UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE & ENGINEERING

DEPARTMENT OF PHYSICS

MAIN EXAMINATION	:	2012
TITLE OF PAPER	:	ELECTRONICS I
COURSE NUMBER	:	P311
TIME ALLOWED	:	THREE HOURS
INSTRUCTIONS	:	ANSWER ANY FOUR OUT OF THE FIVE QUESTIONS
		EACH QUESTION CARRIES 25 MARKS
		MARKS FOR DIFFERENT SECTIONS ARE SHOWN IN THE RIGHT-HAND MARGIN

THIS PAPER HAS 8 PAGES, INCLUDING THIS PAGE.

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QUESTION 1

(a) With the aid of the schematic diagram of the Czochralski apparatus shown in Fig. 1, explain how a single crystal of silicon is produced from an ore of silicon. (7 marks)

(b)

(i) Sketch the energy band diagram of silicon that is doped with a Group V element and label it. (2 marks)

(ii) Explain the meaning of the diagram, with reference to the excitation of electrons occupying various energy levels. (5 marks)

(c) Use the Shockley or diode equation to estimate the current, I_D that would flow through a silicon p-n diode at 300 K, (i) when the forward voltage is + 0.4 V and (ii) when the reverse voltage is -5 V. (6 marks)

Assume that the reverse saturation current is 0.05 μA.

(d)

(i) Use the Shockley equation to derive an expression for the dynamic resistance, $r = dV/dI$ of a germanium p-n junction diode. (3 marks)

(ii) What will be the dynamic resistance of the diode when the forward voltage is 0.1 V. (2 marks)

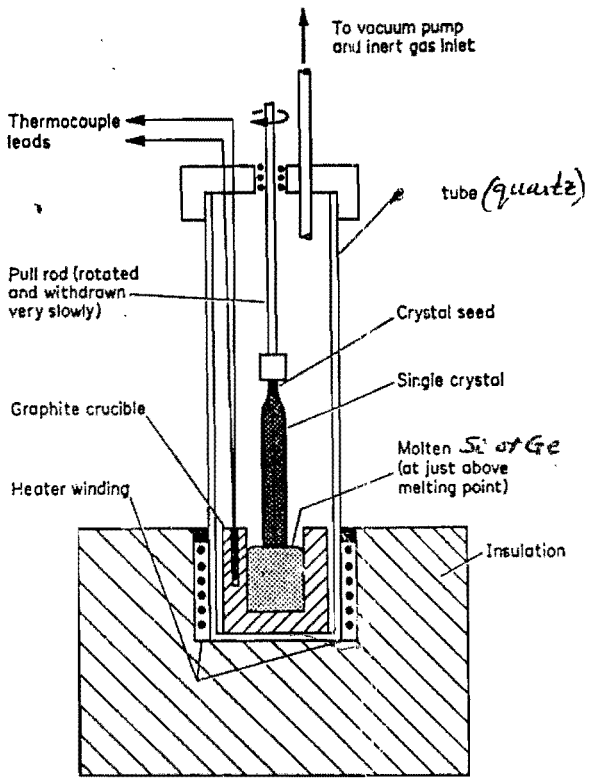

Fig. 1

QUESTION 2

(a) Sketch the basic structure of an n-channel JFET and label it. (2 marks)

(b) How does the JFET behave for (i) small values of V_{DS} and (ii) large values of V_{DS}.

(4 marks)

(c)

(i) An n-channel JFET has the data give in Table 1. Plot the drain characteristics.

(3 marks)

(ii) Use the characteristics to determine the drain-source resistance for V_{GS} = - 2 V.

(3 marks)

Table 1

Drain current (mA)				
Drain-source voltage V_{DS} (V)	Gate-source voltage V_{GS} = 0 V	= - 1V	= - 2 V	= - 3 V
0	0	0	0	0
4	7	5.0	2.4	0.30
8	10.1	5.9	2.7	0.35
12	10.2	6.2	2.9	0.40
16	10.25	6.3	3.0	0.45
20	10.3	6.35	3.05	0.50
24	10.35	6.4	3.1	0.55

(d)

(i) Figure 2 shows both the mutual and drain characteristics of an n-channel JFET. If

V_{DD} = 20 V, draw the load line for R_L = 2 kΩ on the drain characteristic and select the operating point V_{GS} = - 2 V. (4 marks)

(ii) A signal voltage varies V_{GS} between the limits - 1V and - 3 V. From both sets of characteristics, determine the mutual conductance of the device. (3 marks)

(iii) Calculate the voltage gain from both the load line and when using the expression

$A_v = - g_m R_L$. (6 marks)

