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

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \qquad \mu = \frac{q\tau}{m^*}$$

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

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

Energy of a photon $=hc/\lambda$

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

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

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

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

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

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

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

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

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

		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.	B
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.	A
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.	C
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.	B, D (1/2 mark each)
5	What is the resistance of a rod that is 0.1 m long, 5×10^{-6} m^2 in cross-sectional area, and which has a conductivity of 500 Ω^{-1}m^{-1} (*use the appropriate equations on the first page*).	40Ω
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.	B
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*)	0.61

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?	Increase by 50 times (1/2 mark for each point)
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.	D
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.	C
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}?	2.1 x 10^{-3} 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.	D
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)**

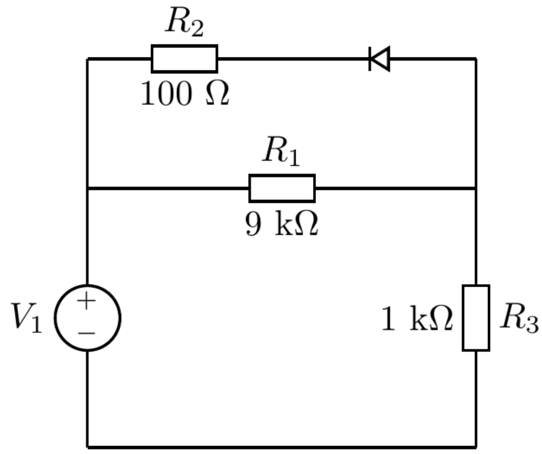


Fig. 1

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)

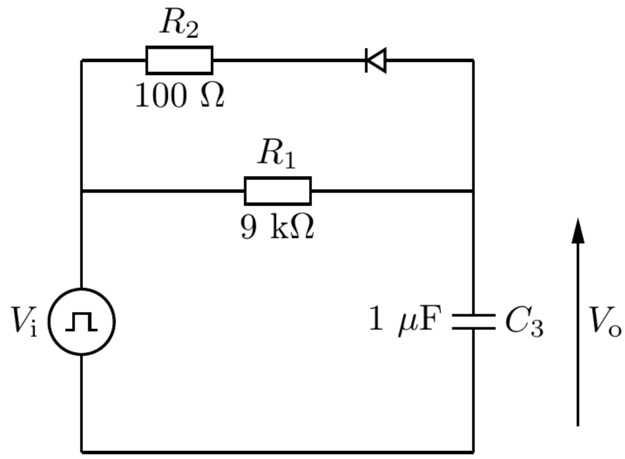


Fig. 2

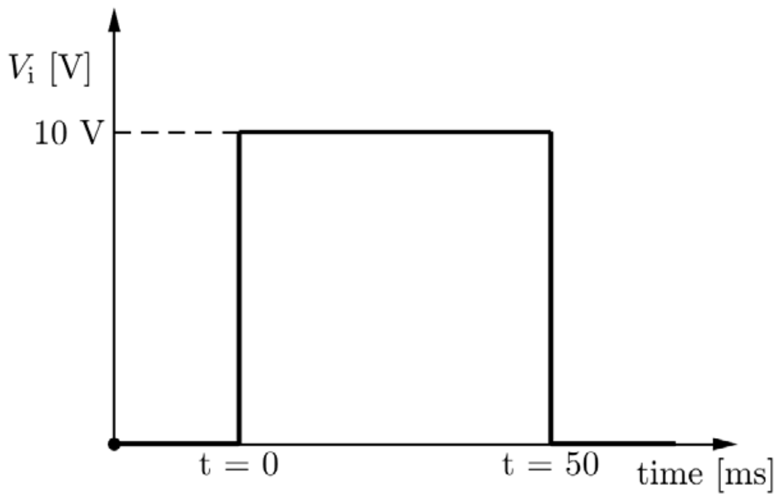
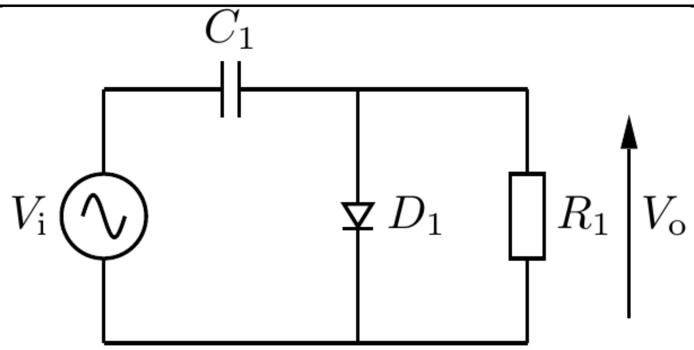


