UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE & ENGINEERING

DEPARTMENT OF PHYSICS

SUPPLEMENTARY EXAMINATION 2013

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 9 PAGES, INCLUDING THIS PAGE.

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QUESTION 1

(a) Explain how you would measure the characteristics of an n-p-n transistor when it is connected in the CE configuration. Use a circuit diagram for illustration.
(2 marks)

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

(c) The transistor used in the circuit shown in Fig. 1 has an a.c. current gain, $h_{fe} = 200$ and input resistance, $h_{ie} = 7\,k\Omega$. The reverse saturation current is negligible. The base-emitter voltage, $V_{BE} \doteq 0.7$ V. Calculate the collector current and the collector-emitter voltage.
(11 marks)

(d) (i) Draw a simplified small-signal model of the circuit shown in Fig. 1 and label it. Why is the output resistance of the transistor usually neglected in the circuit? (4 marks)

(ii) Derive an expression for the voltage gain of this circuit. (2 marks)

(iii) Calculate the voltage gain of the circuit using the data given in Q.1(c) above.
(2 marks)

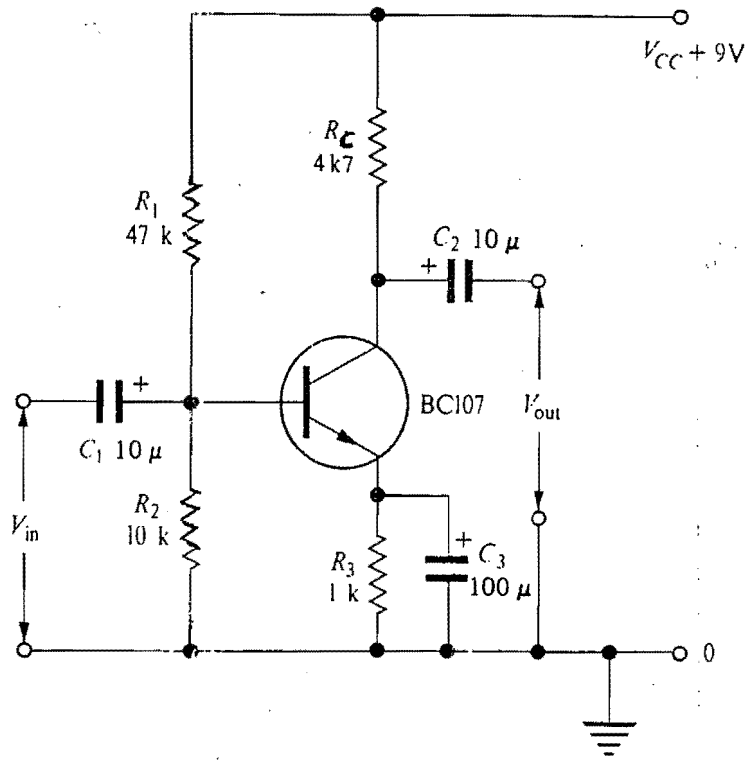

Fig. 1

QUESTION 2

(a) Write down the equation for a *p-n* junction diode which describes the relationship between the (p-n junction) diode current and the diode voltage. Explain what each symbol stands for. (6 marks)

(b) Sketch the current-voltage characteristics of diodes made of silicon and germanium and show the turn-on voltage for each diode. (2 marks)

(c) The characteristic shown in Fig. 2 represents the silicon diode in Fig. 3.

(i) Use Fig. 2 and Fig. 3 to estimate the diode current and diode voltage. [**Hint**: Utilise the enlarged Fig. 2 given on page 7]. (6 marks)

(ii) Calculate the new value of R when V_S is reduced from 1 V to 0.9 V. Assume that the diode current remains at the value calculated in (i). (4 marks)

(d) A 4.7 V, 0.5 W Zener diode is used in the simplified regulator circuit shown in Fig. 4. The input voltage, V_{in} varies from 4 V to 7 V and the load current is 10 mA. Estimate the series resistance R_S and comment on the value obtained with respect to the operation of the regulator. (7 marks)