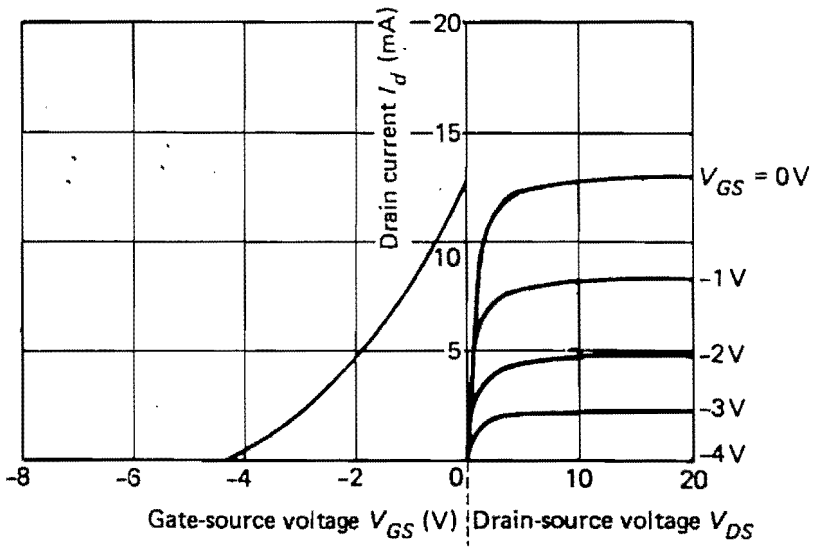

Fig. 2

QUESTION 3

(a) Draw the block diagram of an n-p-n transistor with its base-emitter junction forward biased and its collector-base junction reverse biased. Mark on the diagram the directions of (i) the base current, (ii) electrons in the collector region and (iii) holes in the emitter region. (4 marks)

(b) The application of a signal voltage of 7.5 mV peak between the base and emitter terminals of an n-p-n transistor causes the emitter current to vary by $\pm$ 0.5 mA about its d.c. value. If α = 0.99, calculate the a.c. voltage developed across a 1.2 kΩ load resistor connected in the collector circuit. (3 marks)

(c) The transistor used in a single-stage audio-frequency amplifier with a collector load resistance of 2 kΩ has the data given in Table 2. Plot the output characteristics of the transistor and draw the load line, assuming a collector supply voltage V_{CC} of 8 V. Label the graph fully. (10 marks)

(d)

(i) Select a suitable operating point on the characteristics plotted in (a). (1 mark)

(ii) Determine the current again A_i when an input signal producing a base current swing of 5 μA about the chosen bias current is applied to the circuit. (2 marks)

(iii) Assuming the input resistance of the transistor is 19 kΩ determine the voltage gain A_v. (3 marks)

(iv) Calculate the power gain A_p. (2 marks)

Table 2

	I_C(mA)			
V_{CE}(V)	I_B = 5 μA	I_B = 10 μA	I_B = 15 μA	I_B = 20 μA
2	0.85	1.55	2.32	3.08
4	1.00	1.74	2.56	3.35
6	1.13	1.92	2.76	3.60
8	1.30	2.13	3.00	3.85

QUESTION 4

(a)

(i) Explain, briefly, how the p-n junction diode works. (6 marks)

(ii) Describe the effect of biasing it. Use diagrams to illustrate your point. (5 marks)

(b) Show that the average output voltage of a half-wave rectifier is given by

$$V_{av} = V_m/\pi$$ (5 marks)

(c) A certain unfiltered bridge rectifier circuit of the form of Figure 3 is powered by the 120 V rms ac power system, and the turns ratio is $N_p : N_s = 6 : 1$. Determine

(i) The rms secondary voltage; (3 marks)

(ii) The peak secondary voltage; (2 marks)

(iii) The dc load voltage; and (2 marks)

(iv) The dc load current if $R_L = 5\ \Omega$. (2 marks)

Neglect any diode and transformer losses.

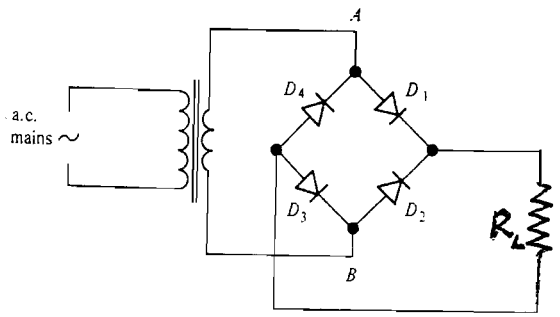

Fig. 3

QUESTION 5

(a)

(i) Draw the circuit diagram of a small signal model of a BJT amplifier. (2 marks)

(ii) Derive the exact expressions of the voltage and current gain of the amplifier. (6 marks)

(iii) A bipolar transistor has the following h parameters : h_{ie} = 1.2 kΩ, h_{fe} = 150, and h_{oe} = 60 x 10^{-6} S. The transistor is used as an amplifier with a collector load resistance of 2 kΩ. Calculate the current gain of the circuit, taking h_{oe} into account. (3 marks)

