UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
MAIN EXAMINATION, DECEMBER 2009

TITLE OF PAPER : ANALOGUE ELECTRONICS

COURSE NUMBER : E361

TIME ALLOWED : THREE HOURS

INSTRUCTIONS : READ EACH QUESTION CAREFULLY ANSWER ANY **FOUR** OUT OF **FIVE** QUESTIONS. EACH QUESTION CARRIES **25 MARKS**. MARKS FOR EACH SECTION ARE SHOWN ON THE RIGHT - HAND MARGIN.

THIS PAPER HAS 8 PAGES INCLUDING THIS PAGE.

THIS PAPER IS NOT TO BE OPENED UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR.

USEFUL INFORMATION

Total drain current $i_D = I_{DSS}\left(1 - \frac{v_{GS}}{V_p}\right)^2$, $r_{ds} = \frac{1 + \lambda V_{DSQ}}{\lambda I_{DSQ}}$

$$g_m = \frac{-2I_{DSS}}{V_p}\left(1 - \frac{V_{GSQ}}{V_p}\right)$$

QUESTION 1

(a) The output characteristics of the Junction Field Effect transistor of Figure 1(a) are as displayed on Figure 1(b) on page 7. A sinusoidal input voltage with a peak value of 0.5 V is applied in series with the 1.5 V supply.
If I_{DSS} = 5 mA, V_p = -3.6 V, λ = 0.01 V^{-1},

(i) give the low - frequency small signal equivalent circuit of Figure 1(a), and (2 marks)

(ii) calculate the instantaneous total output voltage . (17 marks)

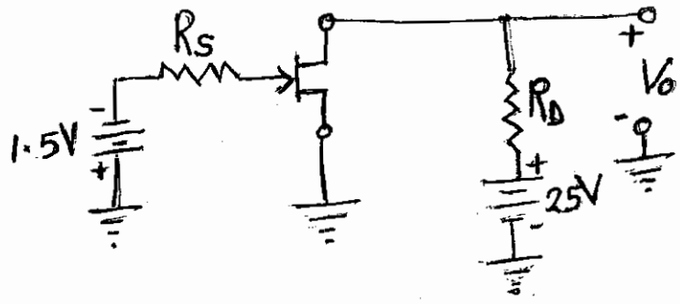

Figure 1(a)

(b) The inverting amplifier stage of Figure 1(c) utilizes an ideal operational amplifier. Derive an expression for the voltage gain. (3 marks)

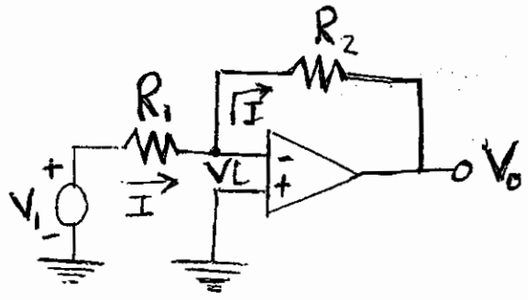

Figure 1(c)

(c) Sketch a unity - gain buffer and name two of its characteristics. (3 marks)

QUESTION 2

In basic amplifier circuits, it is important to note that proper basic amplifier circuit performance requires that the location of the operating point be controlled. The current gain of the npn transistor used in the circuit of Figure 2 varies from $\beta_F = 60$ to $\beta_F = 120$. Let $R_1 = 90\ k\Omega$, $R_2 = 10\ k\Omega$, $R_3 = 6.8k\Omega$ and $R_4 = 1.2\ k\Omega$, $V_{cc} = 28$ V.

