[1 mark]**

A diode is an electronic device, made from a small piece of semiconductor. One half is doped as p-region and the other half as an n-region. The n-region is called a cathode (K). The p-region is called an anode (A).

Q36) What two conditions have to be satisfied, in order to have a *forward-biased* diode? **[2 marks]**

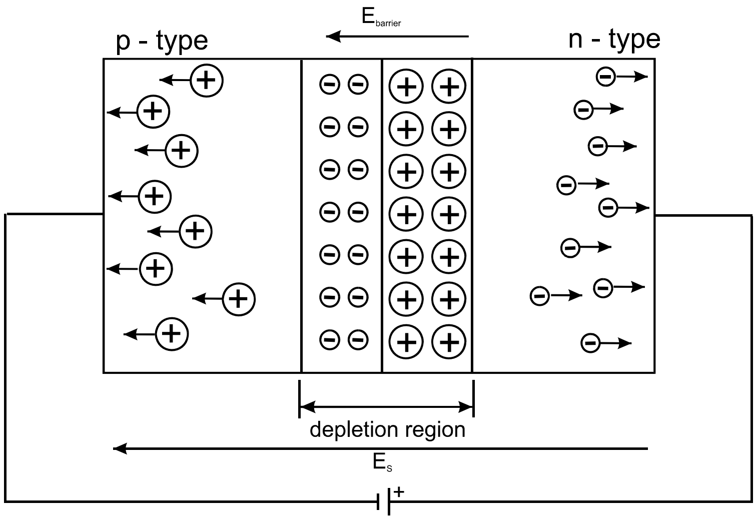
a. The negative terminal of the voltage supply has to be connected to the cathode (the n-region of the junction) and the positive terminal of the voltage supply has to be connected to the anode (the p-region of the junction).
b. The value of the voltage supply has to be greater than the barrier potential (0.7 V for silicon diodes and 0.3 V for germanium diodes).



Q37) What two conditions have to be satisfied, in order to have a *reverse-biased* diode?

[2 marks]

a. The positive terminal of the voltage supply has to be connected to the cathode (the n-region of the junction) and the negative terminal of the voltage supply has to be connected to the anode (the p-region of the junction).
b. The value of the voltage supply has to be less than the breakdown voltage.



Q38) What is *reverse current*? **[1 mark]**

A current with an extremely low value flows through the diode, when it is reverse-biased. This current is called reverse current.

Q39) What is *reverse breakdown voltage*? **[1 mark]**

This is the maximum voltage, which can be applied across the reverse-biased diode. If a greater voltage is applied, the reverse current increases dramatically, which will damage the diode.

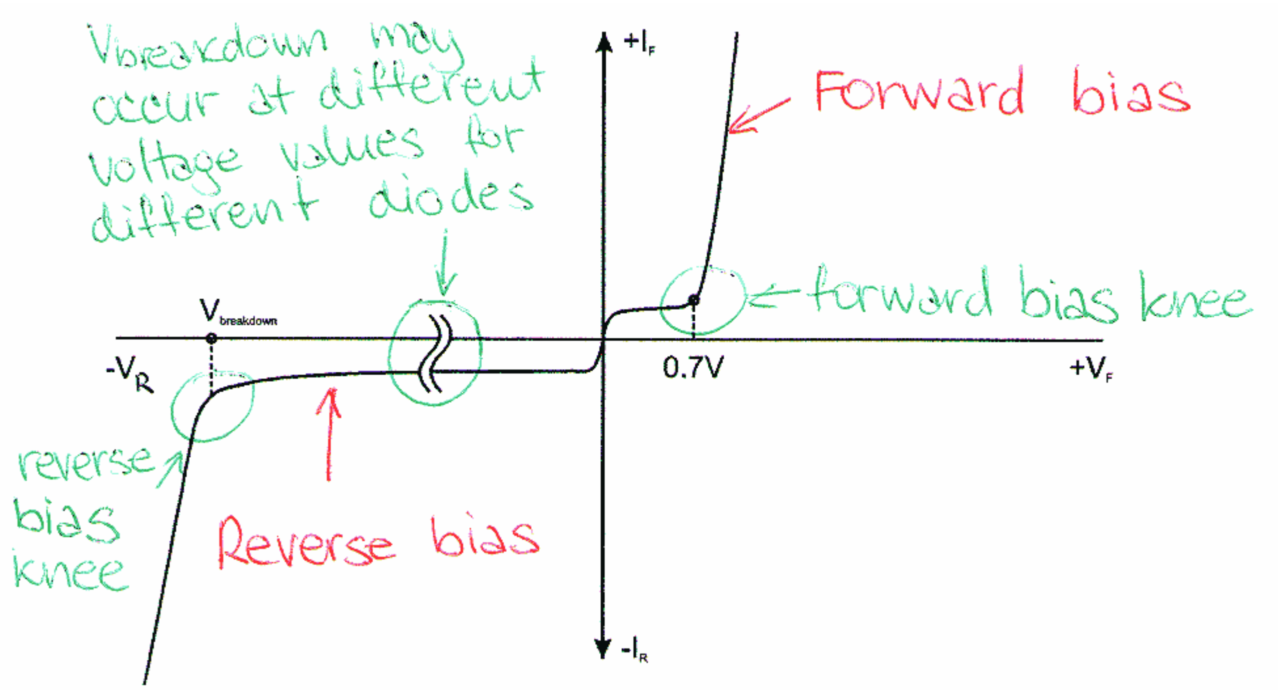
Q40) What is meant by *dynamic resistance* of a diode? **[1 mark]**

The relationship between the current, flowing through a diode and the voltage, applied across it is not linear. Therefore the resistance of the diode changes as we move along the V/A curve. For this reason, it is called dynamic resistance and it is denoted with a lowercase italic *r* with a prime, instead of capital non-italic R. The formula for dynamic resistance is:

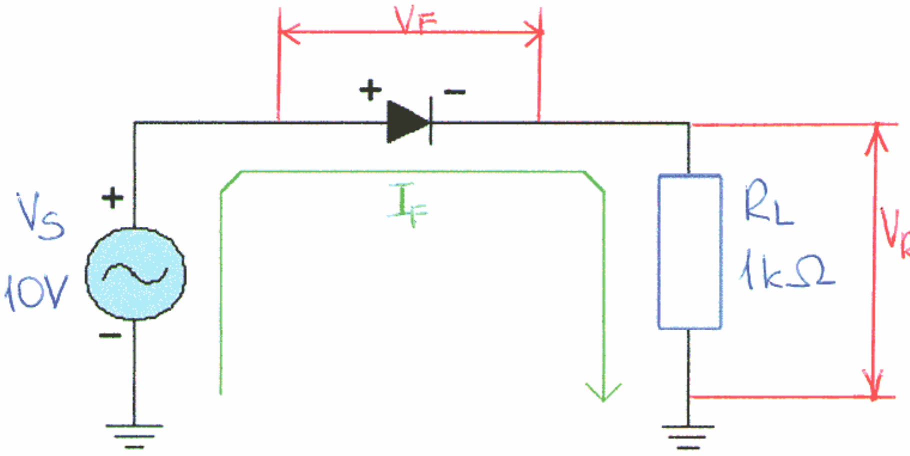
$$r' = \frac{\Delta V_F}{\Delta I_F}$$

Where ΔI_F is a given change of forward current for a given change of forward voltage ΔV_F.

Q41) Draw the voltage-current characteristic of a diode. **[1 mark]**



Q42) Determine the forward current and the voltage drops across the diode and the load resistor in the figure given below, when the diode is conducting. Use the ideal, the practical and the complete diode model. Assume V_S = 10 V, R_L = 1 kΩ and r_d' = 10 Ω. **[3 marks]**



Ideal model:

$V_F = 0V$

$I_F = \frac{V_S}{R_L} = \frac{10}{1 \times 10^3} = 10 mA$

$V_{RL} = I_F R_L = 10 \times 10^{-3} \times 1 \times 10^3 = 10V$

Practical model: $V_F = 0.7V$

$I_F = \frac{V_S - V_F}{R_L} = \frac{10 - 0.7}{1 \times 10^3} = \frac{9.3}{1 \times 10^3} = 9.3 mA$

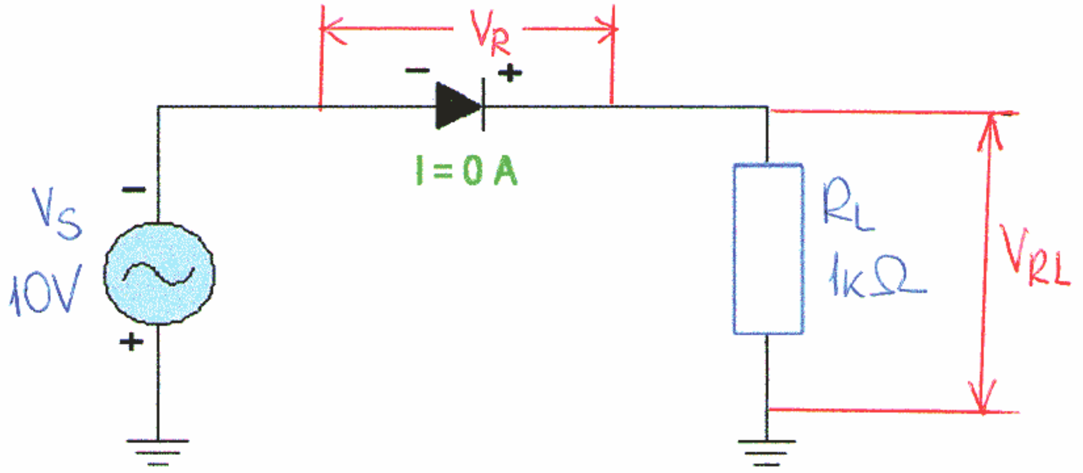
$V_{RL} = I_F . R_L = 9.3 \times 10^{-3} \times 1 \times 10^3 = 9.3V$

Complete model: $I_F = \frac{V_S - 0.7V}{R_L + r_d'} = \frac{10 - 0.7}{1000 + 10} = \frac{9.3}{1010} = 9.21 mA$

$V_F = 0.7V + I_F r_d' = 0.7V + 9.21 \times 10^{-3} \times 10 = 792.1 mV$

$V_{RL} = I_F R_L = 9.21 \times \cancel{10^{-3}} \times 1 \times \cancel{10^3} = 9.21 V$

Q43) Determine the reverse current and the voltage drops across the diode and the load resistor in the figure given below, when the diode is NOT conducting. Use the ideal, the practical and the complete diode model. Assume $V_S = 10$ V, $R_L = 1$ kΩ and $I_R = 1\mu$A. **[3 marks]**



