UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2006/2007

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) Draw the diagram of a circuit you would use to measure the characteristics of an n-p-n transistor in the CE configuration. (3 marks)

(b) Sketch the output characteristics and indicate the active, saturation, and cutoff regions. (5 marks)

(c) The element values in the circuit of Fig. 1.1 are $R_1 = 150\,k\Omega$, $R_2 = 37.5\,k\Omega$, $R_C = 7\,k\Omega$, and $R_E = 3\,k\Omega$. The transistor has $h_{FE} = 100$ and negligible reverse saturation current. $V_{BE} = 0.7$ V. Determine I_C and V_{CE} when $V_{CC} = 9\,V$. (11 marks)

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

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

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

With the aid of the h-equivalent circuit of the amplifier, shown in Fig. 1.2, derive an expression for the current gain of the amplifier and calculate the exact value of the gain. (6 marks)

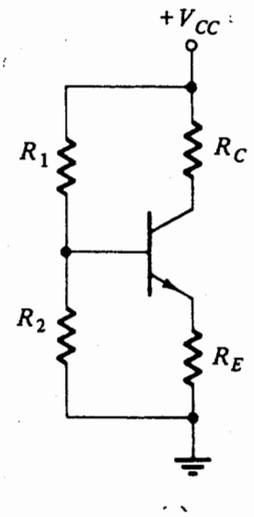

Fig. 1.1

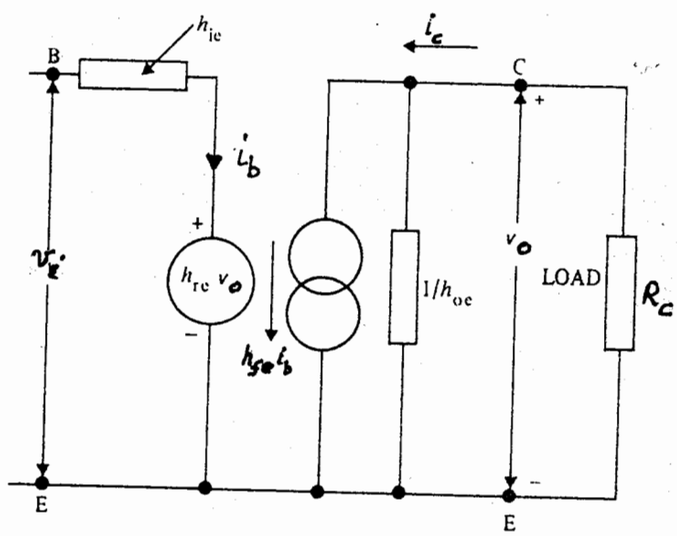

Fig. 1.2

QUESTION 2

(a) Define

(i) *transconductance* g_m and (2 marks)

(ii) *drain resistance* r_d of a JFET. (2 marks)

(b) Plot the transfer characteristic curve of a JFET as given by the equation below, with $I_{DSS} = 10\,mA$ and $V_P = -4\,V$. (4 marks)

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

(c) Sketch the circuit of a self-biasing CS amplifier which utilises an n-channel JFET. (2 marks)

(d) Derive the expression for the voltage gain of the amplifier at low frequencies, with the aid of a small signal model. (7 marks)

(e) The circuit in Fig. 2.1 uses the JFET in Fig. 2.2. The supply voltage is 30 V, and it is desired to have V_{DS} = 17.5 V and I_D = 2.5 mA. Determine R_D and R_S. (8 marks)

