The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

EEE118 Electronic Devices and Circuits

Mid-year test Jan 2014

Student Registration Number:

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

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

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

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

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

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

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

Poisson's Equation $\frac{d^2V}{dx^2} = -\frac{\rho}{\varepsilon}$

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

Energy of a photon $=hc/\lambda$

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

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

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

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

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

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

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

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

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

One mark per question, unless indicated

Answer Here

1	Which ***one*** of the following statements is correct? The mobility of an electron in a semiconductor is a measure of: **A.** how quickly it will recombine with a hole. **B.** how fast it will drift through a device per unit applied electric field. **C.** the energy it emits when it recombines with a hole. **D.** the time between collisions with crystal defects.	
2	Which ***one*** of the following statements about the magnitude of the built-in voltage of a diode is true? **A.** It is a measure of the voltage to be overcome by an applied external forward bias to achieve conduction. **B.** This is the voltage that would be measured at the diode terminals with zero external voltage applied. **C.** It is the external voltage to be applied to stop any current flow in the diode. **D.** It is the voltage where the diode will suffer breakdown failure.	
3	Which ***one*** of the following statements is true? The capacitance of a zero biased p-n junction diode will: **A.** decrease as the p and n doping is increased. **B.** increase when the diode area decreases. **C.** decrease as the p and n doping is decreased. **D.** decrease when either the p or the n region doping is increased.	
4	In an n-type semiconductor, the electron concentration is decreasing from left to right. Which ***two*** of the following statements are true? **A.** Diffusion causes the electrons to move from right to left. **B.** Diffusion causes the electrons to move from left to right. **C.** An electric field from right to left is required to balance this diffusion movement. **D.** An electric field from left to right is required to balance this diffusion movement.	
5	What is the resistance of a rod that is 0.1 m long, $5x10^{-6}$ m^2 in cross-sectional area, and which has a conductivity of 500 $\Omega^{-1}m^{-1}$ (*use the appropriate equations on the first page*).	
6	Which ***one*** of the following statements correctly describes the charge carrier known as a "hole" is in a semiconductor: **A.** The gap left in a semiconductor crystal when an atom is removed is called a hole. **B.** When an electron is given sufficient energy to leave its crystal bond a hole is formed in the bond. **C.** When an electron moves across a p-n junction due to forward bias a hole is formed where it used to be. **D.** A donor atom 'donates' a free electron to the semiconductor leaving behind a positive charge known as a hole.	
7	For a certain concentration of minority holes injected into one side of a semiconductor, calculate the fraction that remain 1 μm away from that side if the minority carrier diffusion length for holes is 2 μm. (*a suitable equation from the first page can be used for the calculation*)	

8	The relative dielectric constant (ε_r) for a certain ceramic insulator is 50. This insulator is used to fill the gap between the parallel plates of a capacitor which previously had air between the plates. How will this affect the capacitance value relative to the air-filled capacitor and by how much?	
9	Which ***one*** of the following statements is true. An LED emitting blue light **A.** is made from a crystal which has a weaker crystal bond compared to that used for a red LED. **B.** has a much higher doping concentration compared to a red LED. **C.** can be made from silicon crystal. **D.** is made from a crystal which is harder compared to that used for a green LED.	
10	Complete the following statement using ***one*** of the alternatives: The process of diffusion of electrons in a semiconductor **A.** results from the movement of electrons from low concentrations to high concentrations. **B.** will increase as the temperature decreases. **C.** will increase as both the concentration gradient and the temperature increases **D:** needs the presence of an electric field.	
11	A piece of silicon is doped n-type to a value 1 x 10^{23} m^{-3}. What is the minority carrier concentration if the intrinsic value is 1.45 x 10^{10} m^{-3}?	
12	Which ***one*** of the following statements is closest to the truth: The small reverse biased leakage or saturation current in a p-n junction diode is mainly due to: **A.** the diffusion of majority carriers from their respective sides over the built-in barrier. **B.** current leakage around the edge of the diode. **C**. crystal defects. **D.** thermally generated electron-hole pairs within the depletion region.	
13	Draw the circuit symbol for a diode ***and*** label the anode and cathode **(1 mark)**.	
14	Add two arrows on your diagram in Q13 which show, • the direction of current flow when the diode is *forward biased* above the turn on voltage. Label this arrow *I*. • the direction of the voltage which forward biases the diode. Label this arrow *V*. **(1 mark)**	