Ideal Model:

$I_R = 0A$

$V_R = V_S = 10V$

$V_{RL} = 0V$

Practical Model:

$I_R = 0A$, $V_R = V_S = 10V$, $V_{RL} = 0V$

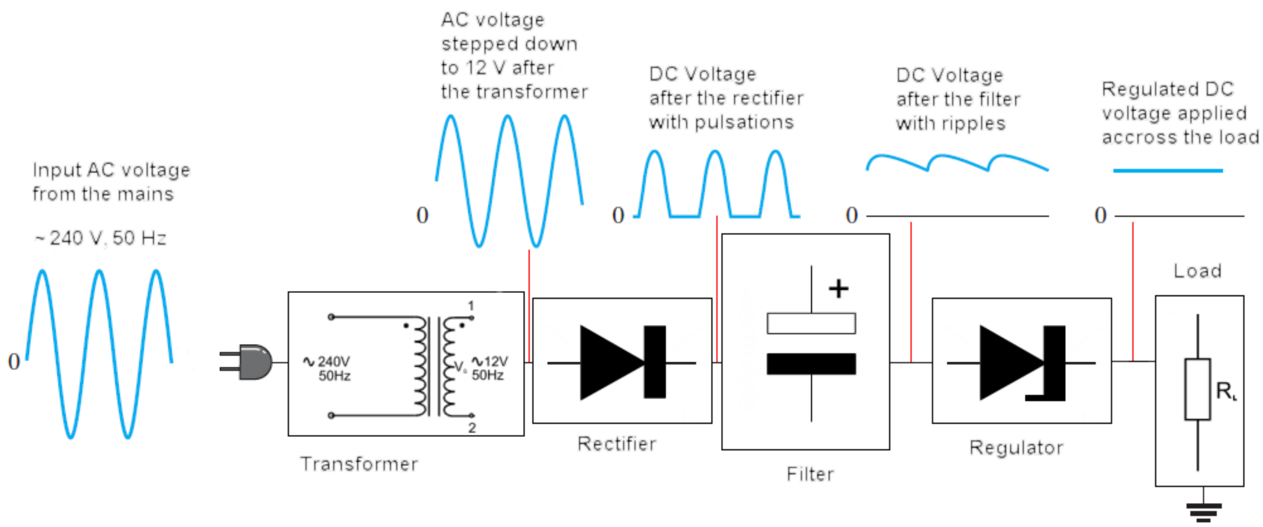
Complete model:

$I_R = 1\mu A$

$V_{RL} = 1 \times \cancel{10^{-6}}^{-3} \times 1 \times \cancel{10^{3}} = 1mV$

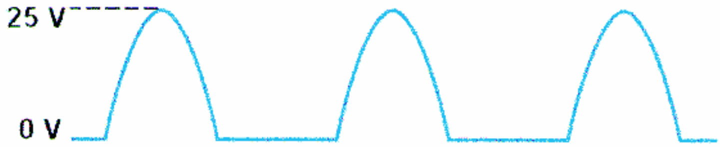
$V_R = V_S - V_{RL} = 10 - 0.001 = 9.999V$

Q44) Draw a complete block diagram of a power supply, clearly indicating the functions of each block and the anticipated output after each one of them. **[2 marks]**



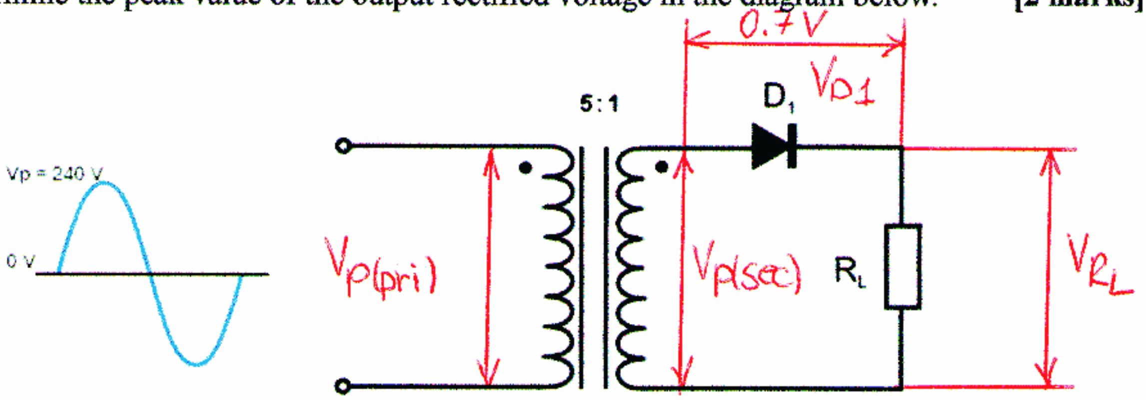
Q45) Determine the average value of the half-wave rectified voltage in the diagram below.

[2 marks]



$$V_{AVG} = \frac{V_P}{\pi} = \frac{25}{\pi} = 7.96V$$

Q46) Determine the peak value of the output rectified voltage in the diagram below. **[2 marks]**



$V_{p(in)} = V_{p(pri)} = 240V$

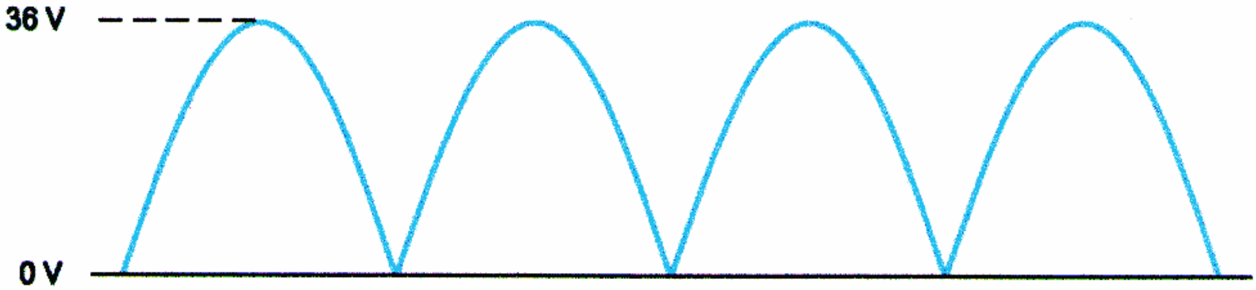
$V_{p(sec)} = V_{p(pri)} / 5 = 240/5 = 48V$

Assuming practical model: $V_{D1} = 0.7V$

$V_{RL} = V_{p(sec)} - 0.7V = 48 - 0.7 = 47.3V$

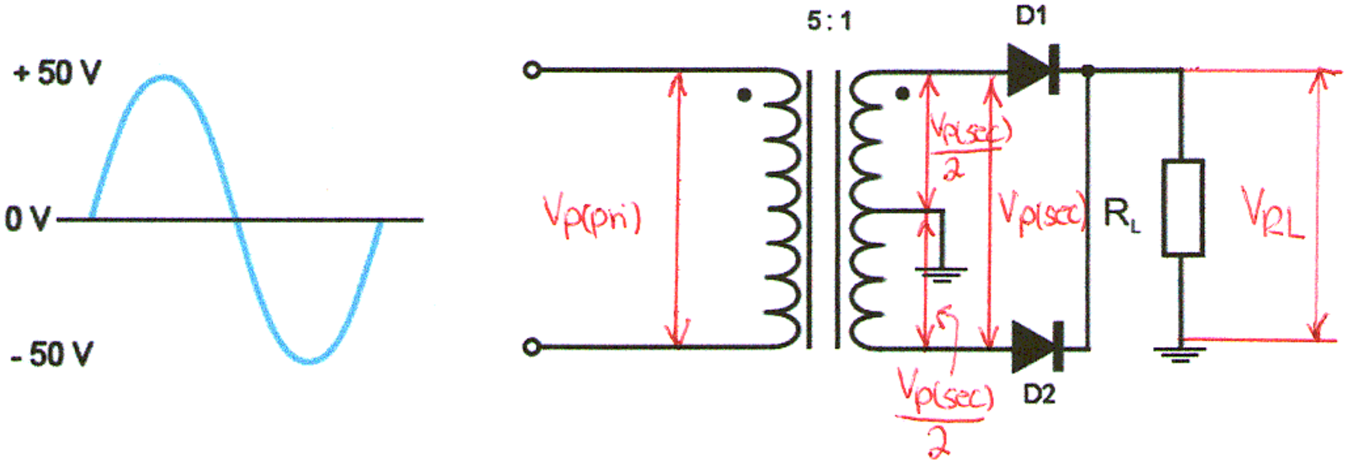
Q47) Determine the average value of the full-wave rectified voltage in the diagram below.

[2 marks]



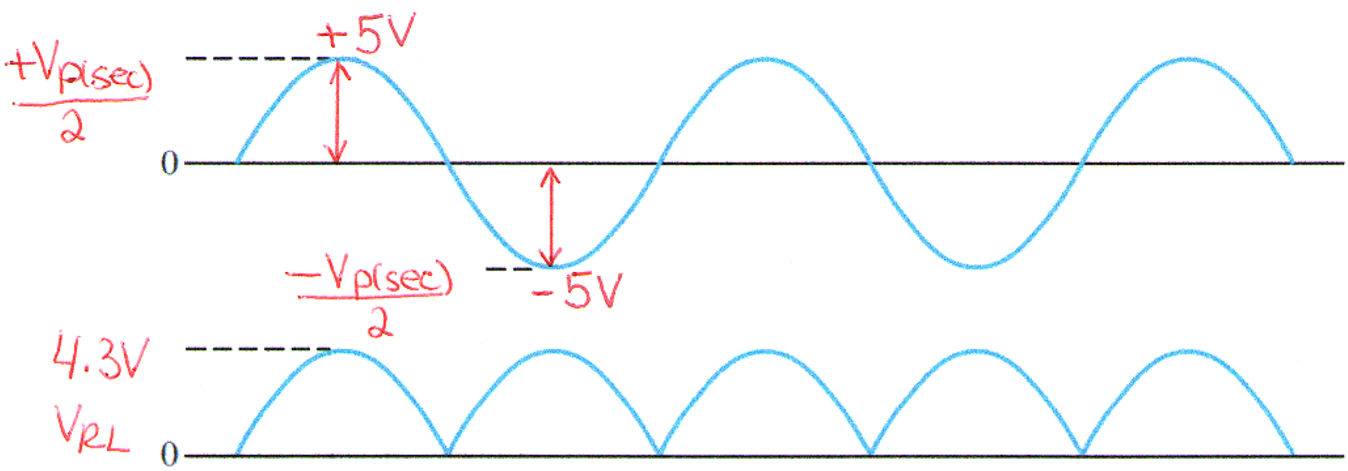
$$V_{AVG} = \frac{2V_P}{\pi} = \frac{2 \times 36}{\pi} = \underline{22.92V}$$