Fig. 3

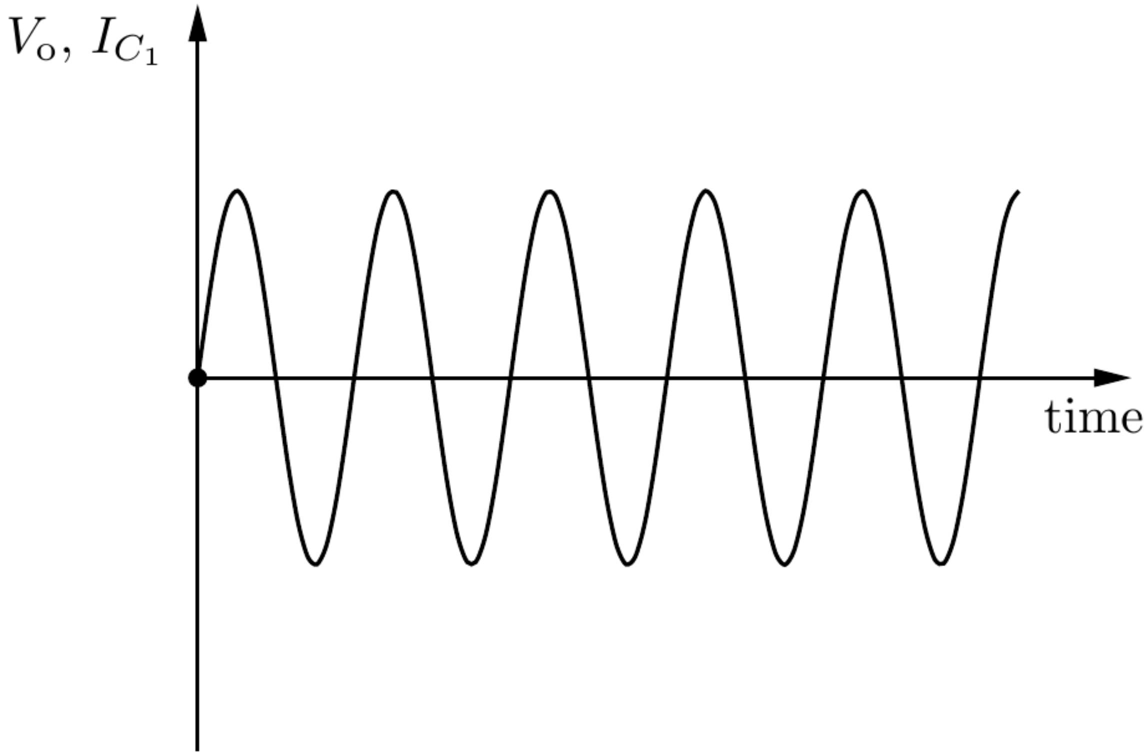
18	State algebraically (i.e. in terms of R_1, R_2 & C_3) **both** time constants associated with the circuit in Fig. 2. **(1 mark)**
19	Calculate the voltage across the capacitor for t = 9 ms **(1 mark)**
20	Name the circuit in Fig. 4. **(1 mark)**  Fig. 4

21

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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10 *Complete the following statement correctly:* As the temperature is increased from room temperature the resistivity of an intrinsic semiconductor

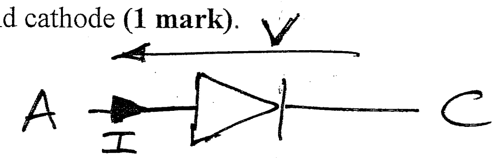
A: will decrease as extra electrons and holes are created to become free to move in the material.
B: will decrease as the effective masses of the electrons and holes become less and so they become easier to move
C: will increase as the effective masses of the electrons and holes become more and so become harder to move
D: will stay the same as the resistivity depends on the materials properties, such as the defect density in the material and these do not change with temperature.