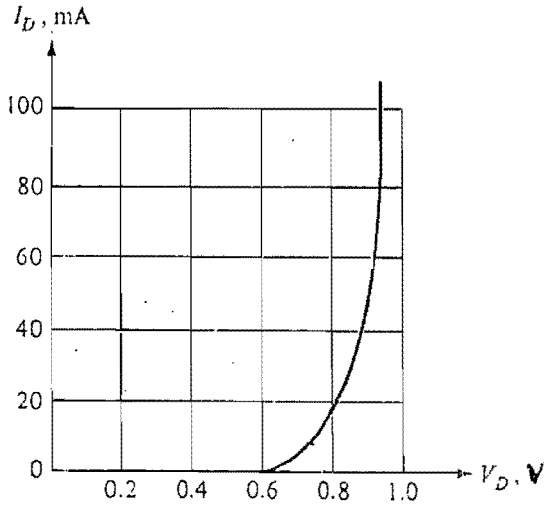

Fig. 2

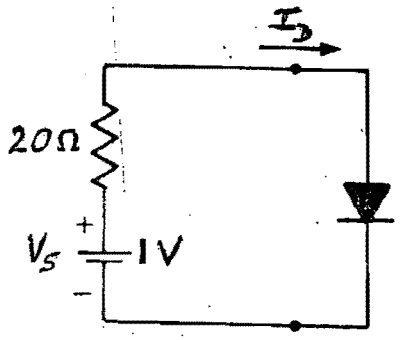

Fig. 3

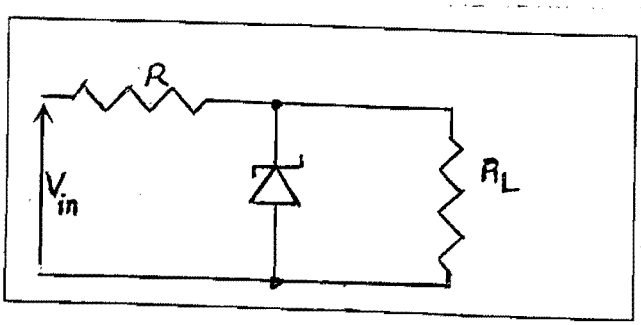

Fig. 4

QUESTION 3

(a) Draw the circuit diagram of a differential amplifier and label it. (3 marks)

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

$$i_{d1} \approx \frac{g_m}{2}\left[v_{i1} - v_{i2}\right]$$

$$i_{d2} \approx \frac{g_m}{2}\left[v_{i2} - v_{i1}\right]$$

where v_{i1} and v_{i2} are the input voltages to the amplifiers consisting of transistors T_1 and T_2 respectively;
i_{d1} and i_{d2} are the drain currents;
g_m is the mutual conductance;
R is the source resistance.

Use the above equations to show that the output voltages of the differential amplifier are equal in magnitude but out of phase by 180°. (11 marks)

(c) (i) Draw the circuit diagram of a source follower. (3 marks)

(ii) Explain why the circuit is called a source follower. (2 marks)

(iii) Show that the output resistance of a source follower is inversely proportional to the mutual conductance. (6 marks)

QUESTION 4

(a) Define the following terms:

(i) *mutual conductance,* g_m and (2 marks)

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

(b) The equation below shows the relationship between the drain current, I_D and the gate-source voltage, V_{GS} for a junction gate field effect transistor (JUGFET). Use this equation to sketch the mutual characteristic curve when $V_p = -2$ V and $I_{DSS} = 8$ mA. (4 marks)

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

(c) An n-channel JFET is used to build an automatic-biasing common-source amplifier. Sketch the circuit diagram of this type of amplifier and label it. (2 marks)

(d) With the aid of a small signal equivalent circuit, derive an expression for the voltage gain of the amplifier described in Q.4(c) above. (7 marks)

(e) The JFET characteristics shown in Fig. 5 are based on the JFET utilised in Fig. 6. The supply voltage, $V_{DD} = 25$ V, and it is desired that $V_{DS} = 12.5$ V and $I_D = 2.5$ mA at the operating point. Find R_D and R_S. Use the enlarged Fig. 5 given on page 8 to find R_D. (8 marks)