(i) Assuming that I_{CO} is negligibly small, through calculations, show the effectiveness of the circuit in keeping the collector current I_C constant as β_F varies.
(12 marks)

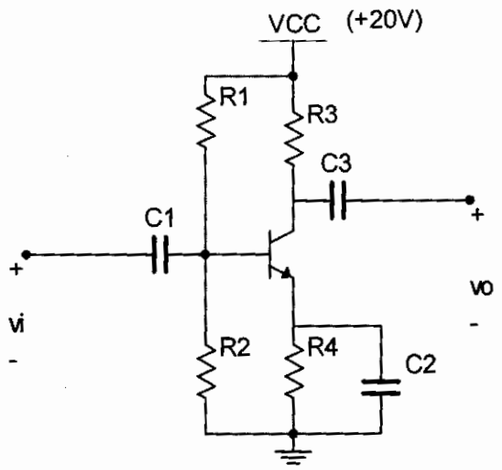

Figure 2

(ii) By finding the operating point for $\beta_F = 60$ and $\beta_F = 120$, determine the percentage change of the operating point.
(12 marks)

(iii) Comment on the changes in I_{CQ} and I_{BQ} relative to that of β_F.
(1 mark)

QUESTION 3

(a) Each stage of the CE - CE cascade of Figure 3(a) uses an npn transistor with $\beta_F = 125$, $\beta_o = 125$ and $r_o = 0$. Each transistor is biased at $I_{CQ} = 1$ mA.

Determine the overall voltage gain A_v assuming $r_b = 0$ and that operation is at 25 °C. (14 marks)

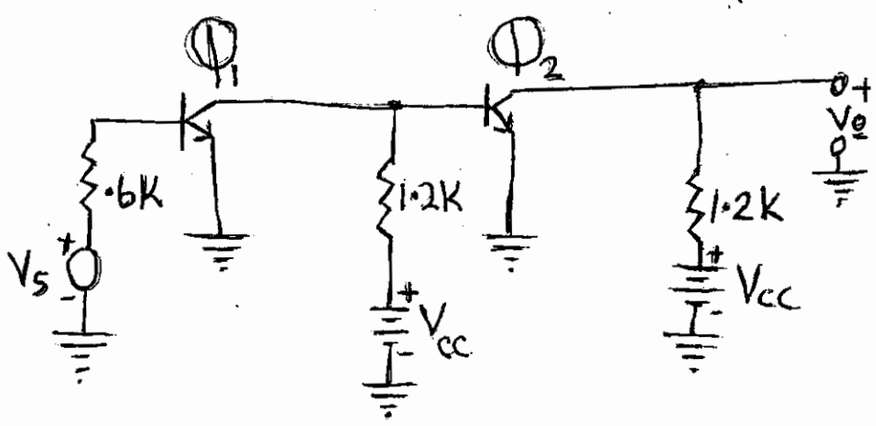

Figure 3(a)

(b) For the circuit of Figure 3(b), $V_{CC} = 10$ V and $R = 10$ kΩ.

(i) In which mode of operation is the transistor ? Justify your answer. (3 marks)

(ii) Derive an expression relating the current I to the base current I_B . (3 marks)

(iii) Evaluate the collector current I_C for $\beta_F = 200$. (5 marks)

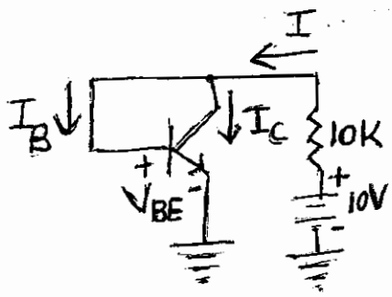

Figure 3(b)

QUESTION 4

In the circuit of Figure 4, v(t) =8 +0.02 Sin ωt. Neglecting the effect of the diffusion capacitance, and assuming that the dc model of the diode is V_γ = 0.6 V and R_f = 0,

(i) present the large - signal and small - signal representation of the circuit. (4 marks)

(ii) Determine the instantaneous output voltage, v_o (t). (17 marks)

(iii) Sketch the output ac current over two cycles. (4 marks)

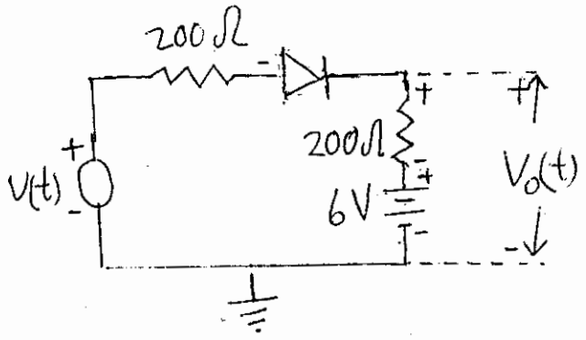

Figure 4

QUESTION 5

A depletion Metal Oxide Field Effect (MOSFET) transistor used in Figure 5(a) has characteristics shown on Figure 5(b),which is displayed on page 7. The threshold voltage, V_T = - 3 V.