Q48) Show the voltage waveforms across each half of the secondary winding and across R_L when a 50 V peak sine wave is applied to the primary winding. Calculate PIV. **[3 marks]**



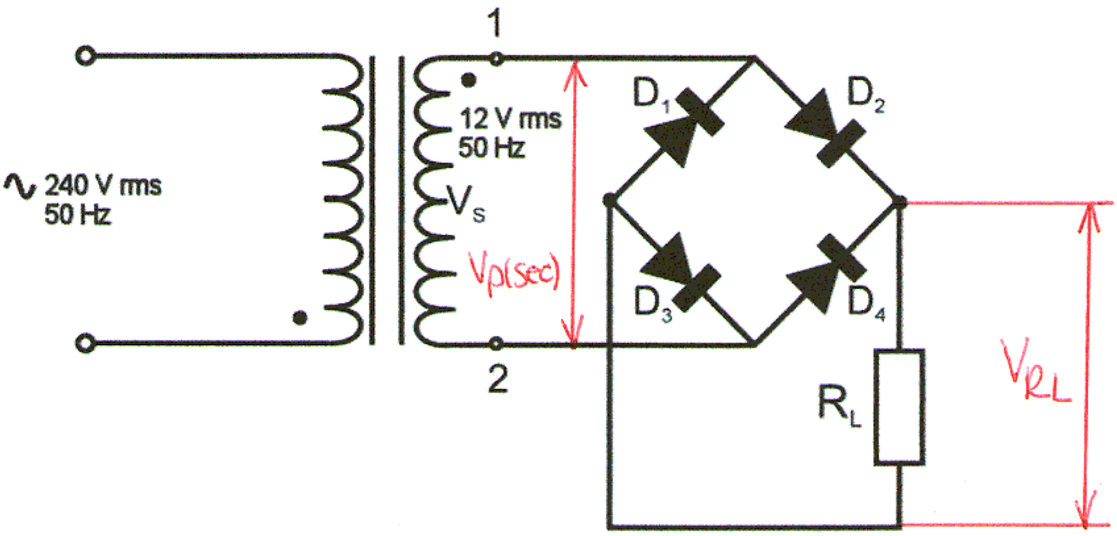
$$V_{p(sec)} = \frac{V_{p(pri)}}{5} = \frac{50}{5} = 10\,V$$

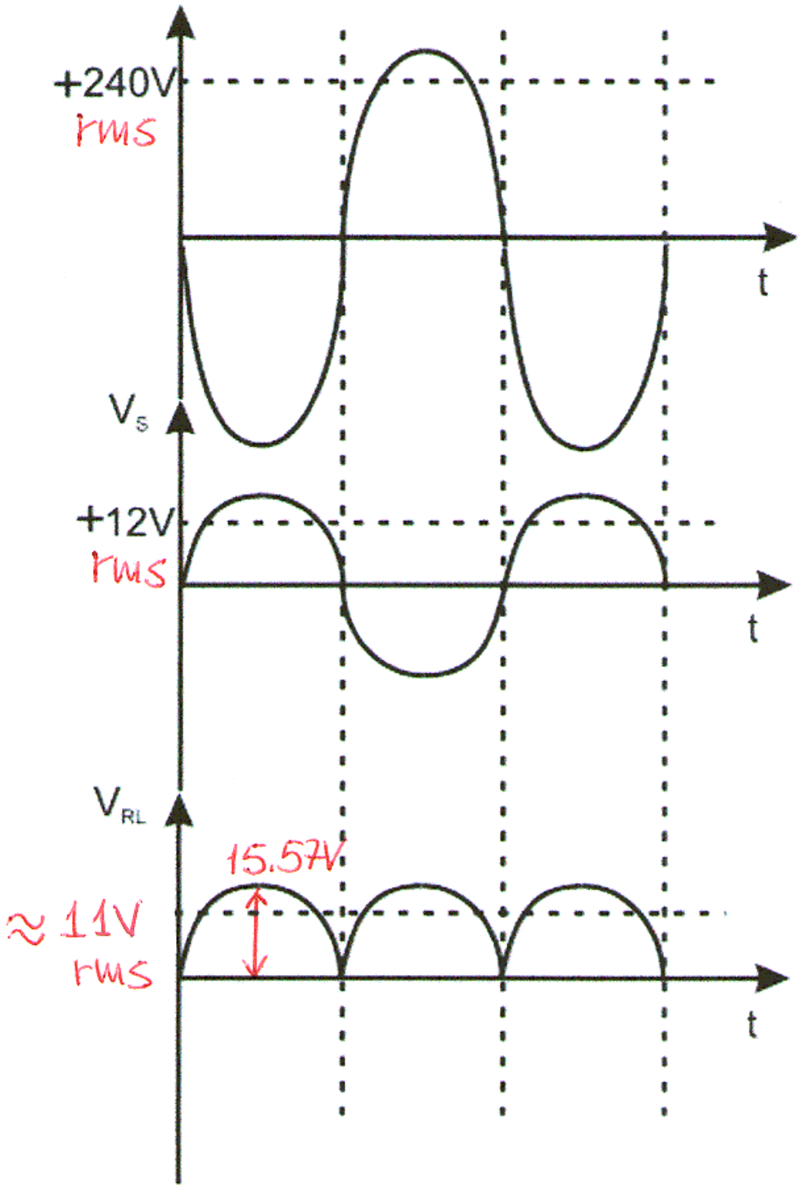
$$V_{RL} = \frac{V_{p(sec)}}{2} - 0.7\,V = \frac{10}{2} - 0.7 = 4.3\,V$$



$$PIV = 2 \times V_{RL} + 0.7\,V = 2 \times 4.3 + 0.7 = 9.3\,V$$

Q49) Determine the peak output voltage for the bridge rectifier given below. Assuming the practical model, what PIV rating is required for the diodes? The transformer is specified to have 12 V rms secondary voltage for the standard 240 V across the primary. **[3 marks]**



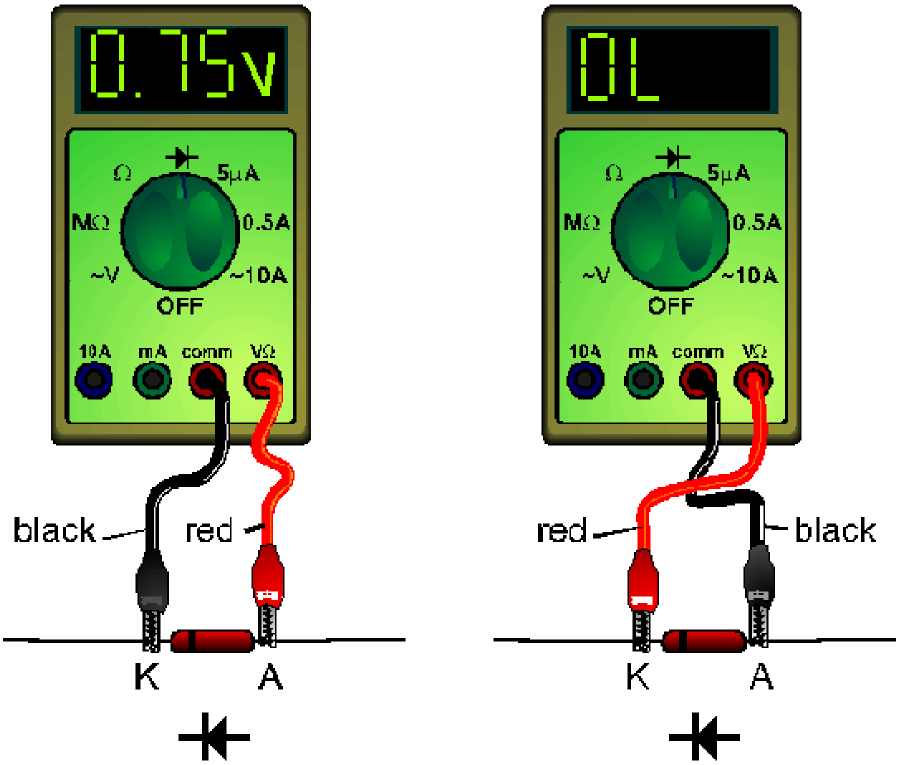


$$V_{p(sec)} = \frac{V_{rms(sec.)}}{0.707} = \frac{12}{0.707} = \underline{16.97\,V}$$

$$V_{RL} = V_{p(sec)} - 1.4V = 16.97 - 1.4 = \underline{15.57\,V}$$

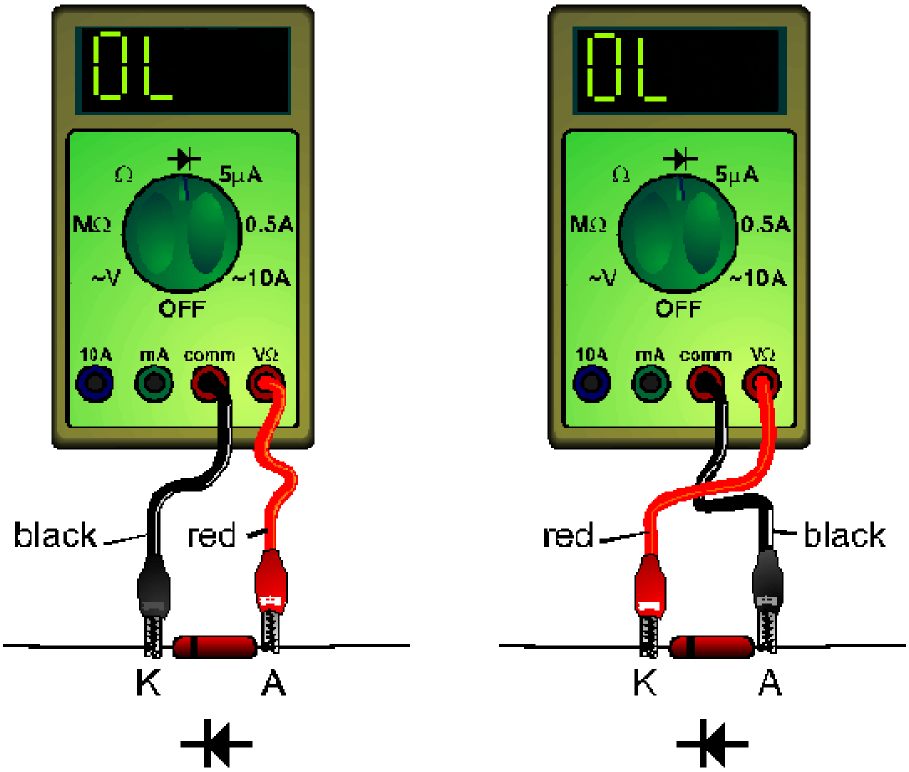
$$PIV = V_{RL} + 0.7V = 15.57 + 0.7 = \underline{16.27\,V}$$

