UNIVERSITY OF SWAZILAND

70218 115

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

SUPPLEMENTARY EXAMINATION 2012

TITLE OF PAPER : ELECTRONICS I

COURSE NUMBER : P311

TIME ALLOWED : THREE HOURS

INSTRUCTIONS : ANSWER ANY FOUR OUT OF FIVE QUESTIONS

EACH QUESTION CARRIES 25 MARKS

MARKS FOR DIFFERENT SECTIONS ARE SHOWN IN THE RIGHT-HAND MARGIN.

THIS PAPER HAS 7 PAGES, INCLUDING THIS PAGE.

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QUESTION 1

(a) Consider an n-p-n transistor connected in the common-emitter configuration. Sketch a circuit that you would use to measure the characteristics of the transistor. (2 marks)

(b) Sketch the output characteristics of an n-p-n transistor and show the active, saturation, and cutoff regions. (4 marks)

(c) The element values in the circuit shown in Fig. 1 are $R_1 = 150\,k\Omega$, $R_2 = 37.5\,k\Omega$, $R_C = 2\,k\Omega$ and $R_E = 3\,k\Omega$. The transistor has $h_{FE} = 100$ and negligible reverse saturation current. $V_{BE} = 0.7$ V.

Calculate I_C and V_{CE} when $V_{CC} = 9\,V$. (11 marks)

(d) A C-E amplifier is based on an *n-p-n* silicon transistor with the following parameters:

$h_{ie} = 5k\Omega$, $h_{fe} = 250$, $h_{oe} = 2.0 \times 10^{-4}$ Siemen and $h_{re} = 10^{-5}$.

The collector resistor is $R_C = 2\,k\Omega$.

With the aid of a small signal model of the amplifier,

(i) Derive the exact (rather than approximate) expression of the current gain, A_i of the amplifier (6 marks)

(ii) Calculate the exact value of the current gain. (2 marks)

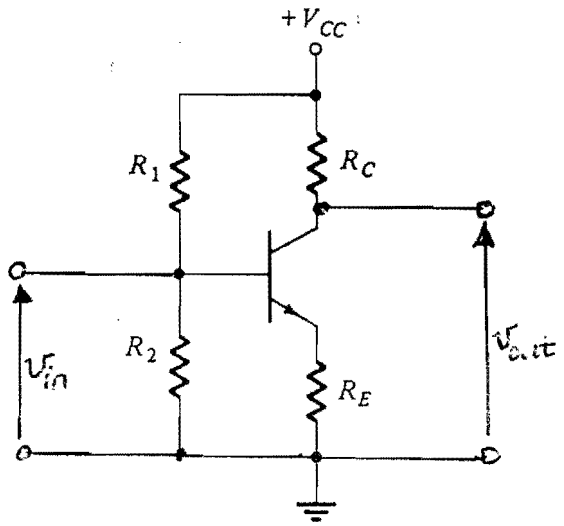

Fig. 1

QUESTION 2

(a) With reference to a junction field effect transistor, define the following terms:
(i) *Mutual conductance* (2 marks)
(ii) *Drain resistance.* (2 marks)

(b) Plot the mutual characteristic of a JFET with the aid of the equation below for $I_{DSS} = 20\,mA$ and $V_P = -2\,V$. (5 marks)

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

(c) Sketch the circuit of a self-biasing common-source amplifier which utilises an p-channel junction field effect transistor. (3 marks)

(d) With the aid of a small signal model, derive an expression for the voltage gain of a common-source amplifier. (9 marks)

(e) The drain characteristics shown on page 7 are based on the JFET amplifier illustrated in Fig. 2 below. The supply voltage V_{DD} is 30 V and I_D = 2.5 mA. Use these drain characteristics to find R_D. (4 marks)

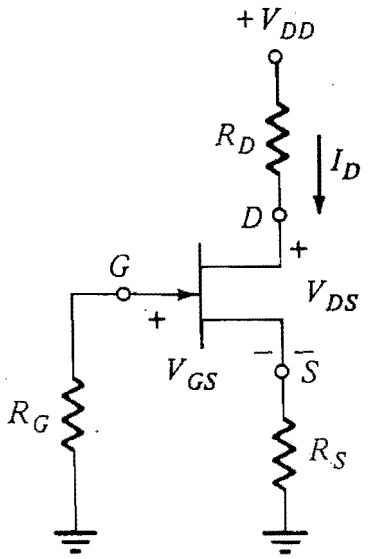

Fig. 2

QUESTION 3

(a) Define

(i) *donor* impurities in semiconductors; (2 marks)

(ii) *acceptor* impurities in semiconductors. (2 marks)

(b) Explain, with the aid of simple diagrams, how n-type silicon is produced. (6 marks)

(c) Show (in two dimensions) the crystal structure of silicon containing a donor impurity atom. Explain, briefly, the effect of donor impurities on the conductivity of the material. (5 marks)

(d) Sketch and comment on the energy-band diagrams representing

(i) *n*-type silicon that is produced using phosphorous and show the donor energy level; (5 marks)

(ii) *p*-type silicon that is produced using boron and show the acceptor energy level. (5 marks)

Label both diagrams.