With the waveform $v_i = \begin{cases} 0 & \text{for } t < 0 \\ -3.5 & \text{for } t > 0 \end{cases}$ as the input

and also using Figure 5(b),

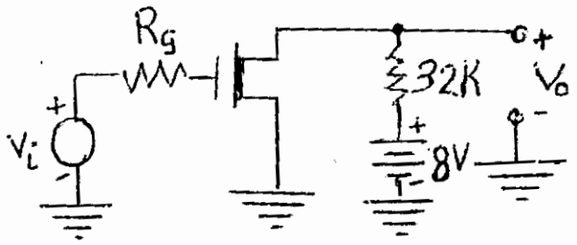

Figure 5(a)

(i) explain the operation of the circuit of Figure 5(a).
(9 marks)

(ii) Sketch the output waveform, v_o next to Figure 5(b).
(3 marks)

(iii) What type of behavior does the circuit display?
(1 mark)

Examination N0:.....

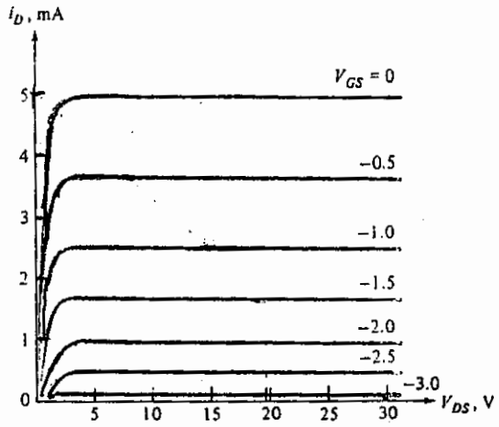

Figure 1 (b)

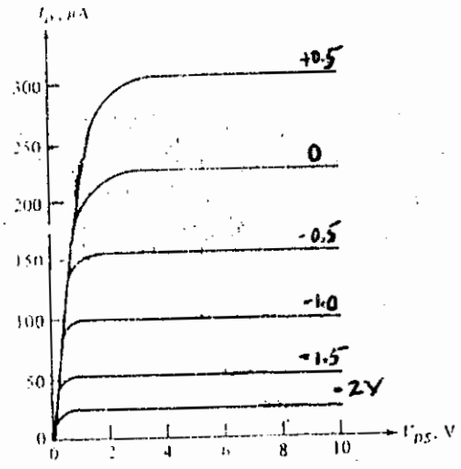

Figure 5 (b)

QUESTION 5 (continued)

(b) The silicon diodes used in the circuit of Figure 5(c) have $R_f = 50\ \Omega$, $V_\gamma = 0.6$ V, $I_s = 0$ and $R_r = \infty$.
Using the piecewise linear diode model representation,

(i) determine the output voltage v_o, (8 marks)

(ii) the voltage across diode D2, and (2 marks)

(iii) the power dissipated by the 250 Ω resistor. (2 marks)

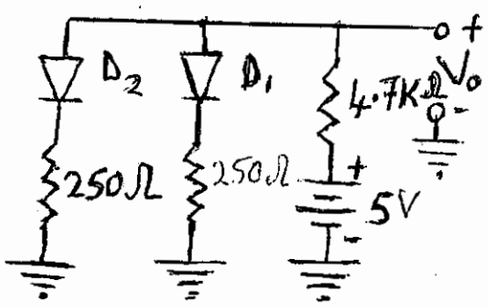

Figure 5(c)

NOTE: IF YOU HAVE ANSWERED QUESTION 1 AND/OR QUESTION 5, REMEMBER TO HAND IN PAGE 7 WITH YOUR ANSWER BOOKLET(S). MAKE SURE YOUR EXAM. NO. IS CLEARLY WRITTEN AT THE TOP OF THE PAGE