Q50) A properly functioning diode will produce a reading in what range when forward biased and reverse biased? **[1 mark]**



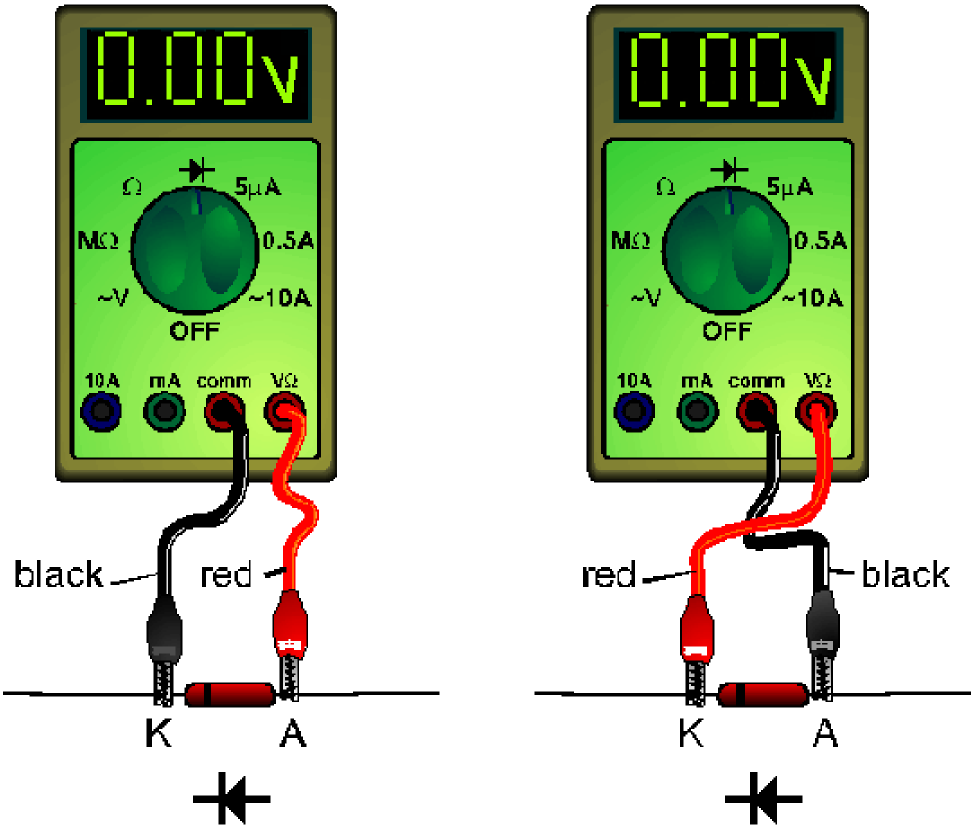
Answer. Most digital multimeters (DMM) have a special 'diode - test' function. In this mode, the DMM provides sufficient internal voltage to forward bias or reverse bias the diode. In a forward bias the readings typically will be in the range from 0.5 V to 0.9 V, with the most common readings being around 0.7 V. In reverse bias, the DMM will most likely show a reading of "OL", which stands for "Open Loop".

Q51) What reading the DMM will produce when a diode has failed open? **[1 mark]**



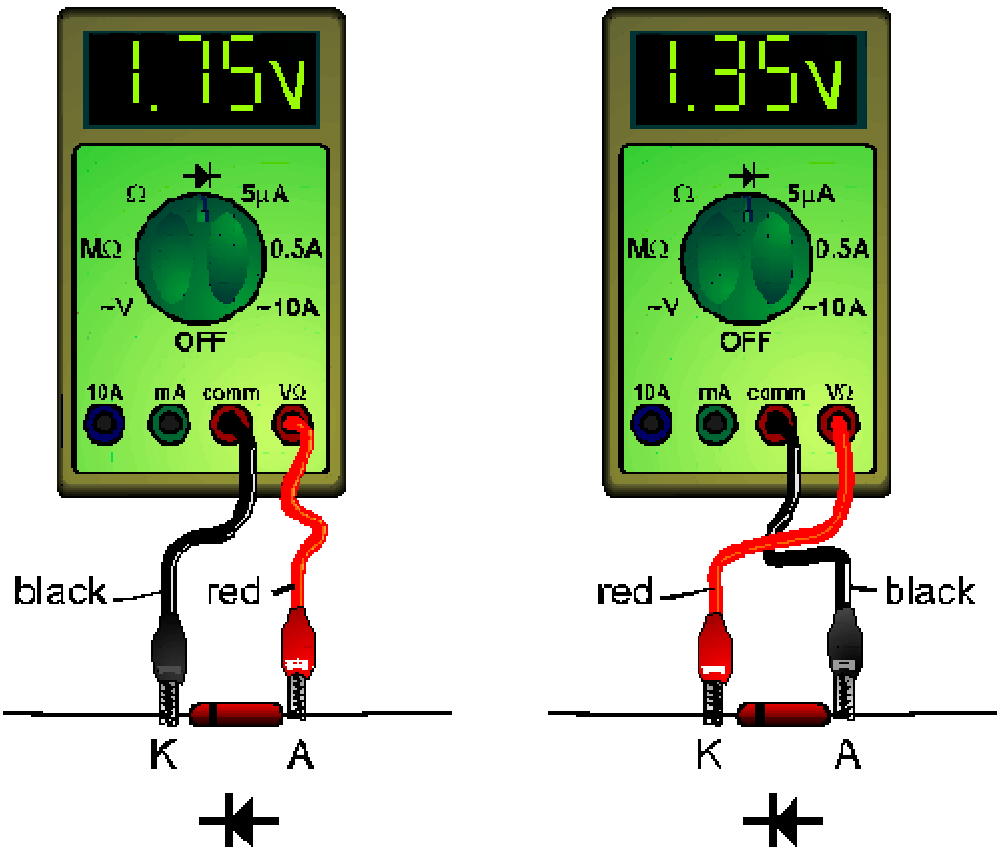
Answer. When the diode has failed open, the DMM will read 'OL' in both directions, as indicated in the illustration.

Q52) What reading will the DMM produce when a diode is shorted? **[1 mark]**



Answer. A defective shorted diode will show about zero volts in both directions.

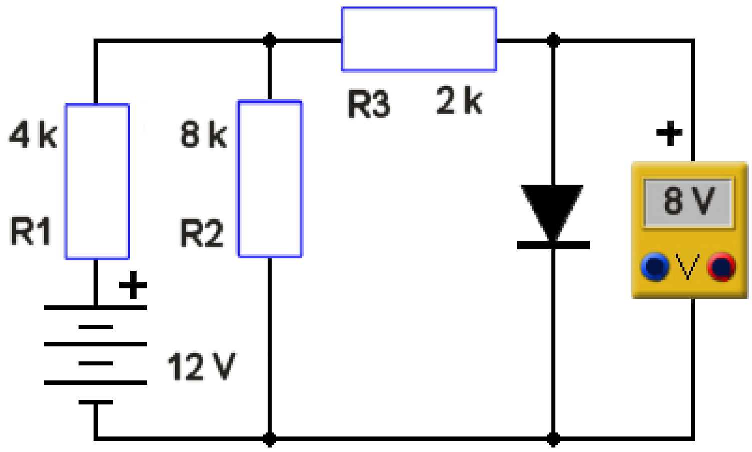
Q53) What reading will the DMM produce when a diode is leaky? **[1 mark]**



Answer. These conditions are difficult to troubleshoot, as the readings vary greatly. However, if the diode is leaky, it will show some unusual voltages, most likely in both directions.

Q54) Consider the meter indications in the circuit and determine whether the diode is functioning properly. If not, state what is the most likely failure (shorted, open or leaky diode). Briefly describe the logical path you have followed, in order to arrive at your conclusion. Assume the ideal model.

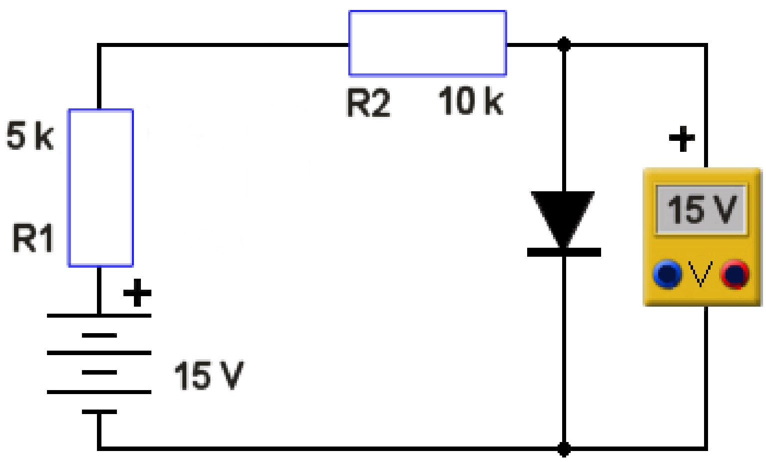
[2 marks]



Answer. The diode is forward biased, therefore it should be conducting. Thus, the normal voltage across it should be zero. But since it isn't, the diode is faulty. The diode is open, because the voltmeter actually measures the voltage across R_2. The only current in this circuit is the current flowing through the voltage divider R_1/R_2. The ratio of the resistors shows that the voltage across R_2 in this case is 8 V.

Q55) Consider the meter indications in the circuit and determine whether the diode is functioning properly. If not, state what is the most likely failure (shorted, open or leaky diode). Briefly describe the logical path you have followed, in order to arrive at your conclusion. Assume the ideal model.

