Data Provided: You may need to use the following physical constants:

Charge on electron:	$q = -1.602 \times 10^{-19}$ C
Free electron rest mass:	$m_0 = 9.110 \times 10^{-31}$ kg
Speed of light in vacuum:	$c = 2.998 \times 108$ m s^{-1}
Planck's constant:	$h = 6.626 \times 10^{-34}$ Js
Boltzmann's constant:	$k = 1.381 \times 10^{-23}$ JK^{-1}
Melting point of ice:	0°C = 273.2 K
Permittivity of free space:	$\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1}
Permeability of free space:	$\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}

The University of Sheffield

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

EEE225 Analogue and Digital Electronics

Answer **ALL** questions.

Part A: State whether each of the following statements is TRUE or FALSE and justify your answer with a brief (2 lines maximum) justification.

1) The conductivity of n-type silicon varies significantly as the room temperature changes.

(2)

2) High doping in semiconductors can enable higher temperature device operation.

(2)

3) The built-in voltage (or contact potential) in a p-n junction is approximately equal to the band-gap of the semiconductor.

(2)

4) Metal-semiconductor schottky junctions are usually used when high speed switching is required.

(2)

5) You can differentiate between an LED and a laser by the amount of optical power they emit.

(2)

6) Any semiconductor material that can be used to make a solar-cell can also be used to make a photodiode.

(2)

7) When a silicon p-n junction diode is exposed to sunlight, you can obtain a voltage at the terminals that is approximately equal to the built-in voltage.

(2)

8) In a perfectly compensation doped semiconductor, the concentration of acceptors and donors falls to below the intrinsic carrier concentration.

(2)

9) Most Blu-Ray DVD players use the semiconductor material InGaAs (Eg = 0.7 eV) to make the blue lasers.

(2)

10) In an enhancement mode MOST, the drain current can vary linearly with drain voltage.

(2)

Part B: Question 11

a) Sketch, label and discuss briefly the conduction mechanisms in an induced channel Metal Oxide Semiconductor Transistor (MOST). Identify all the significant parts of the device.

(10)

b) The unsaturated drain characteristic of such a device as in (a) can be represented by:

$$I_d = \frac{\mu_e C_g}{l^2}\left[V_g - V_T - \frac{V_d}{2}\right]V_d$$

where the symbols have their usual meaning.

i) Under what voltage conditions does saturation of the drain current happen?

(2)

ii) What is the transconductance in the saturation region?

(4)

iii) Show that the transconductance is simply given by twice the ratio of the saturated drain current to drain voltage.

(4)

c) Sketch the schematic band diagram of a rectifying (schottky) metal-semiconductor junction in equilibrium when the semiconductor is n-type, identifying clearly the built-in (contact) potential and the Fermi-level. State clearly the relative work functions for the metal and semiconductor.

(10)

Questions 12 – 20 are about the building blocks of analogue circuits. Answer all questions.

