UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, April 29, 2019
DURATION: **2 hrs**

First Year

MSE160H1S – Molecules and Materials

Exam Type: A

Calculator type 3

Examiner – B. Hatton

Answer the following questions in the exam booklets.

Put your name clearly below and on all exam booklets to be handed in together.

Total marks: 105

1.

(a) Define directional and non-directional bonding, and give examples of each. [4 marks]

(b) Draw a typical interatomic potential energy curve, and show how you can use it to predict the melting point (T_m), elastic modulus (E), and the coefficient of thermal expansion (α) for a material. [5 marks]

2.

(a) Briefly cite the main differences among ionic, covalent, and metallic bonding. [3 marks]

(b) For each of the three types of bonding, what is the general relationship on the bonding type to the following physical properties, and why: [9 marks]

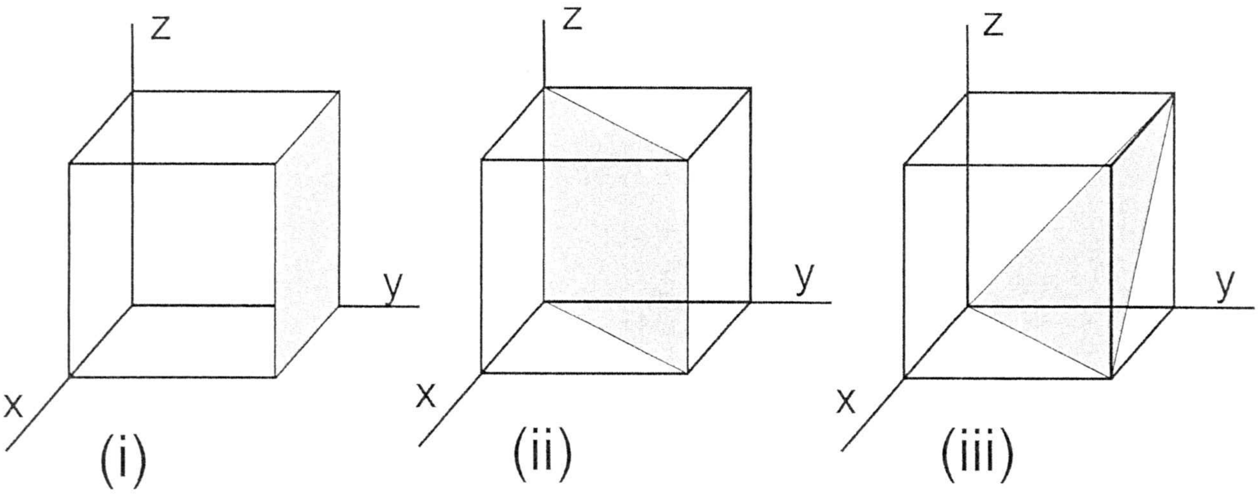
(i) atomic packing factor

(ii) electrical conductivity

(iii) mechanical ductility

3.

(a) Identify the following planes: [6 marks]

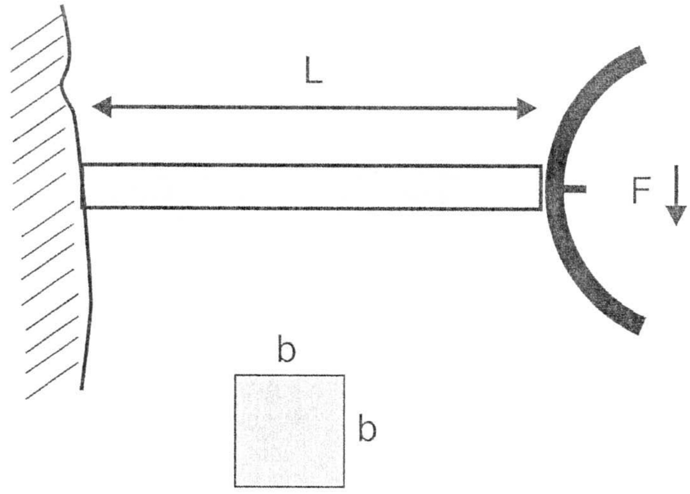


(b) What is an example of a close-packed in an FCC structure? [2 marks]

(c) Why does slip occur first on close-packed planes (how do they represent planes of weakness?) [3 marks]

4.

A company needs to design a support for a satellite dish, as a cantilevered beam off the side of a cell tower. The support beam should have minimum weight, and has a square cross-section (height and width, b). The length (**L**) of the beam is fixed by the design, and it must support an applied load F (weight of the dish), without failure.



(a) Give two reasons why minimum weight would be an important design objective in this case? [2 marks]

(b) Without considering cost, derive a materials performance index for the support beam. [5 marks]

(c) Of the four materials in the table below, which material would you recommend? (show your reasoning). [5 marks]

Material	**Density** (ρ, g-cm^{-3})	**Young's Modulus** (E, GPa)	**Strength** (σ, MPa)	**Cost** (\$ kg^{-1})
316 Steel	7.8	202	872	5
Polyethylene	1.2	5.1	85	2
Carbon fiber composite	2.7	220	980	10
Titanium	4.3	114	1250	20

(d) If cost *is* taken into account, which material would you choose? [6 marks]

(e) Besides this performance index, what other factors would the company have to consider in choosing a material? [3 marks]

(f) In general, how does making the cross-section hollow increase the structural performance of a beam? [3 marks]

5.

(a) How does reducing the grain size make metals stronger? [5 marks]

(b) How do substitutional and interstitial impurities make alloys stronger? [5 marks]

6.

(a) As demonstrated in class, the strength of brittle glass decreases significantly when scratched. But for a metal (copper) bar, it made little difference. Why are these two materials so different? [4 marks]

(b) A manufacturer of ceramic parts has discovered that many parts are failing at a fracture strength less than the required minimum (420 MPa). In one batch, parts were found to fail at an average applied stress 10 MPa lower than the minimum. If the fracture toughness for Al_2O_3 is 3.2 MPa $m^{0.5}$, calculate what the average critical flaw size is for this failed batch. (Assume Y = 0.75). [6 marks]

(c) Why is flaw detection equipment used regularly and repeatedly for engineering components? (ie; a pipeline is inspected every month). Name **three** physical mechanisms that can cause flaws to increase in size over time? [4 marks]

7.

(a) A plastic door handle was found to break unexpectedly, and catastrophically (into two pieces), in an old car. Draw a sketch of the structural loading on the door handle, and describe how the handle failed (describe three stages involved). [5 marks]

(b) How is Gorilla Glass (chemically-strengthened glass) made stronger than normal glass? ie; how does it prevent surface flaws (cracks) from propagating through the material? [5 marks]

8.

(a) A carbon steel wire 3 mm in diameter is to offer a resistance of no more than 20 Ω. If the conductivity of the steel is 0.6×10^7 $(\Omega\ m)^{-1}$, calculate the maximum wire length. [4 marks]

(b) How does electronic band structure explain why some materials have high conductivity (metals) and some have very low conductivity (ceramics)? Use a diagram to explain your answer. [5 marks]

(c) At room temperature the electrical conductivity of Si is 25 $(\Omega\cdot m)^{-1}$. The electron and hole mobilities are 0.06 and 0.02 $m^2/V\cdot s$, respectively. Calculate the intrinsic carrier concentration for Si at room temperature. [3 marks]

(d) Briefly, why does the conductivity of semiconductors increase dramatically when adding dopants (impurities)? [3 marks]