EEE118 Test solutions 2012/2013.

1. $v = \frac{qE\tau}{m^*} = \frac{\left(1.60\times10^{-19}\right)\times 200\times 1\times 10^{-10}}{0.1\times\left(9.11\times10^{-31}\right)} = 3.5\times10^{4}\,ms^{-1}$

2. **D**

3. **D** (Redistribution of the fixed charges)

4. $\rho = {1}/{nq\mu} = {1}/{\left(1\times10^{23}\right)\times\left(1.6\times10^{-19}\right)\times(0.7)} = 8.9\times10^{-5}\,\Omega\mathrm{m}$

5. $R = \frac{l}{\sigma A} = \frac{0.1}{500\times\left(3\times10^{-6}\right)} = 67\Omega$

6. **B** (positively charged hole in a bond)

7. $\sigma = nq\left(\mu_e + \mu_h\right) = \left(1.45\times10^{16}\right)\times\left(1.60\times10^{-19}\right)\times\left(0.12+0.045\right) = 3.82\times10^{-4}\,\Omega^{-1}\mathrm{m}^{-1}$

8. $n_p = {n_i^2}/{p} = \frac{\left(1.45\times10^{16}\right)^2}{\left(4\times10^{24}\right)} = 5.3\times10^{7}\,\mathrm{m}^{-3}$

9. **D** (forbidden gap near VB edge)

10. **A** (extra electrons and holes generated)

11. $p = p_0 \exp\left(-\frac{t}{\tau_h}\right) = \left(1\times10^{20}\right)\exp\left(-\frac{500\mathrm{ns}}{100\mathrm{ns}}\right) = 6.7\times10^{17}\,\mathrm{m}^{-3}$

12. **A** and **B**

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

EEE118 Electronic Devices and Circuits

Mid-year test Jan 2013

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, $k = 1.38\text{x}10^{-23}$ 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 $= hc/\lambda$

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

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

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

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

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

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

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

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	A certain semiconductor has an electron effective mass of $0.1m_e$ and an effective scattering time of $1\text{x}10^{-10}$ s. Calculate the drift velocity of the electron for an applied field of 200 Vm^{-1}.	

2	Which ***one*** of the following statements about the built-in voltage of a diode is true? **A.** electrons and holes are repelled from the junction towards the surface of the material. These surface charges lead to a voltage across the diode which can be measured. **B.** n-type material is negatively charged and p-type material is positively charged, so when they are put together we get a field. **C.** It is created by the placing of an external bias across the device. **D.** It is created by the recombination of electrons and holes in the region around the p-n junction leaving ionized donor and acceptor atoms which cannot move and form a built-in field and voltage.	
3	Which ***one*** of the following statements is true: A dielectric is inserted between two capacitor plates. The capacitance will: **A.** Decrease since the dielectric can absorb charges from the capacitor plates. **B.** Decrease due to current flowing in the dielectric between the plates **C.** Not change. The only reason dielectrics are used in making capacitors is that it is an easy way to hold the plates a fixed distance apart. **D.** Increase since the fixed charges in the dielectric can change their distribution to oppose an electric field applied across the capacitor. **E.** Increase as the charges from the dielectric travel to the capacitor plates.	
4	What is the resistivity of a material with a free electron concentration of $1x10^{23}$ m^{-3} and mobility of 0.7 $m^2V^{-1}s^{-1}$.	
5	What is the resistance of a rod that is 10 cm long, $3mm^2$ in cross-sectional area, and which has a conductivity of 500 $\Omega^{-1}m^{-1}$.	
6	Which one of the following statements correctly describes a "hole" in a semiconductor: **A.** When an electron is given sufficient energy it leaves a bond. All these free electrons repel each other, move to the sample surface, leaving a large positively charged region called a hole in the middle. **B.** When an electron is given sufficient energy to leave its bond then it leaves behind a hole in the bond it left. This hole is positively charged as the electron that left was negatively charged. **C.** A hole is a place in the semiconductor crystal where an atom is missing. **D.** When an electron is given sufficient energy to leave a bond it can move freely round the material, we call this negatively charged free particle a hole as it behaves as if it has a negative mass. **E.** When energy is applied to a material, atoms can jump out of their bonds and travel around the material, the atoms are positively charged ions and are called holes as they behave as a hole that electrons can fall into.	
7	In an intrinsic piece of silicon the electron and hole density is equal at $1.45x10^{16}$ m^{-3}. The mobility of electrons and holes are 0.12 $m^2V^{-1}s^{-1}$.and 0.045 $m^2V^{-1}s^{-1}$, respectively. What is the conductivity of the material?	
8	A piece of Si with the same intrinsic carrier density as in question 7 above is doped to give a hole carrier density of $4x10^{24}$ m^{-3}. What is the density of free electrons in this sample?	
9	Using a band description, the energy state associated with an acceptor atom will be: A. Inside the conduction band B. In the forbidden gap near the conduction band edge C. In the middle of the forbidden gap D. In the forbidden gap near the valence band edge E. Inside the valence band.	