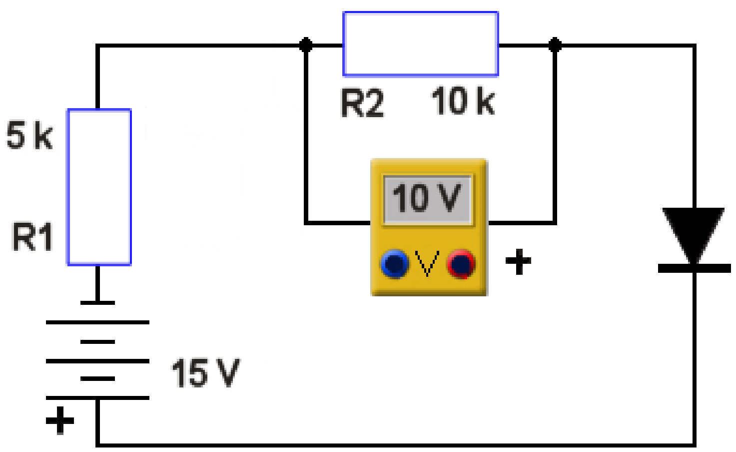
[2 marks]



Answer. The diode is forward biased, therefore it should be conducting. Thus, the normal voltage across it should be zero. Therefore, the diode is faulty. The diode is open, because it measures the voltage across the power supply in a series open circuit.

Q56) Consider the meter indications in the circuit and determine whether the diode is functioning properly. If not, state what is the most likely failure (shorted, open or leaky diode). Briefly describe the logical path you have followed, in order to arrive at your conclusion. Assume the ideal model.

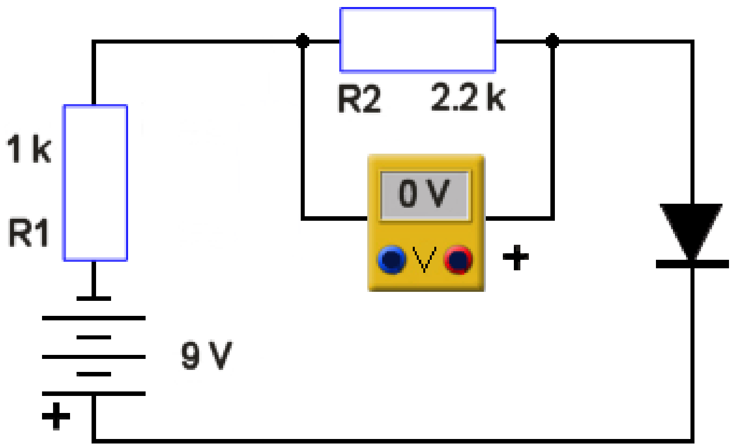
[2 marks]



Answer. The diode is reverse biased; therefore all 15 V from the power supply should drop across it. The voltage across each resistor in the voltage divider should be zero. However, since two thirds of the supply voltage drops across the 10 kΩ resistor (following exactly the resistor's ratio), this is an indicator that the diode is conducting, i.e the diode is shorted.

Q57) Consider the meter indications in the circuit and determine whether the diode is functioning properly. If not, state what is the most likely failure (shorted, open or leaky diode). Briefly describe the logical path you have followed, in order to arrive at your conclusion. Assume the ideal model.

[2 marks]

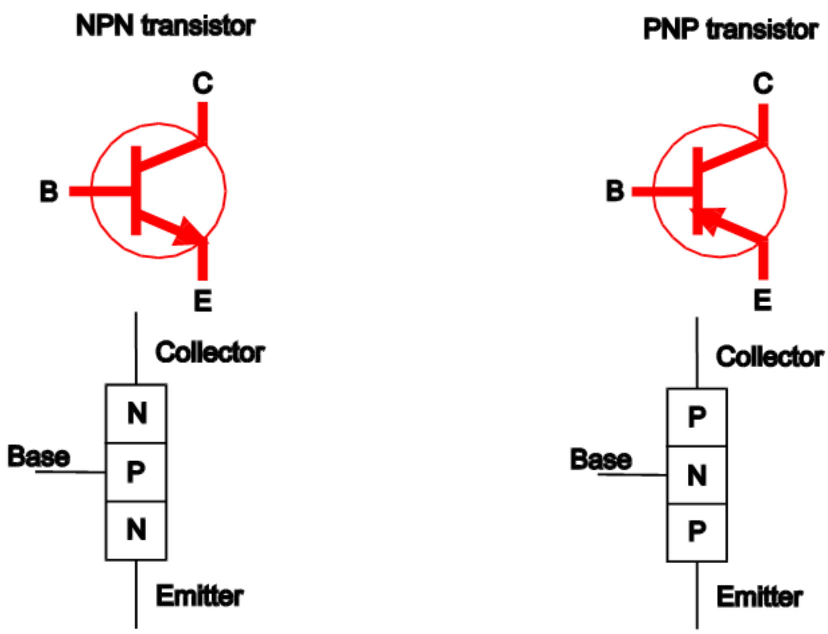


Answer. The diode is reverse biased; therefore all 9 V from the power supply should drop across it. The voltage drop across the resistor should be zero, which is the case; therefore, the diode is functioning properly.

Q58) Describe the construction and depict the symbol of an NPN type transistor. **[1 mark]**

The answer is given in the next question.

Q59) Describe the construction and depict the symbol of an PNP type transistor. **[1 mark]**

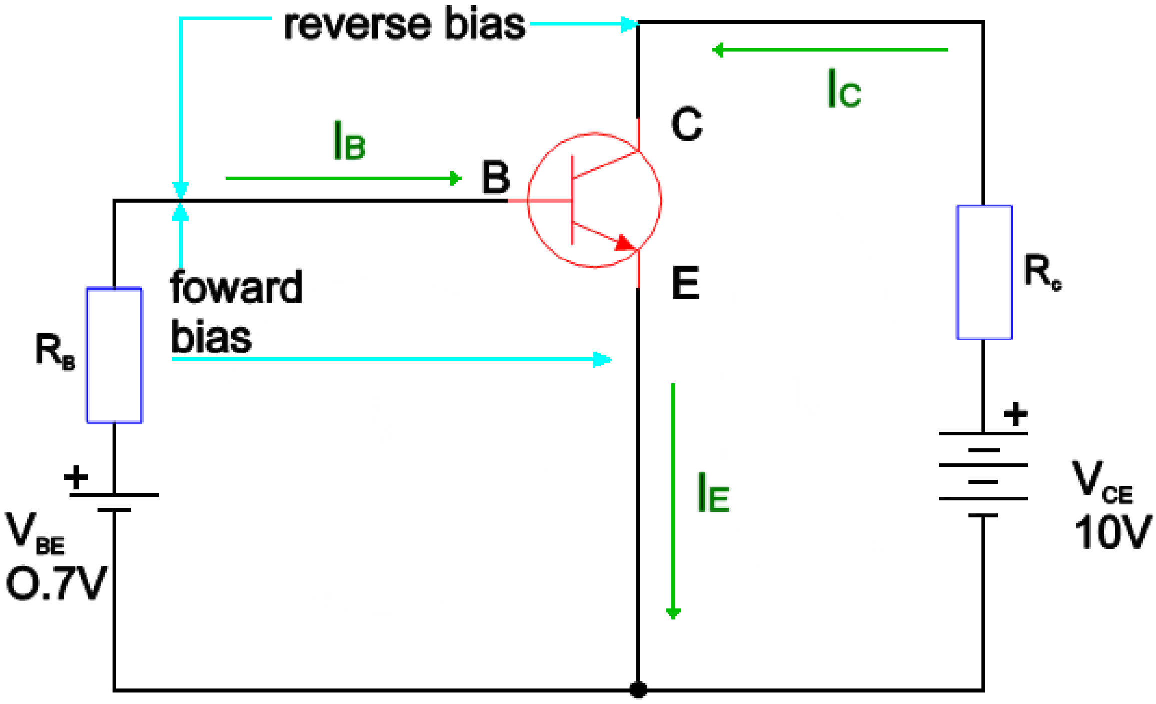


Answer for both questions 58 and 59. Bipolar junction transistors (BJT) are constructed from three doped semiconductor regions, separated by two p-n junctions. Two types exist: NPN and PNP. The three regions are called emitter (E), base (B) and collector (C). The respective diagrams are given in the diagram above.

Q60) Describe the two modes of operation of a transistor. **[2 marks]**

a. **Switch.** In this mode, the current through the transistor is either flowing at its maximum, or it is not flowing at all. A small input current controls the large output current.
b. **Amplifier.** In this mode, small changes in the amount of the input current result in large changes in the amount of the output current. The shape of the output current is the same as the shape of the input current, but the amplitude of the output current is larger.

Q61) Sketch a diagram, depicting a transistor as an amplifier. **[2 marks]**



Q62) Determine the DC current gain β_{DC} and the emitter current I_E for a transistor, where I_B is 50 μA and I_C is 5 mA. **[2 marks]**

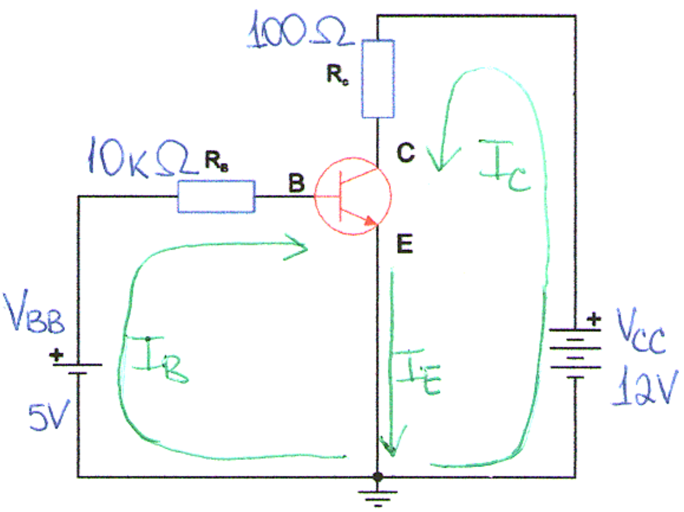
$$\beta_{DC} = \frac{I_C}{I_B} = \frac{5\times10^{-3}}{50\times10^{-6}} = \underline{100}$$

$$I_E = I_C + I_B = 5\times10^{-3} + 0.05\times10^{-3} = \underline{5.05\,mA}$$

Q63) A certain transistor is to be operated with V_{CE} = 6V. If its maximum power rating is 300 mW, what is the most collector current that it can handle? **[2 marks]**

$$I_C = \frac{P_{D(max)}}{V_{CE}} = \frac{300\times10^{-3}}{6} = \underline{50\,mA}$$

Q64) Determine I_B, I_C, I_E, V_{BE}, V_{CE} and V_{CB} in the circuit below. The transistor has a $\beta_{DC} = 150$ **[3 marks]**