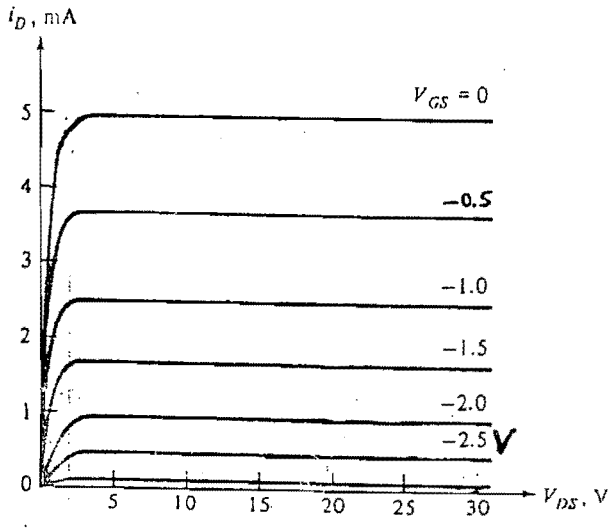

Fig. 5

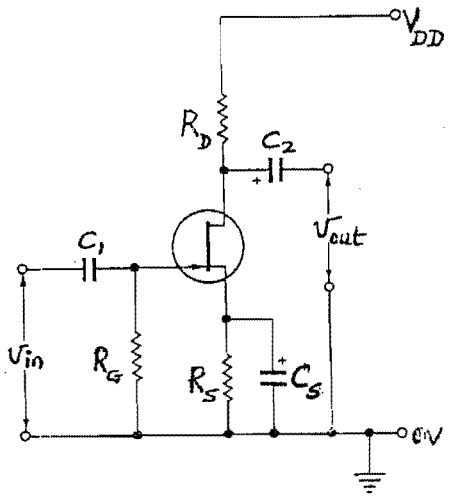

Fig. 6

QUESTION 5

(a) What is meant by the following terms:

(i) *intrinsic semiconductor*? (2 marks)

(ii) *valence band*? (2 marks)

(b) Sketch a two-dimensional crystal structure of silicon that has been doped with phosphorous. Describe the effect of the dopant on the resistivity of the material. (5 marks)

(c) Sketch the energy-band diagrams for both intrinsic and p-type silicon. Label the diagrams and interpret the meaning of each diagram. (10 marks)

(d) A germanium diode is operated at a junction temperature of 27°C. For a forward current of 10 mA, V_D is found to be 0.3 V.

(i) Find the reverse saturation current. (2 marks)

(ii) If $V_D = 0.4$ V, find the forward current. (4 marks)

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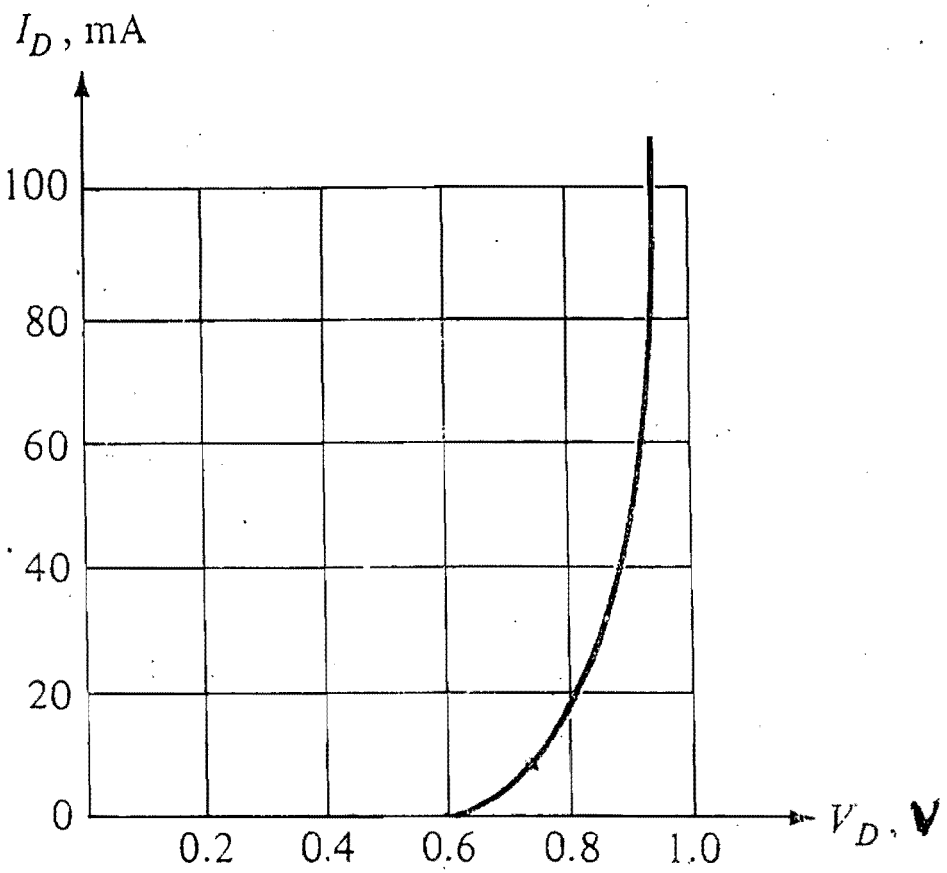