15 What does "on the edge of conduction" mean when considering a diode? **(1 mark)**

16 For the circuit in Fig. 1, find the value of V_i that puts the diode on the edge of conduction **(3 marks)**

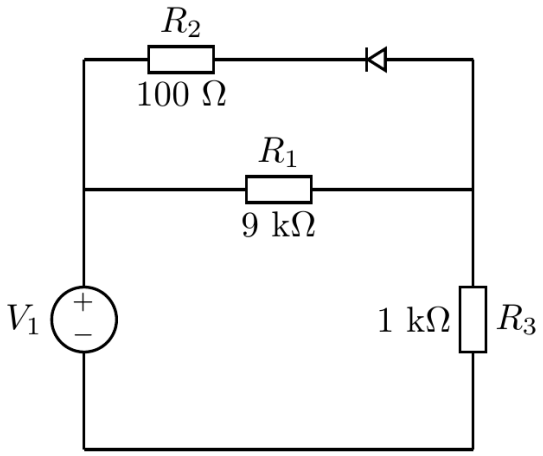

Fig. 1

17 A diode, resistor, capacitor circuit is shown in Fig. 2. The input pulse, V_i is shown in Fig 3.

Draw, on Fig. 3, the shape of the capacitor voltage, V_o waveform due to the input

(1 mark)

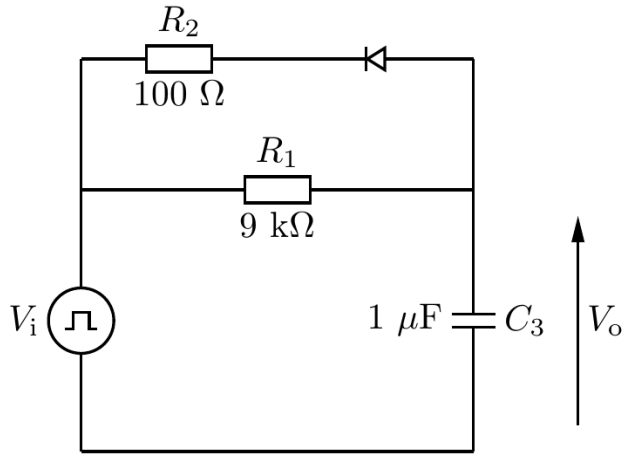

Fig. 2

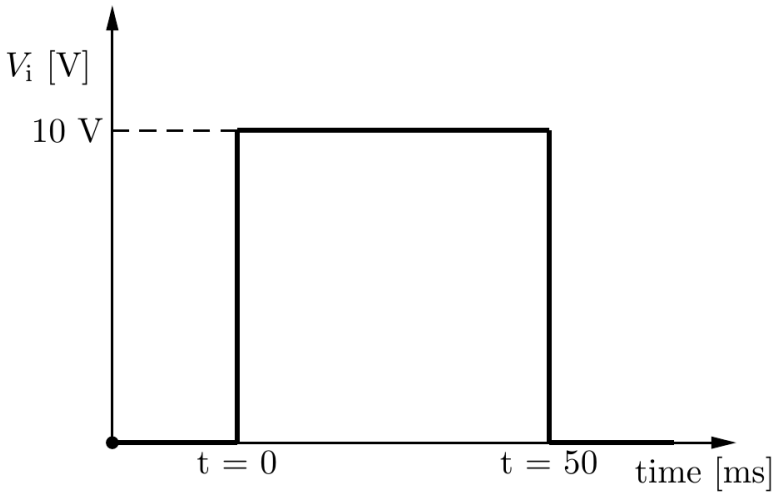

Fig. 3

18 State algebraically (i.e. in terms of R_1, R_2 & C_3) **both** time constants associated with the circuit in Fig. 2. **(1 mark)**

