The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

EEE118 Electronic Devices and Circuits
Mid-year test 17th January 2017

Student Registration Number:

as shown on U.Card, but not U.Card number

Mass of free electron, $m_e = 9.11 \times 10^{-31}$ kg

Charge on electron, $q = 1.60 \times 10^{-19}$C

Boltzmann constant, $k_B = 1.38 \times 10^{-23}$ J/K

Electron effective mass in Silicon, $m^* = 0.98 m_e$

Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

Planck's constant, $h = 6.63 \times 10^{-34}$ Js

$$C = \frac{\varepsilon_o \varepsilon_r A}{d} \qquad \mu = \frac{q\tau}{m^*}$$

$$E = -\frac{dV}{dx} \qquad J = qD\frac{dn}{dx}$$

Energy of a photon $= hc/\lambda$

$$R = \rho L/A \qquad \rho = 1/\sigma \qquad D = \frac{kT}{q}\mu$$

$$\sigma = \frac{1}{\rho} = ne\mu_e + pe\mu_h$$

$$n_i = C\ T^{3/2} \exp\left(-\frac{E_g}{2k_B T}\right)$$

$$L = \sqrt{D\tau}$$

$$n_i^2 = n_n p_n = n_p p_p$$

$$\partial p = \partial p_0 \exp\left(\frac{-x}{L_h}\right)$$

$$\langle v_d \rangle = -\mu E$$

$$\langle v_d \rangle = -\frac{qE\tau}{m^*}$$

$$I_0 = eAn_i^2\left[\frac{D_e}{L_e N_A} + \frac{D_h}{L_h N_D}\right]$$

$$\gamma = \frac{I_{Eh}}{I_{Ee} + I_{Eh}}$$

$$\beta = \frac{\alpha}{1-\alpha}$$

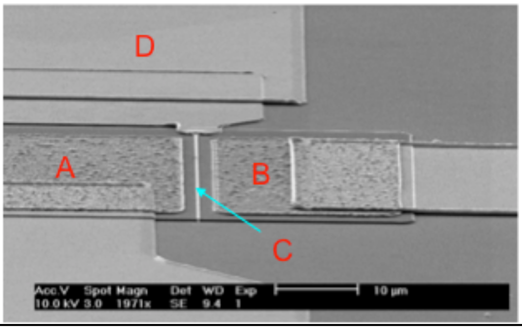
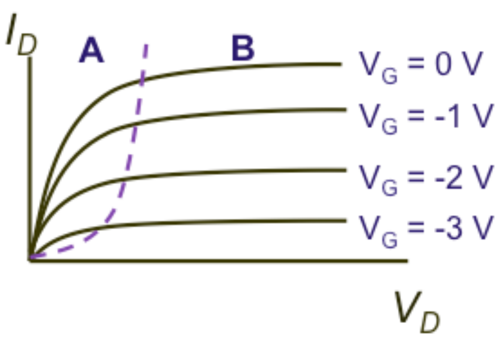
$$\alpha = \gamma\ B$$

Answer all questions by writing the answer in the box provided (there is no requirement to show workings on this sheet)

Answer Here

	Question	Answer Here
1	Which ***one*** of the following statements is correct? The conduction band in a semiconductor **A.** is the lowest energy band available for free electrons in the semiconductor **B.** contains free electrons at a temperature of absolute zero **C.** contains thermally generated free holes at room temperature **D.** is where photons are located in the semiconductor	A
2	Which ***one*** of the following is not a semiconductor at room temperature? **A.** Silicon **B.** Germanium **C.** Aluminium Oxide **D.** Gallium Arsenide	C
3	Name **three** types of imperfections in a crystal that scatter electrons?	Phonons Vacancies Impurities Interstitials
4	A 15V battery is connected across a 2cm length of Silicon. If the average resultant drift velocity of the electrons in the Silicon $90ms^{-1}$, calculate the mobility of the electrons ***and*** the average time between scattering events in the Silicon. State clearly the units in each answer.	$0.12m^2V^{-1}s^{-1}$ $6.7x10^{-13}s$
5	Which of the of the following semiconductors has the smallest electron effective mass and hence is most suitable for high speed electronic devices A. Silicon (Si) B. Germanium (Ge) C. Indium Phosphide (InP) D. Gallium Arsenide (GaAs) E. Indium Antimonide (InSb)	E
6	Boron is a p-type dopant in Silicon. Which ***one*** of the following statements correctly describes a Boron atom in a Silicon semiconductor: A. It is an impurity atom with 5 outer electrons B. It is a positively charged impurity ion C. It is an impurity atom with 3 outer electrons D. It is a negatively ionized silicon atom	C