(b) A transistor has an output resistance of 15 kΩ and its operating point is V_{CE} = 6 V, I_C = 2 mA. What will be the collector current when V_{CE} = 8 V? (6 marks)

(c) List three factors that should be taken into account when choosing a suitable operating point for a transistor. (3 marks)

(d)

(i) In Fig. 4 the collector-to-earth voltage is 9 V, R_C = 3 kΩ and I_C = 2mA. Calculate the supply voltage V_{CC}. (3 marks)

(ii) If the emitter resistor is 1 kΩ calculate V_E. (2 marks)

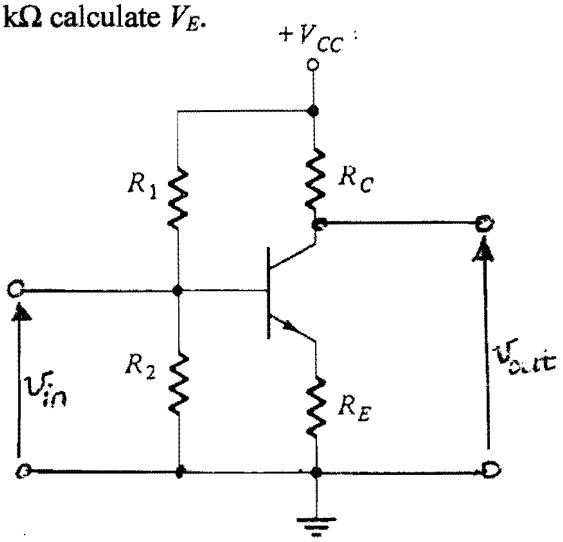

Fig. 4

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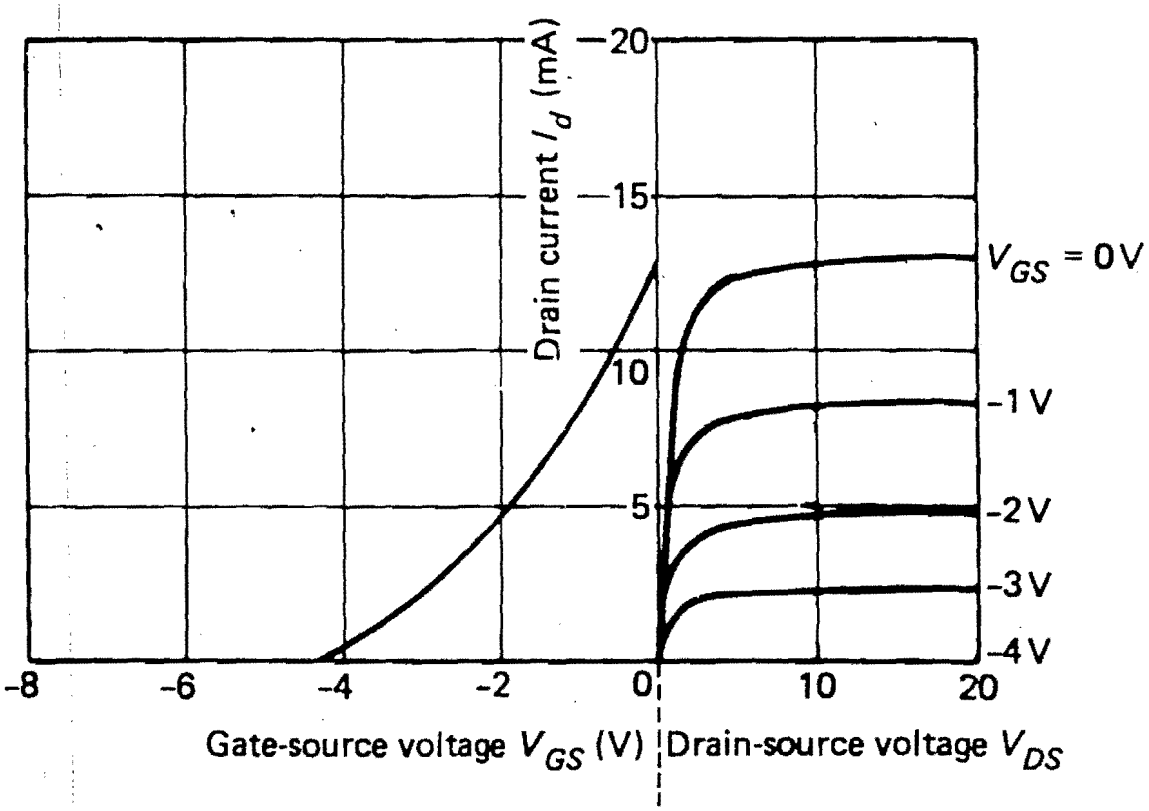
USE THE GRAPH BELOW TO ANSWER QUESTION 2(d)(i)

(An enlarged version of Fig. 2)



NOTE: This graph should be handed in together with the answer book.