19 Calculate the voltage across the capacitor for t = 9 ms **(1 mark)**

20 Name the circuit in Fig. 4. **(1 mark)**

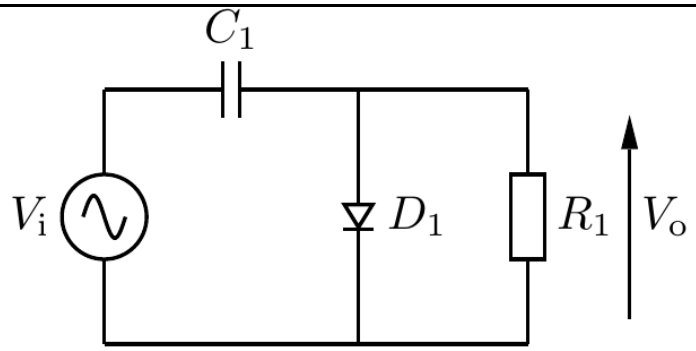

Fig. 4

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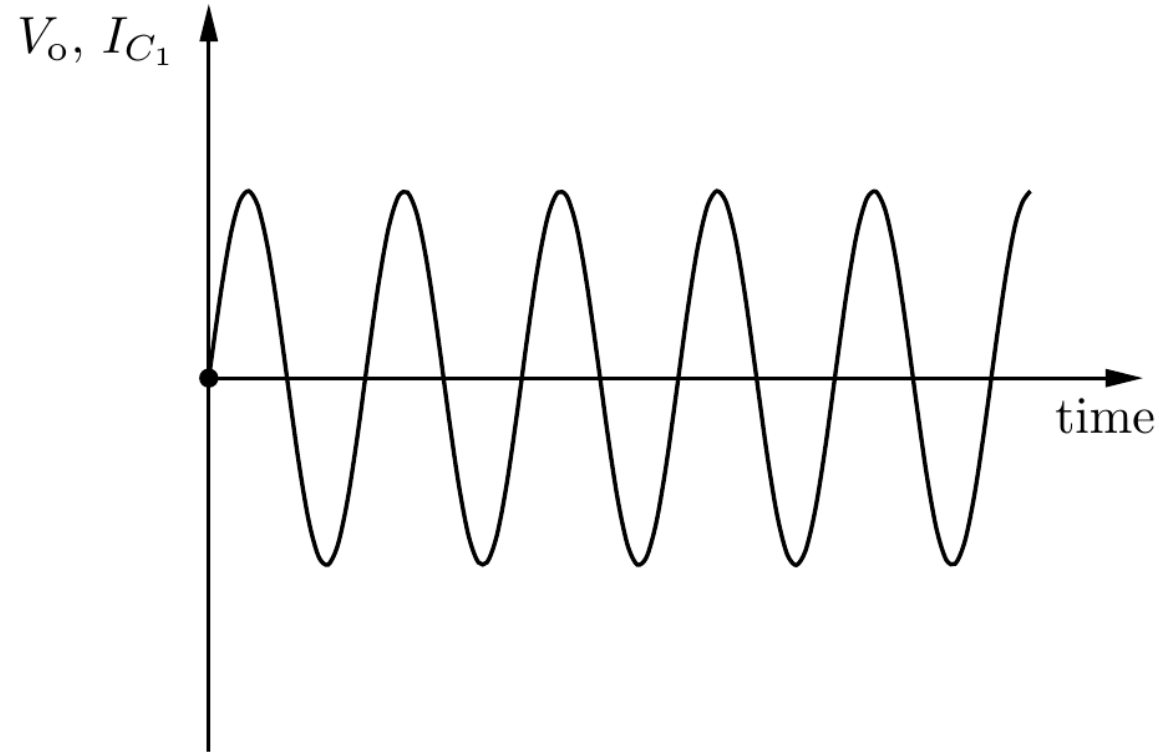
Consider the circuit in Fig. 4 driven by the sine wave input below. Sketch on the axes below

- The output voltage, V_o
- The capacitor current, I_{C1}.

(2 marks)



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