QUESTION 4

(a) Write the Shockley equation for a *p-n* diode and state the meaning of each symbol. (6 marks)

(b) Plot the diode characteristics for germanium and silicon on the same graph and show the turn-on voltage for each of the semiconductors. (2 marks)

(c) The current, I_D in the circuit shown in Fig. 3.1 and the diode voltage, V_D can be estimated, theoretically, with the aid of the diode characteristics in Fig. 3.2. Given that $V_{AA} = 0.8\,V$ and $R = 10\,\Omega$,

(i) Use the diode characteristics to find approximate values of the diode current and the diode voltage. (7 marks)

(ii) If V_{AA} is increased from 0.8 V to 1 V, what will be the new value of R when the diode current is to remain at the value obtained in (i) above? (5 marks)

(d) Consider a Zener diode with a Zener voltage of 5.2 V and a maximum power rating of 250mW. The diode is used in the simple regulator circuit illustrated in Fig. 3.3 to provide a maximum load current of 12 mA. The voltage supply varies from 9 V to 11 V.

Calculate the value of the series resistance, R_S required for this circuit. (5 marks)

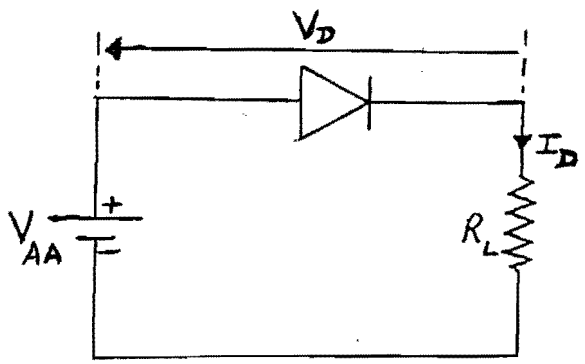

Fig. 3.1

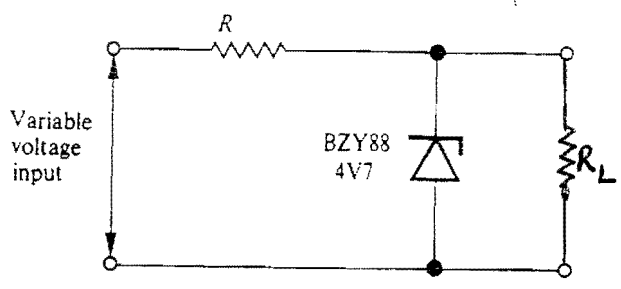

Fig. 3.3

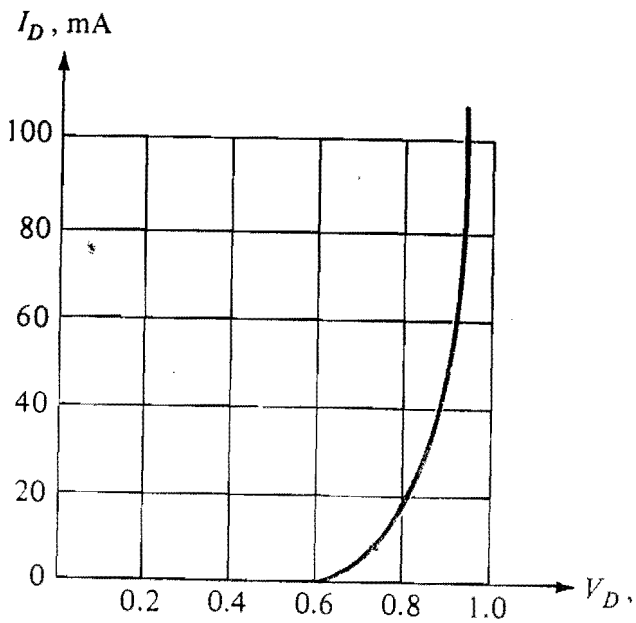

Fig. 3.2

QUESTION 5

(a) (i) What type of circuit is referred to as a source follower? (3 marks)

(ii) Show that the output resistance of a source follower is given by

$$r_{out} = \frac{1}{g_m}$$

where g_m represents the transconductance of the JFET used. (7 marks)

(b) The equations below provide information about the relationship between the currents and voltages associated with a difference amplifier.

$$g_m v_{in}(1) = i_{d2} g_m R_s + i_{d1}\left(1 + g_m R_s\right)$$

$$g_m v_{in}(2) = i_{d1} g_m R_s + i_{d2}\left(1 + g_m R_s\right)$$

where g_m is the transconductance;
$v_{in}(1)$ and $v_{in}(2)$ are the input voltages to transistors T_1 and T_2 respectively;
i_{d1} and i_{d2} are the drain currents associated with transistors T_1 and T_2 respectively;
R_s is the source resistance.

(i) Draw the circuit diagram of a difference amplifier and label it; (4 marks)

(ii) Show that $i_{d1} = -i_{d2}$. Assume that R_s is large. (8 marks)

(iii) Show that the output voltages are equal in magnitude but out of phase by 180°. (3 marks)

STUDENT NUMBER:.....

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