Department of Materials Science and Engineering
University of California at Los Angeles

Question	Points
1 (24 pts)	
2 (38 pts)	
3 (22 pts)	
4 (16 pts)	
Total	

MSE 104, Spring 2022 Quiz No. 2

Show all work and include units to receive full credit.
Check that all parts are answered.

1. Electrical Conductivity of Metals

(a) Does sterling silver (an alloy of silver) have higher, same, or lower conductivity than that of pure silver? Justify your answer (6 pts).

(b) State for copper whether electrical conductivity will increase or decrease with increasing temperature. Justify your answer. (6 pts)

(c) Describe in your own words what an intrinsic semiconductor is? (3 pts)

(d) Describe in your own words what an extrinsic semiconductor is? (3 pts)

(e) When ceramic superconductor was immersed in liquid nitrogen and cooled below its critical temperature, it was able to levitate which of the following (6 pts)?

A. itself above liquid surface
B. a magnet
C. itself above glass surface
D. a sugar cube

2. Semiconductors

(a) Draw a schematic plot and label all characteristic regions for the carrier concentration n versus temperature T for two materials (10 pts):

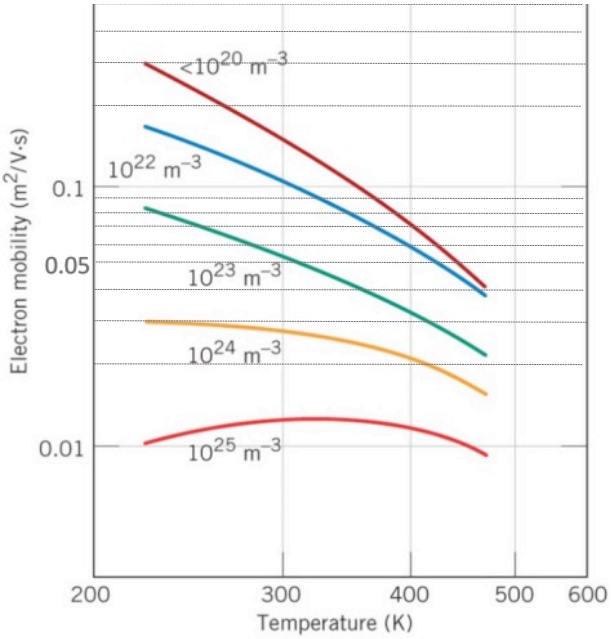
A. an extrinsic n-type semiconductor
B. an intrinsic semiconductor.

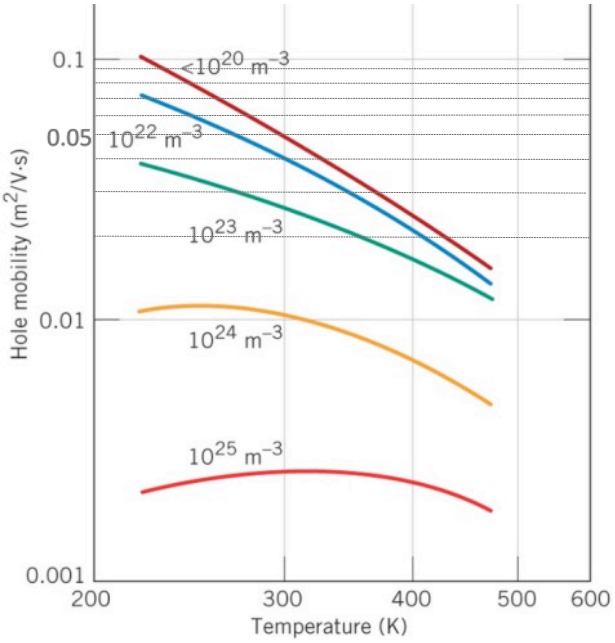
(b) Name the majority charge carriers in cadmium (Cd) doped GaN semiconductor (4 pts)

(c) Name the majority charge carriers in gallium (Ga) doped CdS semiconductor (4 pts)

(d) A phosphorus (P)-doped silicon has at room temperature a conductivity of 0.25 Ω^{-1} m^{-1}. What is the concentration of the majority charge carriers (in m^{-3})? The mobilities of electrons and holes in doped silicon as function of temperature are shown in graphs below (logarithmic scale). You will be given full credit as long as are within reasonable error limits and your process is correct (10 pts)

(e) Calculate the electrical conductivity of Si doped with 1 x 10^{22} m^{-3} of boron at 350K. (10 pts)





3. Electric Properties of Ceramics

(a) Briefly describe the three main origins of polarization in solid-state materials. (10 pts)

(b) A 1.0 kV voltage is applied on a dielectric film capacitor having an area of 100 cm^2 and a thickness of 10 μm (micrometers). The dielectric material has a dielectric constant of 3.0. Compute the capacitance and the stored energy density (J/cm^3). (12 pts)

4. Optical Properties

(a) Give a 1-2 sentence explanation why adding lead (Pb) oxide in glass increases its index of refraction (4 pts)

(b) ZnO has a bandgap of 3.4 eV. Is a ZnO crystal transparent, opaque, or colored? Provide a 1-2 sentence explanation (6 pts)

(c) A laser beam is (choose one answer) (6 pts)