$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5 - 0.7}{10 \times 10^3} = 430\mu A$$

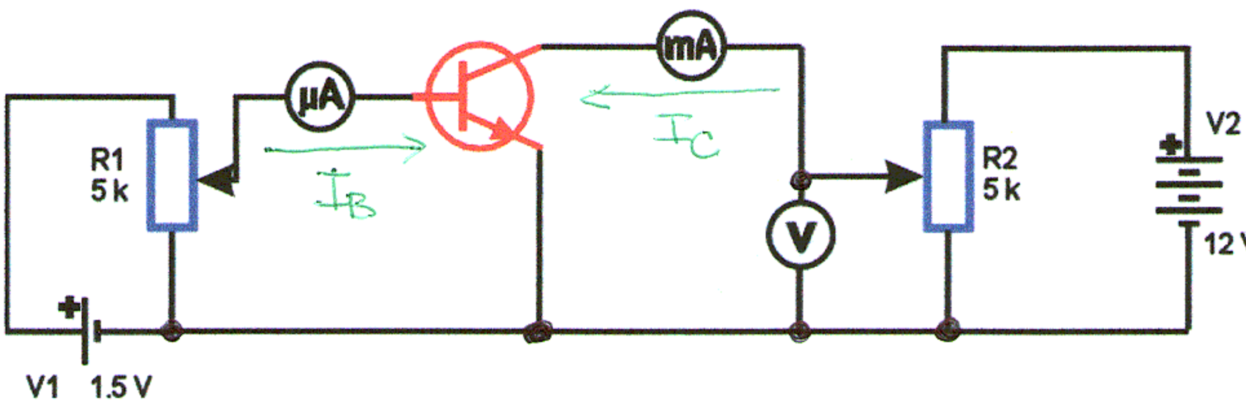
$$I_C = \beta_{DC} \times I_B = 150 \times 430 \times 10^{-6} = 64.5mA$$

$$I_E = I_C + I_B = 64.5 \times 10^{-3} + 0.43 \times 10^{-3} = 64.93mA$$

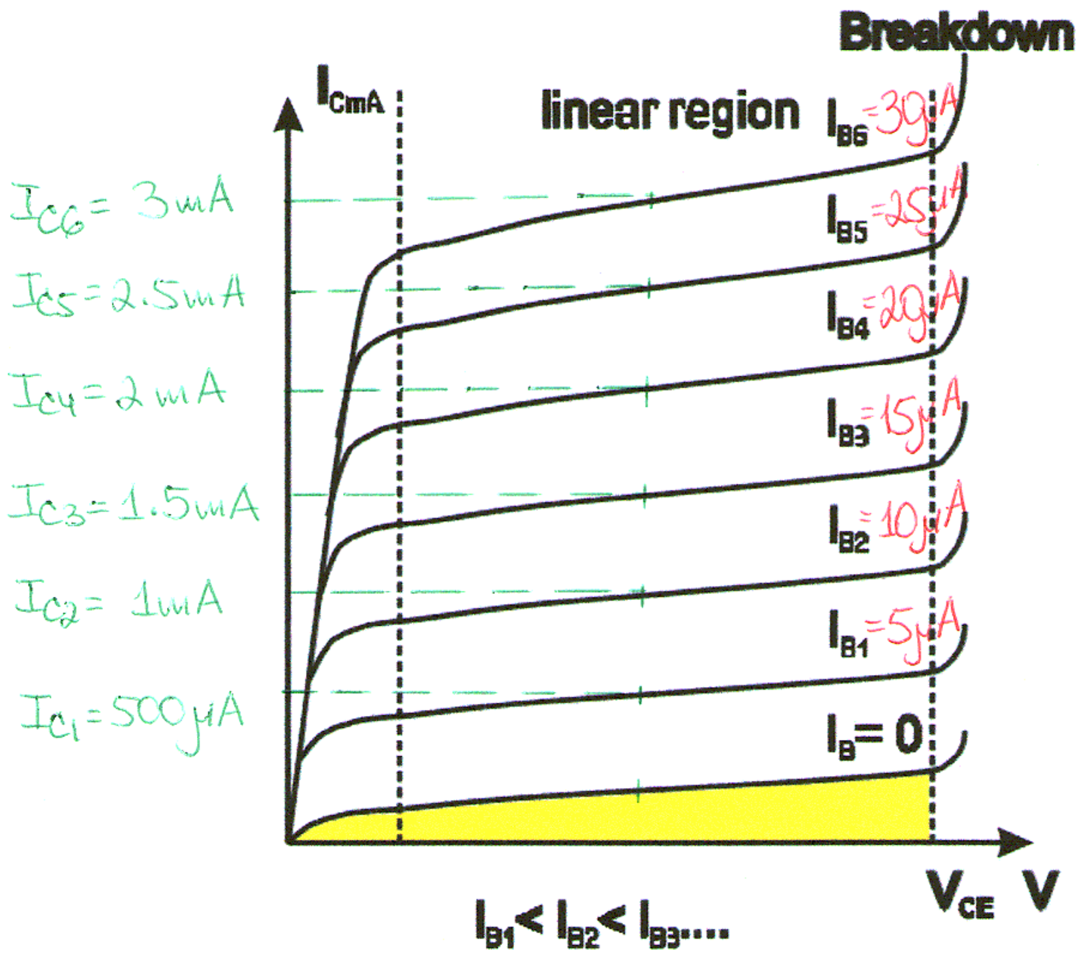
$$V_{CE} = V_{CC} - I_C R_C = 12 - 64.93 \times 10^{-3} \times 100 = 5.51V$$

$$V_{CB} = V_{CE} - V_{BE} = 5.51 - 0.7 = \underline{4.81V}$$

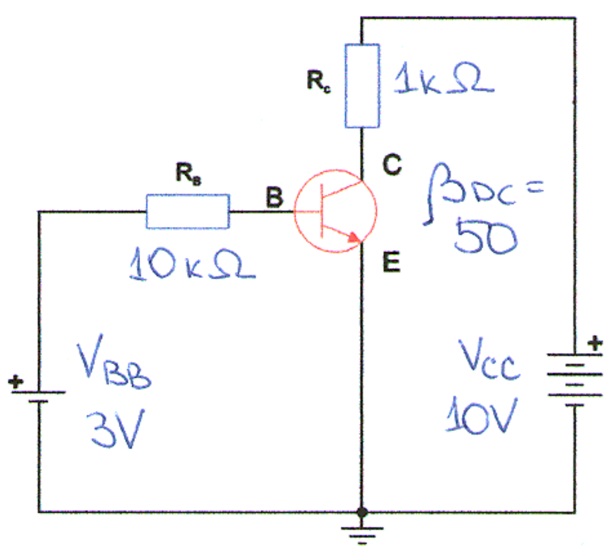
Q65) Sketch an ideal family of collector curves for the circuit given below for I_B = 5 μA to 30 μA in 5 μA increments. Assume $\beta_{DC} = 100$ and that V_{CE} does not exceed breakdown. **[3 marks]**



Answer. I_C (5μA) = $\beta_{DC} \times I_B$ = 100 x 5 x 10^{-6} = 500 μA
I_C (10μA) = $\beta_{DC} \times I_B$ = 100 x 10 x 10^{-6} = 1.0 mA
I_C (15μA) = $\beta_{DC} \times I_B$ = 100 x 15 x 10^{-6} = 1.5 mA
I_C (20μA) = $\beta_{DC} \times I_B$ = 100 x 20 x 10^{-6} = 2.0 mA
I_C (25μA) = $\beta_{DC} \times I_B$ = 100 x 25 x 10^{-6} = 2.5 mA
I_C (30μA) = $\beta_{DC} \times I_B$ = 100 x 30 x 10^{-6} = 3.0 mA



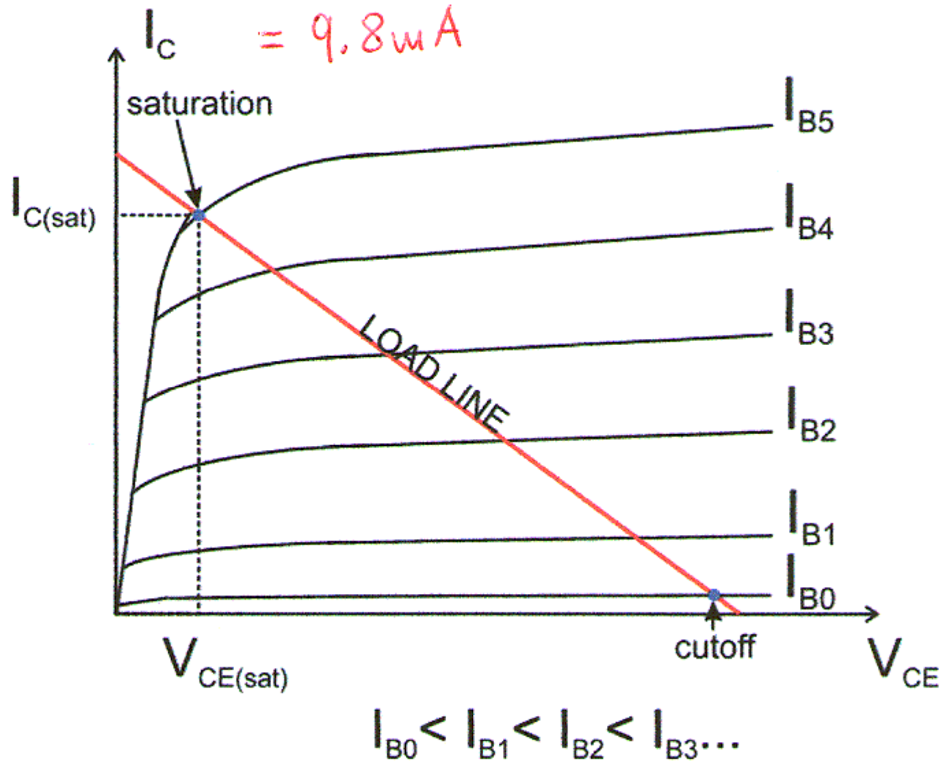
Q66) Determine whether or not the transistor given in the figure below is in saturation. Assume $V_{CE(sat)} = 0.2$ V. **[3 marks]**



$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C} = \frac{10 - 0.2}{1000} = \underline{9.8\,mA}$$

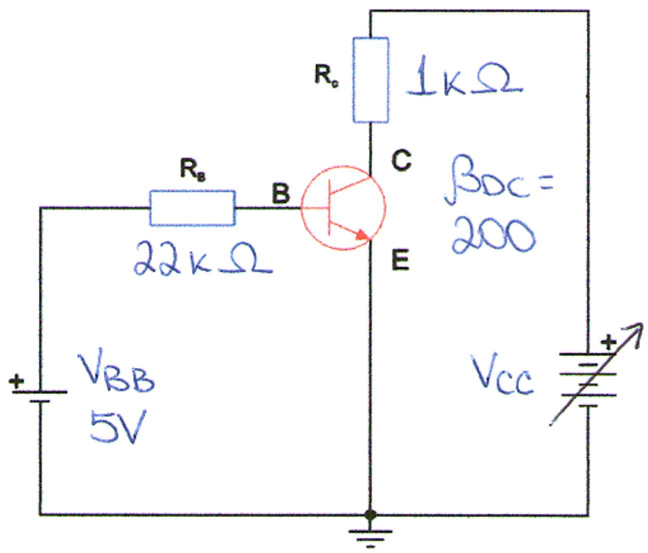
$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{3 - 0.7}{10 \times 10^3} = 0.23\,mA = \underline{230\,\mu A}$$

$$I_C = \beta_{DC} I_B = 50 \times 230 \times 10^{-6} = \underline{11.5\,mA}$$



This shows that with the specified β_{DC}, this base current is capable of producing a collector current, greater than $I_{C(sat)}$. Therefore, *the transistor is saturated*, and the collector current value of 11.5 mA is never reached. Further increase of the base current does not produce any further increase of the collector current and it remains at its saturated value of 9.8 mA.