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

13 The circuit in Fig. 1 shows an RC network driven by a voltage pulse, v_i. Circle the correct expression for the time domain function of the circuit. **(1 mark).**

a. $v_o = A_0\left(1 - \exp\left(\frac{t}{\tau}\right)\right)$

b. $v_o = A_0\left(1 - \exp\left(-\frac{t}{\tau}\right)\right)$

c. $v_o = A_0\left(\exp\left(-\frac{t}{\tau}\right)\right)$

d. $v_o = A_0\left(\exp\left(\frac{t}{\tau}\right) - 1\right)$

e. $v_o = -A_0\left(1 + \exp\left(-\frac{t}{\tau}\right)\right)$

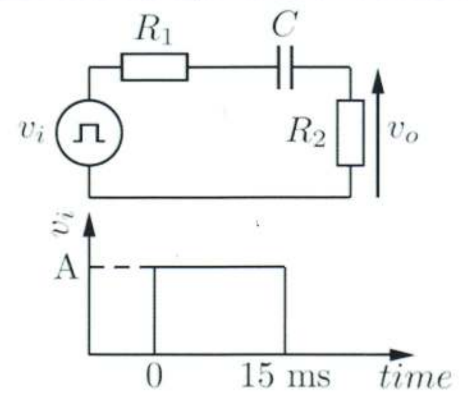


Fig. 1: Above, an RC circuit. Below, input voltage, v_i, graph.

14 What is the relationship (in terms of R_1 and R_2) between A_0 and A (the pulse amplitude of v_i on the graph in Fig. 1) in Q13. **(1 mark).**

A_0 = R2 / (R1+R2)

15 What is the relationship between τ and R_1, R_2 and C in Q13. **(1 mark).**

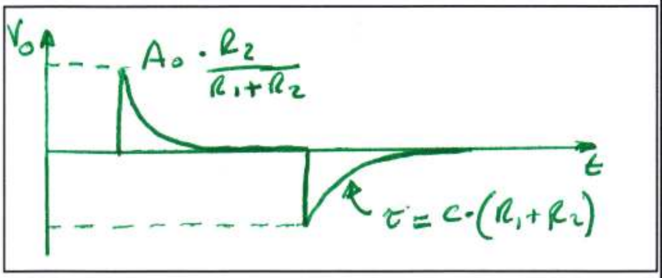
τ = C·(R1 + R2)

16 For the circuit in Q13, sketch the output voltage v_o due to the input shown in Fig. 1. **(2 marks)**

Anotate the sketch with,

a. The peak value of the voltage in terms of the circuit components R_1, R_2. **(1 mark).**

b. The time constant in terms of the circuit components R_1, R_2 and C. **(1 mark).**



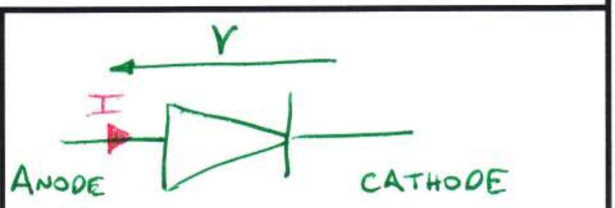
17 Assuming A = 10 V, $R_1 = R_2 = 1$ kΩ and C = 1 μF what is the value of v_o at $t = 2$ ms? **(1 mark).**

1.8394 V

18 What is the significance of 2 ms in this circuit? **<u>(2 marks)</u>.**

2ms is the time constant for the values in Q17

19 Draw a circuit symbol for a diode. **(1 mark).**



20 Label the anode and cathode in Q19. **(1 mark).**

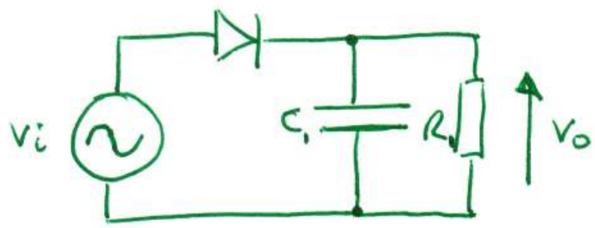
21 Add two arrows on your diagram in Q19. Show,

- the direction of current flow when the diode is *forward biased* above the turn on voltage. Label this arrow *I*. **(1 mark).**
- the direction of the voltage which biases the diode. Label this arrow *V*. **(1 mark).**

22 What does "on the edge of conduction" mean when considering a diode circuit? **(2 marks)**

Anode is at 0.7 V greater potential than the cathode but no current is flowing in the diode.