11 A very short pulse of light is shone uniformly onto an n-type semiconductor sample, creating 10^{20} m^{-3} electron-hole pairs. The minority carrier lifetime is 100 ns. How many holes are left after 0.5 μs? [Hint: the equation you need to use is in the form of an exponential decay with time]

12 Which ***two*** of the following statements are true:
For an LED to emit light:
A. A pn junction is required
B. It needs to be forward biased
C. It needs to be reverse biased
D. It can be made from silicon

2

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)**

0.7 V ACCROSS THE DIODE WHERE THE ANODE IS MORE POSITIVE THAN THE CATHODE AND NO CURRENT FLOWS IN THE DIODE

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

IF DIODE NOT CONDUCTING,

$I_{R_2} = 0$ AND $V_D = 0.7V$

$\therefore \; V_{R_1} = 0.7V$

$I = V_{R_1}/R_1 = \frac{0.7}{9k\Omega}$

$V_1 = -0.7 - \left(\frac{0.7}{9k\Omega} \cdot 1k\Omega\right)$

$= -0.777\,V$

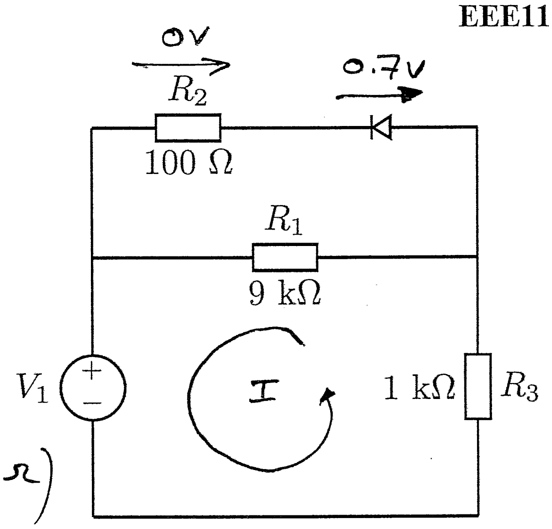


Fig. 1

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

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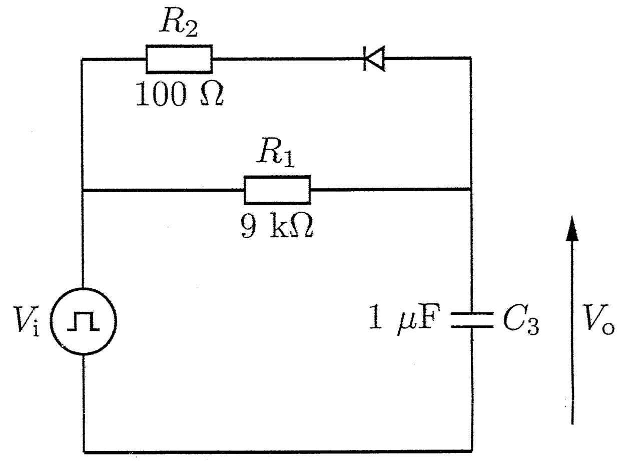


Fig. 2

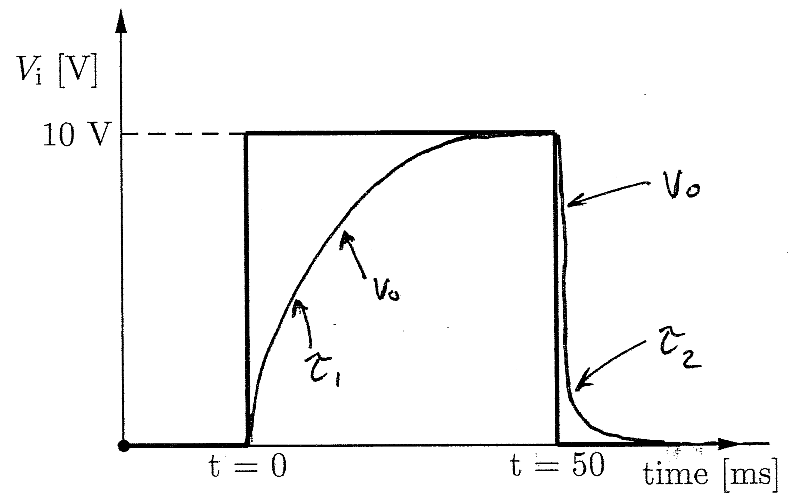


Fig. 3

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)**

$\tau_1 = R_1 C_3$, $\tau_2 = (R_2 // R_1) \cdot C_3$

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

6.3212 V

NOTE IT IS NOT REQ'D TO SHOW WORKING !!