A. coherent
B. of high intensity
C. highly collimated
D. all of the above

Useful equations, units, tables and constants:

$N_A = 6.02 \times 10^{23}$/mole Units: $(\Omega\text{-m})^{-1} = C/(m\text{-V-sec})$

$k = 8.62 \times 10^{-5}$ eV/atom-K

$e = 1.602 \times 10^{-19}$ C

$\varepsilon_o = 8.85 \times 10^{-12}$ F/m [C/(V-m) or F is C/V]

$C = Q/V$ $E = V/l$ $p = qd$ $P = \Sigma qd/V_c$

$C = \varepsilon_o A/l$ (vacuum) $C = \varepsilon A/l$ (dielectric material)

$D_o = \varepsilon_o E$ (vacuum) $D = \varepsilon E = \varepsilon_o E + P$ (dielectric material) $\varepsilon_r = \varepsilon/\varepsilon_o$

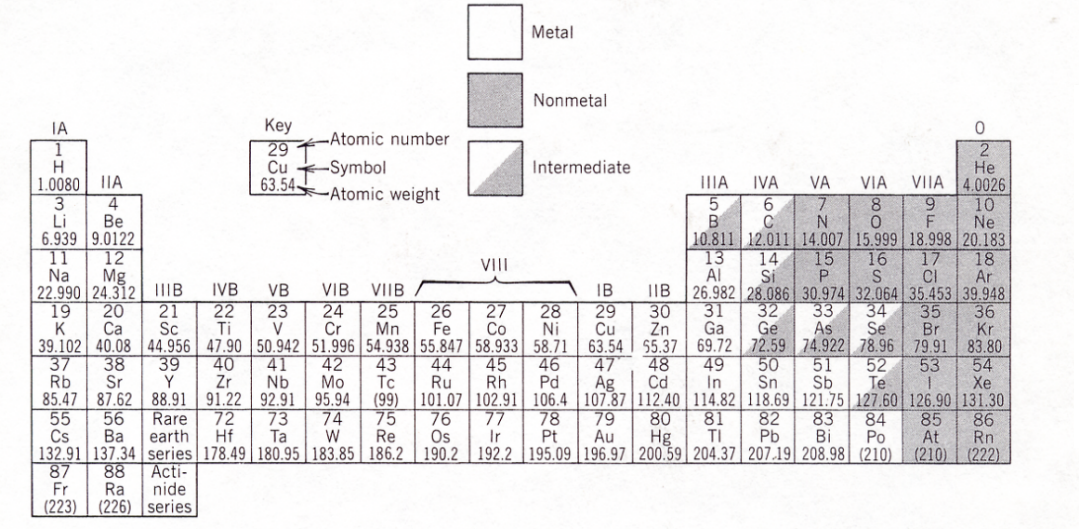
Stored dielectric energy equals to $\frac{1}{2}CV^2$

$\rho = RA/l$, $\sigma = 1/\rho$, where σ is electrical conductivity and ρ is electrical resistivity

$\sigma_{total} = n|e|\mu_e + p|e|\mu_h$ (if there are any holes)

$\sigma \approx \sigma_o \exp(-Eg/2kT)$

$\sigma \approx \sigma_o \exp(-\Delta E/kT)$



Factor by Which Multiplied	*Prefix*
10^9	giga
10^6	mega
10^3	kilo
10^{-2}	centi[a]
10^{-3}	milli
10^{-6}	micro
10^{-9}	nano
10^{-12}	pico

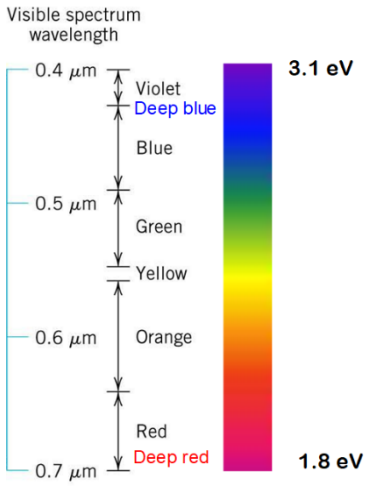


Table 18.6 Primary and Derived Units for Various Electrical Parameters and Field Vectors

		SI Units	
Quantity	*Symbol*	*Derived*	*Primary*
Electric potential	V	volt	$kg\text{-}m^2/s^2\text{-}C$
Electric current	I	ampere	C/s
Electric field strength	E	volt/meter	$kg\text{-}m/s^2\text{-}C$
Resistance	R	ohm	$kg\text{-}m^2/s\text{-}C^2$
Resistivity	ρ	ohm-meter	$kg\text{-}m^3/s\text{-}C^2$
Conductivity	σ	$(\text{ohm-meter})^{-1}$	$s\text{-}C^2/kg\text{-}m^3$
Electric charge	Q	coulomb	C
Capacitance	C	farad	$s^2\text{-}C^2/kg\text{-}m^2$
Permittivity	ϵ	farad/meter	$s^2C^2/kg\text{-}m^3$
Dielectric constant	ϵ_r	ratio	ratio
Dielectric displacement	D	$farad\text{-}volt/m^2$	C/m^2
Electric polarization	P	$farad\text{-}volt/m^2$	C/m^2