24 Sketch a peak detector circuit. Label the components and the input and output voltages of your circuit. **(1 mark).**



$\tau = R_1 . C_1$

25 Write on the time constant, τ, of the circuit in terms of the component names. **(1 mark).**

26 Give one application of a peak detector, **<u>other than the detection of AM radio</u>. (1 mark).**

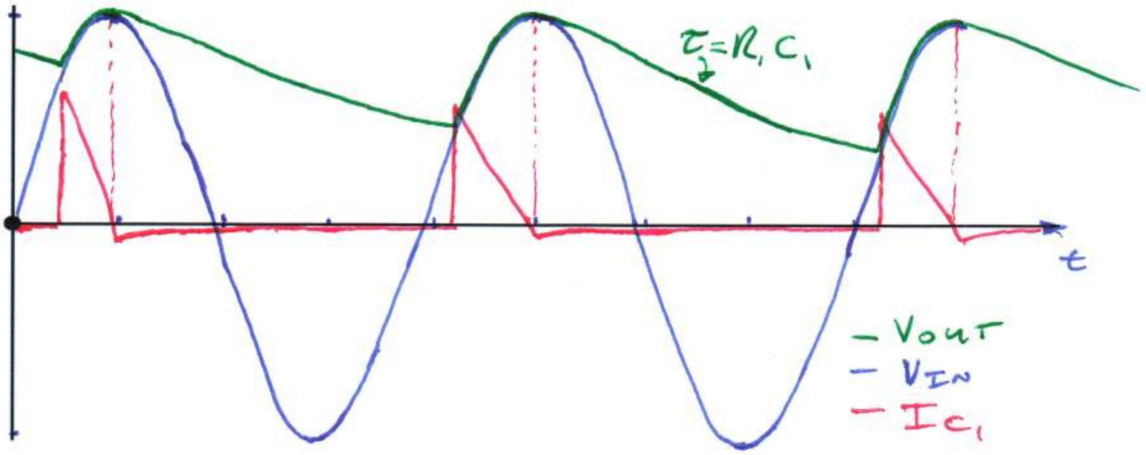
"Linear power supply" (any plausible answer is ok, but very generic answers gain no mark)

27 On the axes below, sketch:

- A sine input voltage waveform.
- A peak detector output voltage waveform.
- The capacitor current.

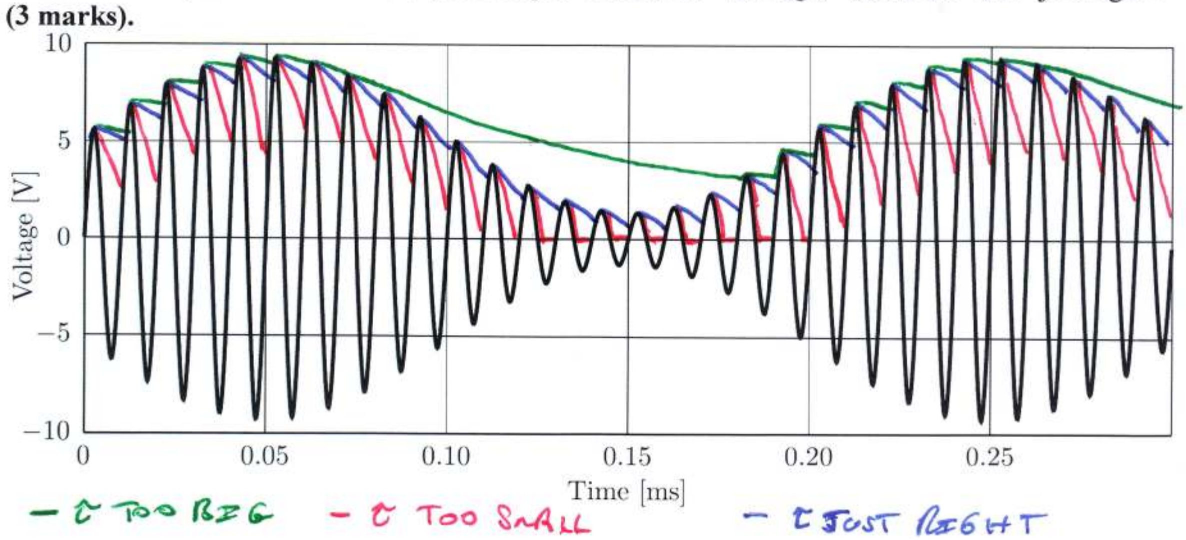
(3 marks)

Label the axes **and** write on the graph, the value of τ in terms of the components names you used in Q24 and Q25. Draw an arrow to link your expression for τ and the output waveform. **(1 mark).**



27 On the axis below, a sine wave modulated AM radio signal has been drawn. This voltage signal is passed into the input of a peak detector.

Sketch on the axis below, three output voltage waveforms showing the effect of changing the time constant of the peak detector. Label your output waveforms "too big", "too small" and "just right". **(3 marks).**



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