Q67) The transistor, given in the figure has the following maximum ratings: $P_{D(max)}$ = 700 mW, $V_{CE(max)}$ = 15 V, and $I_{C(max)}$ = 100 mA. Determine the maximum value to which V_{CC} can be adjusted without exceeding the rating. Which rating would be exceeded first? **[3 marks]**



Solution. First we have to find I_B. This will allow us to determine I_C.

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5 - 0.7}{22 \times 10^3} =$$

$$= 195.45\,\mu A$$

$$I_C = \beta_{DC} I_B =$$

$$= 200 \times 195.45 \times 10^{-6} =$$

$$= 39.09\,mA$$

The obtained value for I_C is much less than its specified maximum value. It is unlikely that it will dramatically change with the change of V_{CC}, as it almost exclusively depends on I_B and β_{DC} only.

$$V_{RC} = I_C R_C = 39.09 \times 10^{-3} \times 1 \times 10^{3} = 39.09\text{ V}$$

Now we can determine the value of V_{CC}, when $V_{CE} = V_{CE(max)} = 15\text{ V}$.

$$V_{RC} = V_{CC} - V_{CE}$$

$$V_{CC(max)} = V_{RC(max)} + V_{CE(max)} = 39.09 + 15 = \underline{54.09\text{ V}}$$

Therefore, under the existing conditions, V_{CC} can be increased to 54.09 V, before $V_{CE(max)}$ is exceeded. However, at this point it is unknown if $P_{D(max)}$ is exceeded.

$$P_D = V_{CE(max)} I_C = 15 \times 39.09 \times 10^{-3} = \underline{586.35\text{ mW}}$$

Since $P_{D(max)}$ is 700 mW, the maximum power rating of the transistor is not exceeded, when V_{CC} is 54.09 V. However, if the base current is removed, the transistor will be turned off, causing the entire supply voltage V_{CC} to drop across it. If this happens, $V_{CE(max)}$ will be exceeded first, as this rating is specified as 15 V only.

Q68) In the circuit, given in the previous question 67, assume that the transistor 2N3904 is used. Your task is to obtain the datasheet for this transistor and to determine the maximum value to which V_{CC} can be adjusted without exceeding the rating. Which rating would be exceeded first?

[3 marks]

It is sufficient to type the name of the transistor in 'Google' plus the keyword 'datasheet' in order to obtain many similar datasheets, produced by different companies. Although the layout of the datasheet may vary from manufacturer to manufacturer, the characteristics of the actual transistor should be the same. In this case, I am including here just the first two pages of the datasheet, produced by STMicroelectronics. For more information go to http://www.st.com.

From the datasheet we obtain the following data:

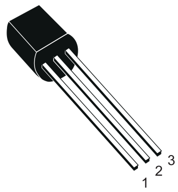
$P_{D(max)} = P_D = 625$ mA
$V_{CE(max)} = V_{CEO} = 40$ V
$I_{C(max)} = 200$ mA
$h_{FE} = \beta_{DC} =$ from 100 to 300

(The last parameter varies greatly from transistor to transistor; therefore we will assume that we have measured it with a DMM and that we have obtained a value of 200)

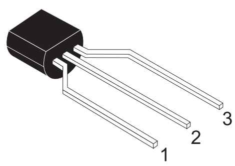
SMALL SIGNAL NPN TRANSISTOR

PRELIMINARY DATA

Ordering Code	Marking	Package / Shipment
2N3904	2N3904	TO-92 / Bulk
2N3904-AP	2N3904	TO-92 / Ammopack



TO-92
Bulk



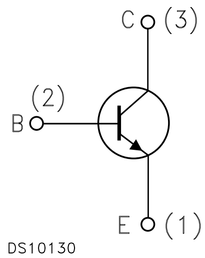
TO-92
Ammopack

- SILICON EPITAXIAL PLANAR NPN TRANSISTOR
- TO-92 PACKAGE SUITABLE FOR THROUGH-HOLE PCB ASSEMBLY
- THE PNP COMPLEMENTARY TYPE IS 2N3906

APPLICATIONS

- WELL SUITABLE FOR TV AND HOME APPLIANCE EQUIPMENT
- SMALL LOAD SWITCH TRANSISTOR WITH HIGH GAIN AND LOW SATURATION VOLTAGE

INTERNAL SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{CBO}	Collector-Base Voltage (I_E = 0)	60	V
V_{CEO}	Collector-Emitter Voltage (I_B = 0)	40	V
V_{EBO}	Emitter-Base Voltage (I_C = 0)	6	V
I_C	Collector Current	200	mA
P_{tot}	Total Dissipation at T_C = 25 ^oC	625	mW
T_{stg}	Storage Temperature	-65 to 150	^oC
T_j	Max. Operating Junction Temperature	150	^oC

THERMAL DATA

$R_{thj-amb}$ •	Thermal Resistance Junction-Ambient	Max	200	^{o}C/W
$R_{thj-case}$ •	Thermal Resistance Junction-Case	Max	83.3	^{o}C/W

ELECTRICAL CHARACTERISTICS (T_{case} = 25 ^{o}C unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
I_{CEX}	Collector Cut-off Current (V_{BE} = -3 V)	V_{CE} = 30 V			50	nA
I_{BEX}	Base Cut-off Current (V_{BE} = -3 V)	V_{CE} = 30 V			50	nA
$V_{(BR)CEO}$∗	Collector-Emitter Breakdown Voltage (I_B = 0)	I_C = 1 mA	40			V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage (I_E = 0)	I_C = 10 μA	60			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage (I_C = 0)	I_E = 10 μA	6			V
$V_{CE(sat)}$∗	Collector-Emitter Saturation Voltage	I_C = 10 mA I_B = 1 mA I_C = 50 mA I_B = 5 mA			0.2 0.2	V V
$V_{BE(sat)}$∗	Base-Emitter Saturation Voltage	I_C = 10 mA I_B = 1 mA I_C = 50 mA I_B = 5 mA	 0.65		0.85 0.95	V V
h_{FE}∗	DC Current Gain	I_C = 0.1 mA V_{CE} = 1 V I_C = 1 mA V_{CE} = 1 V I_C = 10 mA V_{CE} = 1 V I_C = 50 mA V_{CE} = 1 V I_C = 100 mA V_{CE} = 1 V	60 80 100 60 30		 300 	
f_T	Transition Frequency	I_C = 10 mA V_{CE} = 20 V f = 100 MHz	250	270		MHz
C_{CBO}	Collector-Base Capacitance	I_E = 0 V_{CB} = 10 V f = 1 MHz		4		pF
C_{EBO}	Emitter-Base Capacitance	I_C = 0 V_{EB} = 0.5 V f = 1 MHz		18		pF
NF	Noise Figure	V_{CE} = 5 V I_C = 0.1 mA f = 10 Hz to 15.7 KHz R_G = 1 KΩ		5		dB
t_d t_r	Delay Time Rise Time	I_C = 10 mA I_B = 1 mA V_{CC} = 30 V			35 35	ns ns
t_s t_f	Storage Time Fall Time	I_C = 10 mA I_{B1} = -I_{B2} = 1 mA V_{CC} = 30 V			200 50	ns ns

∗ Pulsed: Pulse duration = 300 μs, duty cycle ≤ 2 %

Therefore, the value of I_C = 39.09 mA and V_{RC} = 39.09 V as previously calculated. I_C is less than the maximum value, specified in the datasheets and ideally it will not change with the increase of V_{CC}. Therefore, the maximum value to which V_{CC} can be increased, before $V_{CC(max)}$ is reached is:

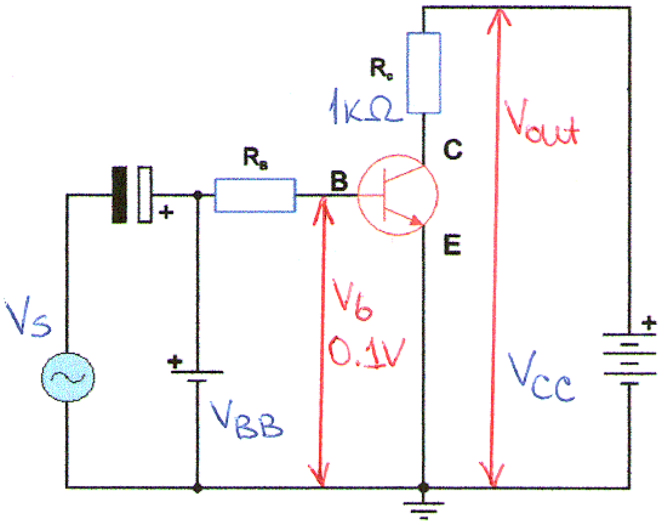
$$V_{CC(max)} = V_{CE(max)} + V_{RC} = 40 + 39.09 = 79.09 \text{ V}$$

We also have to check the maximum power dissipation at the maximum value of V_{CE}, which is:

$$P_D = V_{CE(max)} \times I_C = 40 \times 39.09 \times 10^{-3} = 1.56 \text{ W}$$

This value greatly exceeds the maximum power dissipation for this transistor, which is only 625 mW.