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

ACCEPT "CLAMP" OR "NEGATIVE CLAMP"

NOT "POSITIVE CLAMP" !!!

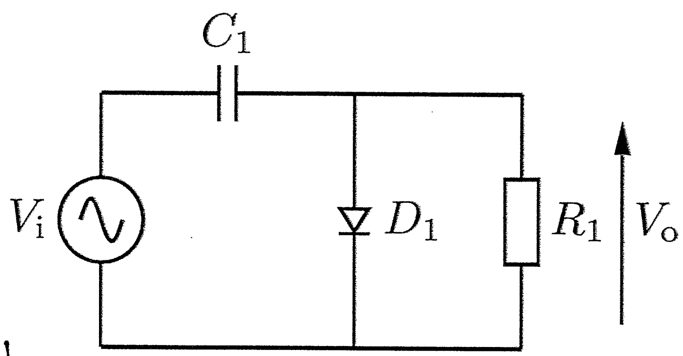
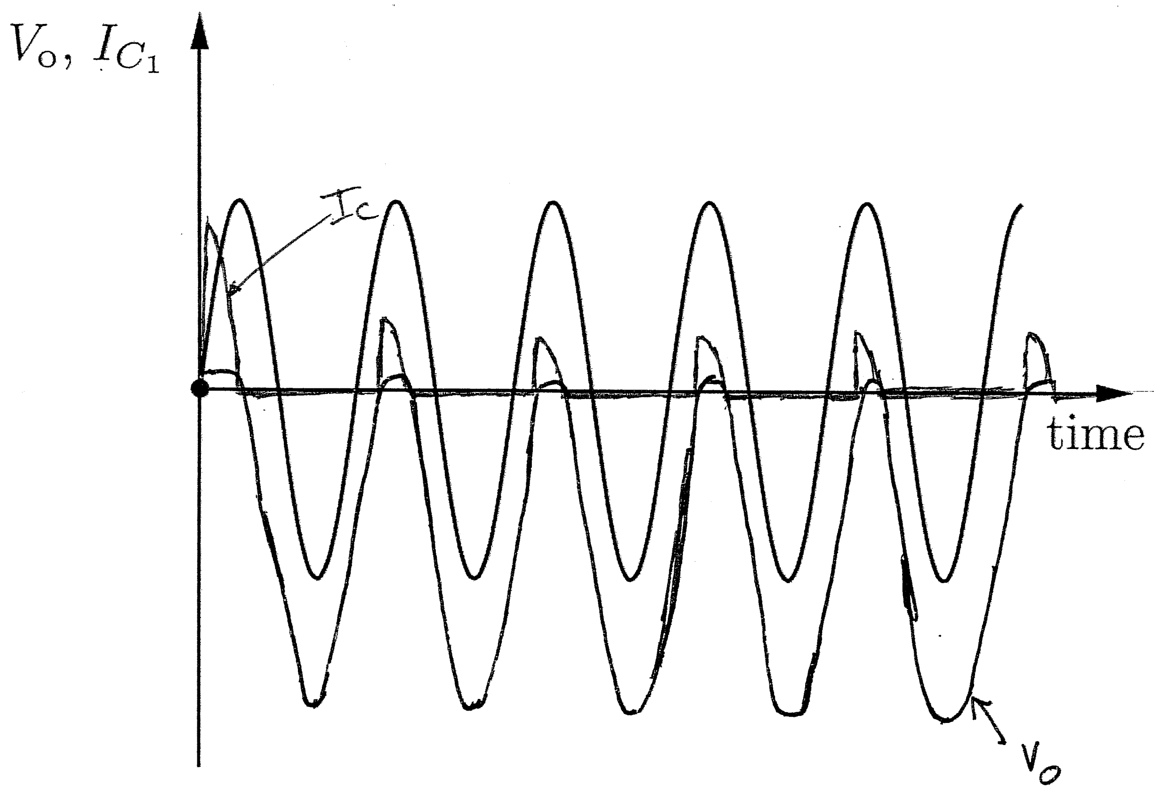


Fig. 4

21 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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