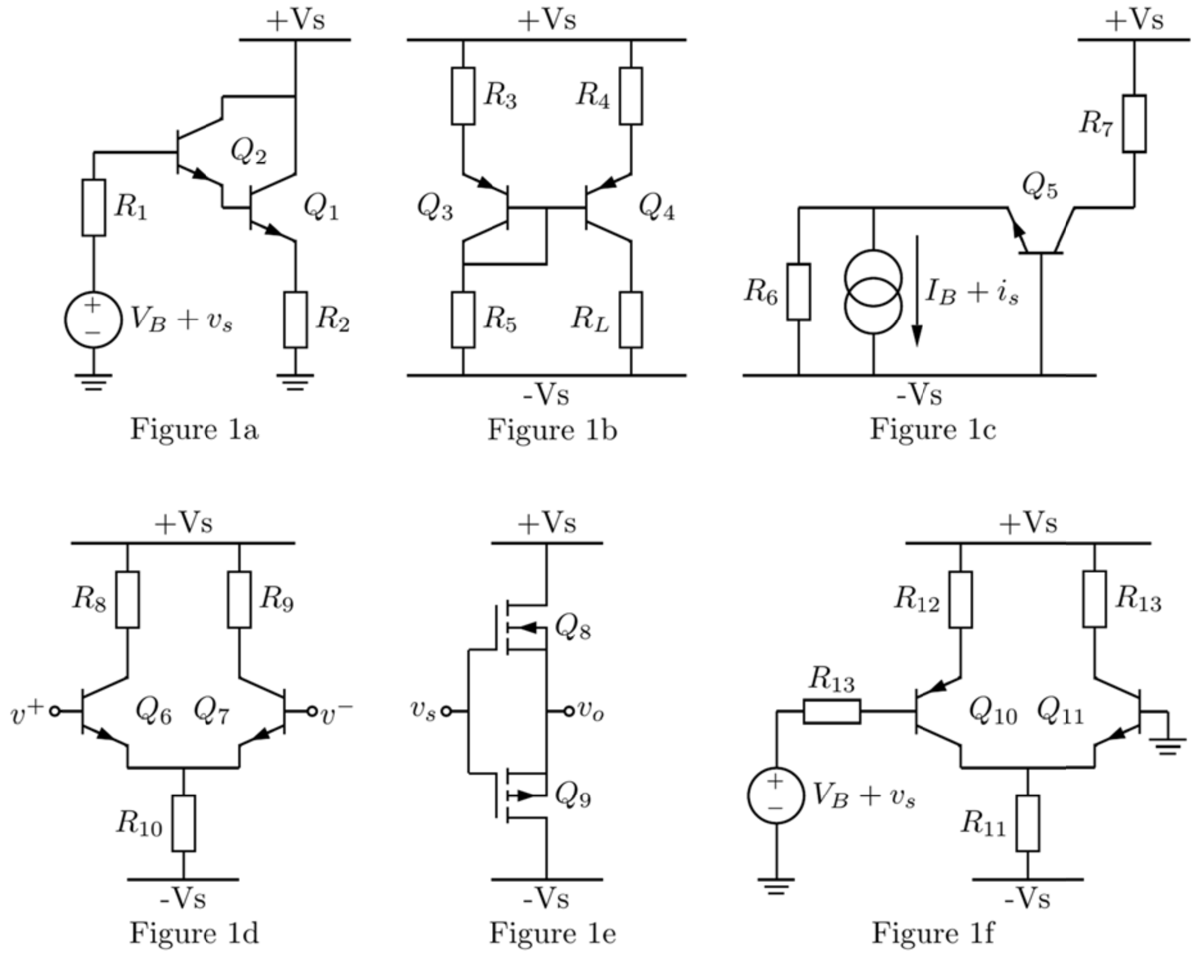

Figure 1: Some Common Analogue Transistor Circuit Blocks

12 Identify the circuits in Figure 1 by writing the letters A to F next to the names below. *Some Letters may fall into two categories.* **{1 mark for each correct assignment}**

Emitter follower	Differential amplifier	Cascode
Common base	Push pull	Current Mirror
Common collector	Darlington	Common Emitter

13 Using the column headings below list the transistors in Figure 1 according to type.
{1 mark for each correct}

NPN and N Channel	PNP and P Channel

14 In Figure 1d, $+V_s = 15$ V, $-V_s = -15$ V, $v^+ = v^- = -1$ V and $R_{10} = 10$ kΩ. Find $I_{R_{10}}$. State two assumptions you made. **{3 marks}**

15 Is the input described in Question 14 *common mode* or *differential* mode? **{1 mark}**

16 In Figure 1f, $+V_s = 15$ V, $-V_s = -15$ V, $V_B = 4.3$ V and the collector currents of both transistors are 100 μA. Find values of R_{11} and R_{12} that would satisfy these DC conditions. State one assumption you have made. **{6 marks}**

17 Draw the small signal equivalent circuit of Figure 1c and label all components. **{3 marks**}

18 Derive an expression for the transimpedance (collector voltage/input current, v_c/i_{in}) of Fig. 1c. **{7 marks}**
Hint: Start by summing currents at the emitter.

19 Why is R_6 is often neglected in the calculation of transimpedance for this circuit. **{2 marks}**

20 Derive an expression for the output impedance of the circuit in Fig 1a. hint: remove R2 and use a current source to drive the emitter of Q1. **{7 marks}**

21 Hence or otherwise describe the impedance transforming nature of the transistor in a few sentances. **{3 marks}**