Fig. 2 (enlarged)

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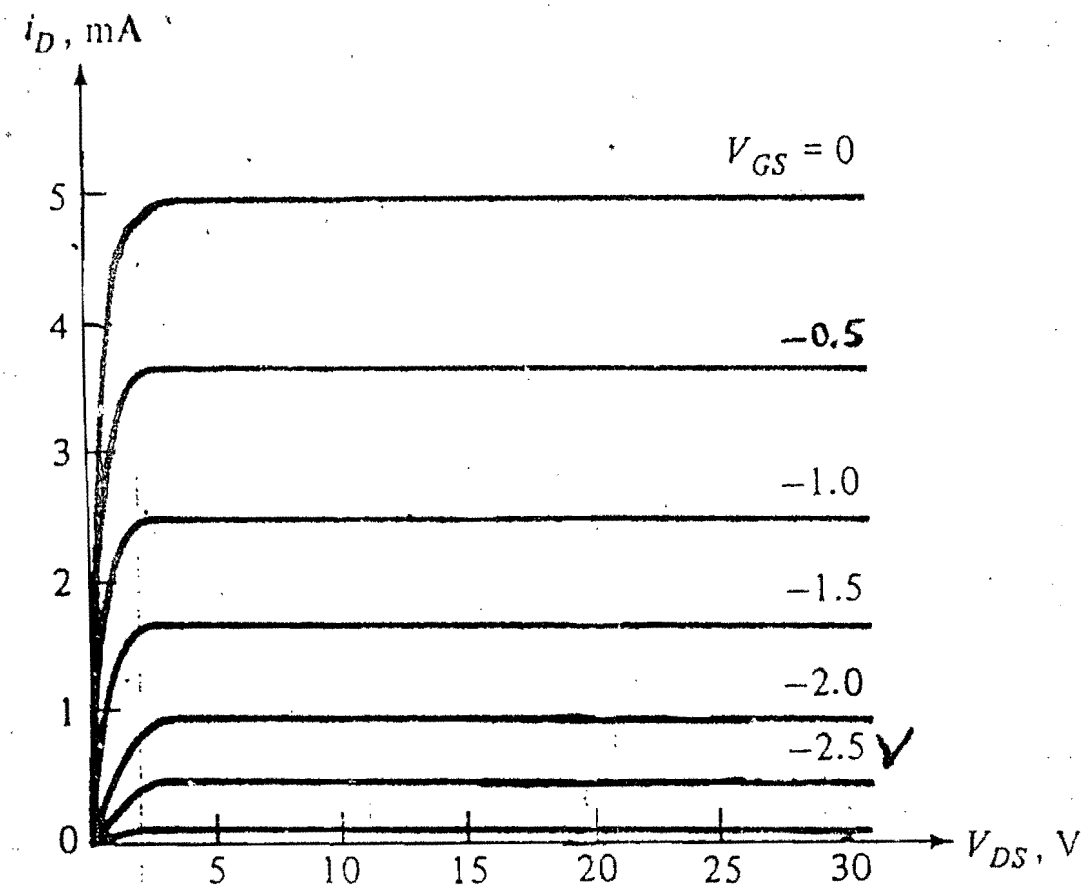

Fig. 5 (enlarged)

PHYSICAL CONSTANTS

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