Q69) Determine the voltage gain and the AC output voltage in the figure below if r_e' = 75Ω and V_b = 0.1 V **[2 marks]**



$$A_V \approx \frac{R_C}{r_e'} = \frac{1000}{75} = 13.33$$

$$V_{out} = A_V \times V_b =$$

$$= 13.33 \times 0.1 =$$

$$= 1.33 \text{ V rms}$$

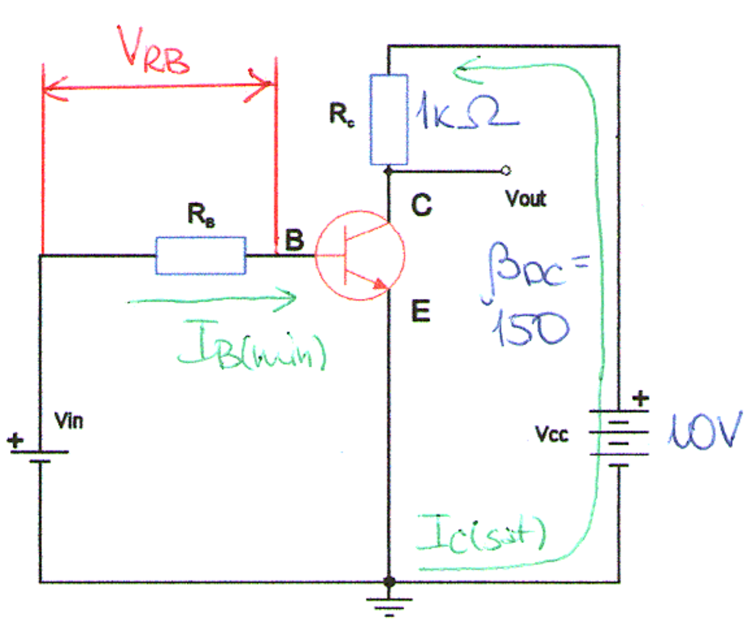
Q70) For the transistor, given in the figure, what is V_{CE} when V_{IN} = 0 V? What minimum value of I_B is required to saturate this transistor if β_{DC} is 150. Assume V_{CC} is 10 V and R_C is 1 kΩ. Neglect $V_{CE(sat)}$. Calculate the maximum value of R_B when V_{IN} = 5 V. **[3 marks]**

When $V_{IN} = 0V$, $V_{CE} = V_{CC} = 10V$.

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{10}{1000} = 10 \text{ mA}$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}} = \frac{10 \times 10^{-3}}{150} = 66.67 \mu A$$

This is the value of I_B necessary to drive the transistor into a point of saturation. Any further increase in I_B will not produce any further increase in I_C.



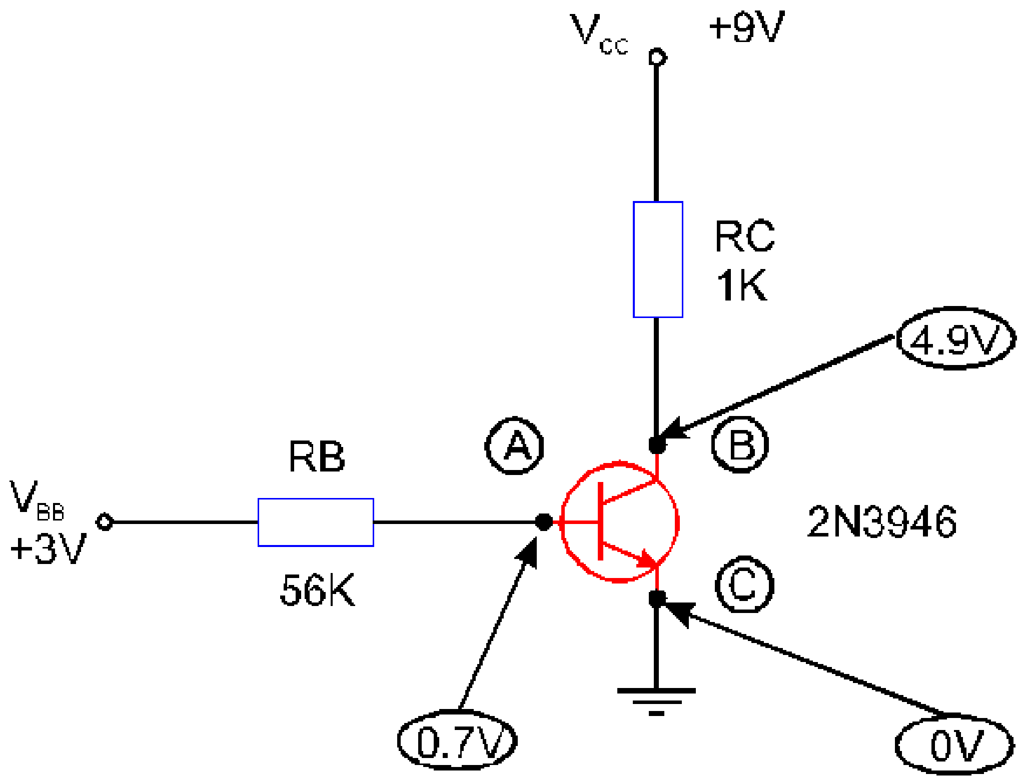
When the transistor is ON, then $V_{BE} \approx 0.7V$.

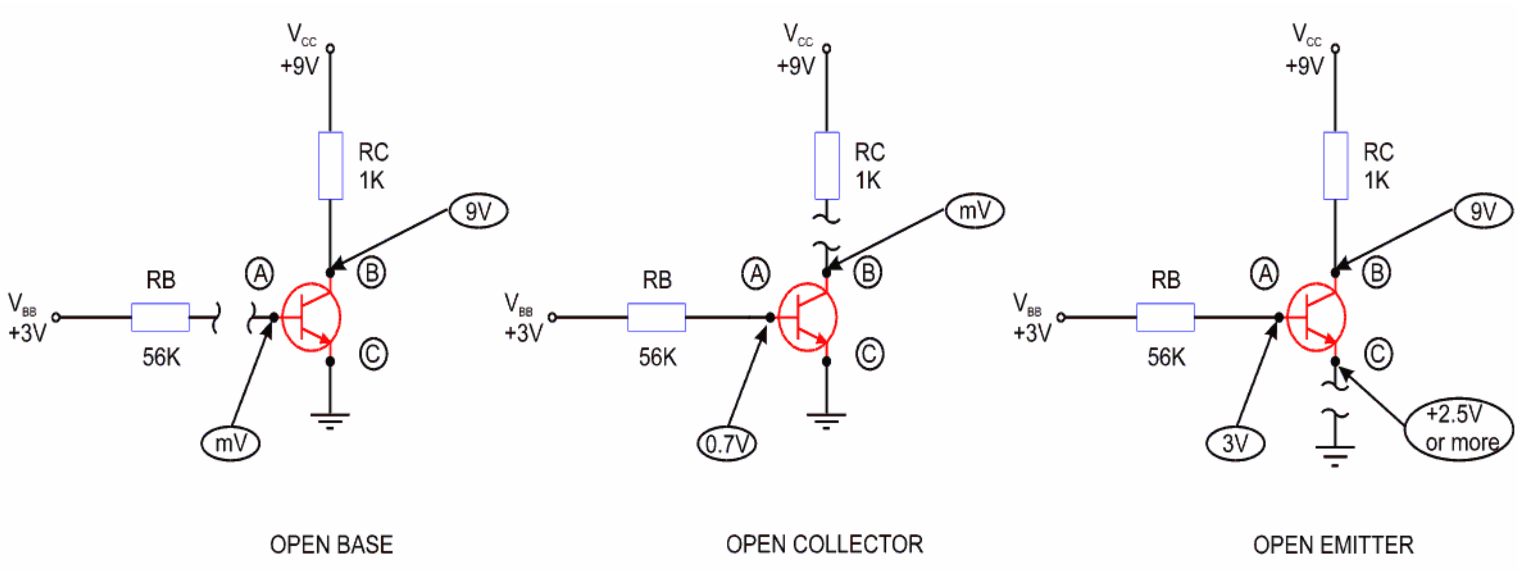
$$V_{RB} = V_{IN} - V_{BE} = 5 - 0.7 = 4.3V$$

$$R_{B(max)} = \frac{V_{RB}}{I_{B(min)}} = \frac{4.3}{66.67 \times 10^{-6}} = 64.5k\Omega$$

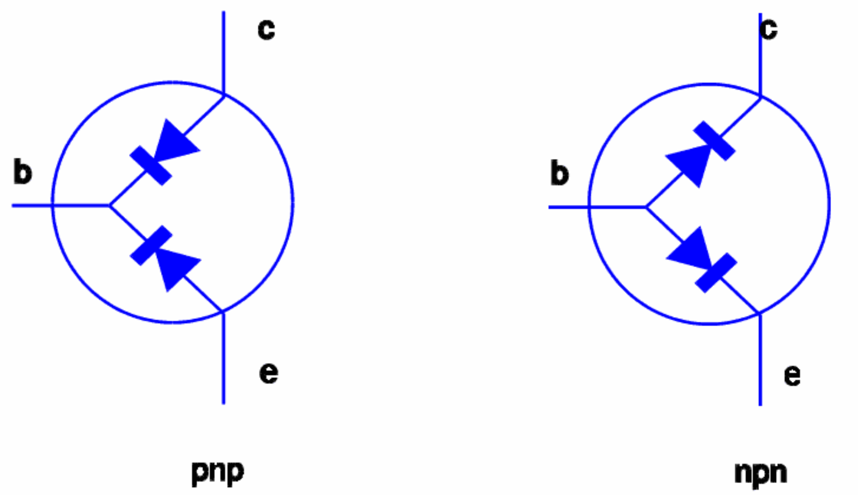
Q71) In the circuit given below the normal operating voltages of the transistor 2N3946 are indicated at points A, B and C in respect to ground. Sketch three diagrams for the three typical transistor faulty conditions: open base, open collector and open emitter and clearly indicate what voltages you anticipate to measure at points A, B and C for each faulty condition.

[3 marks]





Q72) How can a transistor be tested with the DMM's diode test function? Draw the equivalent diagram for PNP and NPN transistors. **[3 marks]**



Answer. Each BJT can be represented as a combination of two diodes, connected together. Both p-n junctions are tested separately as two independent diodes. If both of them show no defects, the transistor is working properly. (For how to test diodes see Q.50 – 53)

NOTE: Only about 20 of the questions solved in this trial test will be given to you on the actual test. The values of the components, power supplies etc. will be changed, but in essence the questions will remain almost identical.

END OF TEST
(Check your work!)