7	Which ***one*** of the following statements is incorrect A. An intrinsic semiconductor contains no dopant atoms B. The density of free electrons in an extrinsic semiconductor depends only on the number of dopant atoms C. Acceptor atoms donate a hole to the valence band D. There is a small energy difference between the electron level associated with a donor atom and the conduction band	B
8	Which ***one*** of the following statements is correct A. Drift current arises from non-uniform carrier densities in a semiconductor B. Minority carriers can give rise to large diffusion currents in semiconductors C. Dopant atoms diffuse until there is equilibrium in a semiconductor D. Majority carriers stay near their respective donor or acceptor atoms	B
9	Using the equation at the start of this paper, calculate the room temperature intrinsic carrier concentration in the semiconductor Indium Arsenide (InAs) which has a band-gap of 0.345eV. Take the value of C in the equation as $C=1.344\times10^{20}m^{-3}K^{-3/2}$ and room temperature as T=298K. Suggest why the value obtained might make this a difficult semiconductor to make devices from.	$1\times10^{21}m^{-3}$ Difficult to p-dope, overcoming the intrinsic values
10	A sample of silicon is doped n-type to a value 1×10^{14} mm^{-3}. If the electron mobility is 0.12 $m^2V^{-1}s^{-1}$, calculate the conductivity in the sample.	$1.92 \times 10^3\ \Omega^{-1}m^{-1}$
11	GaAs has a band gap of 1.45 eV. Using this information, what forward bias would you expect to have to apply to a p-n diode made from this material to cause it to fully conduct? Assume there in negligible series resistance associated with the diode.	~1.45 V
12	Explain qualitatively why the saturation current in a pn diode depends on temperature	Depends on n_i Also arises from thermally generated carriers
13	Which ***two*** of the following statements are correct. A. Light is emitted from an LED by spontaneous emission of photons in reverse bias B. Above threshold, light in a laser arises mainly from stimulated emission of photons C. The energy of photons emitted from an LED is approximately that of the band gap of the semiconductor D. Germanium is an excellent semiconductor for LEDs	B & C

14	Gallium Nitride (GaN) is a direct band-gap semiconductor with a band-gap of 3.2eV. What is the wavelength of light emitted by an LED made from a GaN pn junction. What is the colour of this light?	388nm ultra-violet
15	The electron microscope image below shows the surface of a JFET. Identify the features marked, A,B,C and D  	A – source B- Drain C- gate D – gate bond pad
16	The gate voltage in a silicon JFET in the saturation region is reduced from V_g= -3.1V to V_g= -3.0V If the resultant drain source current I_{DS} changes from 1mA to 1.3mA calculate the transconductance of the JFET	3mA/V
17	Which of the following statements is not true A. A MOSFET is special kind of MISFET B. Moore's law is a fundamental law of physics derived from the physical properties of dielectrics C. Both JFETs and MOSFETs are a unipolar device D. The gate in a MOSFET is capacitively coupled to the conducting channel	B
18	The diagram below shows the transfer characteristics of MOSFET device. Name the regions labeled A and B in the diagram  	A – linear B – saturation

19	In an n^+pn Bipolar Junction Transistor the emitter efficiency, γ is defined as: A. The fraction of emitter current due to electrons B. The fraction of emitter current due to holes C. The fraction of electrons that reach the collector D. The fraction of holes that reach the collector E. The ratio of emitter current to collector current	A
20	An p^+np bipolar junction transistor has an emitter current dominated by hole flow where the hole emitter current exceeds the electron emitter current by a ratio of 200. Calculate the current gain, β (I_C/I_B), for this device if the base transport factor, B, is 0.97	**27.7**

END OF PAPER