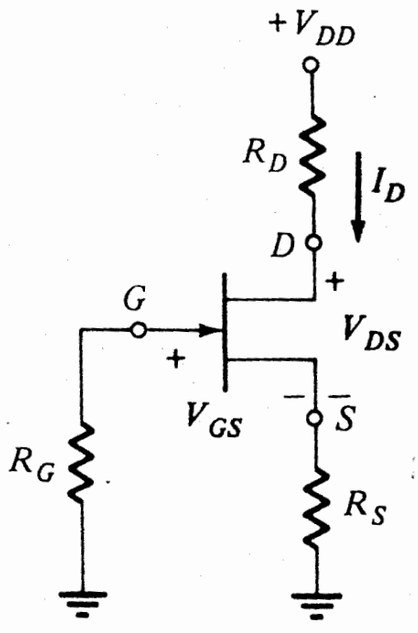

Fig. 2.1

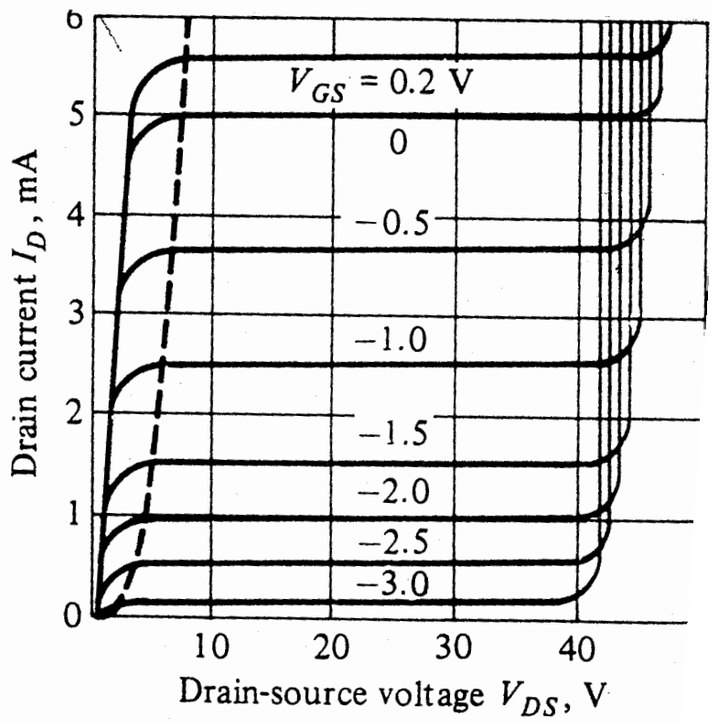

Fig. 2.2

QUESTION 3

(a) Define

(i) *donor*, (2 marks)

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

(b) Explain, with the aid of suitable diagrams, the production of n-type silicon using the Czochralski apparatus. (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) Draw and comment on the energy-band diagrams

(i) for *n*-type silicon produced using phosphorous - showing the donor energy level; (5 marks)

(ii) for *p*-type silicon produced using boron - showing the acceptor energy level. (5 marks)

Label the diagrams.

QUESTION 4

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

(b) Plot the volt-ampere curves for germanium and silicon to the same scale, showing the cut-in value for each. (2 marks)

(c) The silicon diode described in Fig. 4.1 is used in the circuit in Fig. 4.2, with $V_{AA} = 0.8\,V$ and $R = 10\,\Omega$.

(i) Use Fig. 4.1 to estimate the diode current and diode voltage. (7 marks)

(ii) Assume that V_{AA} is increased to 1 V, what must the new value of R be if the diode current is to remain at the value in (i)? (5 marks)

(d) A Zener diode has a Zener voltage of 5.2 V and a maximum power rating of 250mW. It is used in the simple regulator circuit illustrated in Fig. 4.3 to provide a maximum load current of 12 mA where the voltage supply input to this circuit varies from 9 V to 11 V. Calculate the value of the series resistance R_S required in this circuit. (5 marks)

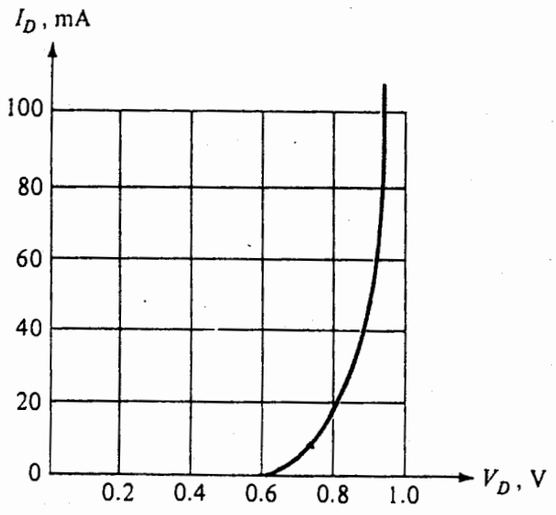

Fig. 4.1

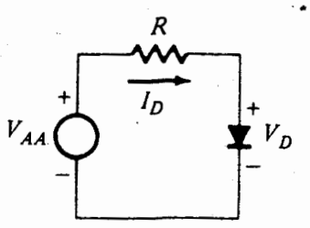

Fig. 4.2

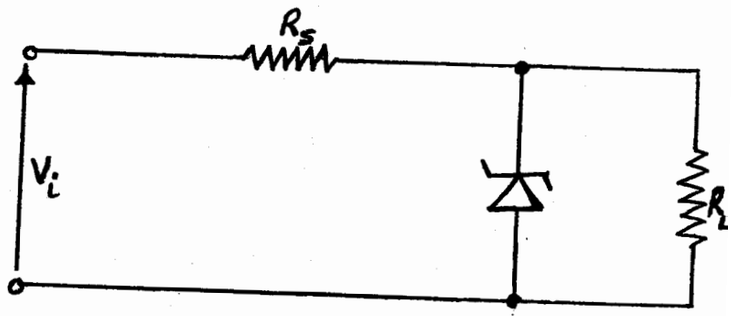

Fig. 4.3

QUESTION 5

(a) 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)

(b) (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)

PHYSICAL CONSTANTS

Boltzmann constant, k $= 1.38 \times 10^{-23}\ J.K^{-1}$
Electronic charge, e $= 1.6 \times 10^{-19}\ C$