**EXAM I**
**MSEG 302**
**Spring 2018**

**Introduction to Materials Science and Engineering**

**The University of Delaware**

**March 22, 2018**

**Prof. David C. Martin**

Name: Key

Honor Pledge:

"I have neither given nor received aid on this examination, nor have I witnessed any one else giving or receiving such assistance".

Sign here only if true: DCM

Useful information:

| | |
|---|---|
| Avogadro's number: $N_{av}$ | $6.02 \times 10^{23}$ molecules/mol |
| Boltzmann's constant: k | $1.38 \times 10^{-23}$ J/atom-K |
| Gas constant: R | 8.314 J/mol-K |
| Electron charge: e | $1.602 \times 10^{-19}$ C |
| 1 MPa = 145 psi | |

A

Score:

1. 16
2. 18
3. 20
4. 16
5. 16
6. 22

| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Tot |
|---|---|---|---|---|---|---|---|
| $\bar{x}$ | 10 | 12 | 19 | 11 | 9 | 16 | 76 |
| $\sigma$ | 4 | 4 | 2 | 5 | 4 | 5 | 15 |
| Max | 16 | 18 | 20 | 16 | 16 | 22 | 105 |
| Min | 0 | 0 | 10 | 0 | 0 | 2 | 32 |

108

1. The following curves show the potential energy (on the y-axis) as a function of intermolecular spacing r (on the x-axis) for four different hypothetical materials (labeled 1, 2, 3, and 4). Each of these curves corresponds to a total energy $E_{tot} = E_A + E_B$ that is a sum of an attractive energy $E_A = -A/r$, and a repulsive energy $E_B = B/r^8$, where A and B are constants.

What is the material that would have:

a) the highest equilibrium intermolecular spacing? $r_0$ @ minimum __4__

b) the lowest equilibrium intermolecular spacing? __1__

c) the highest melting temperature? E bond @ $r_0$ __3__

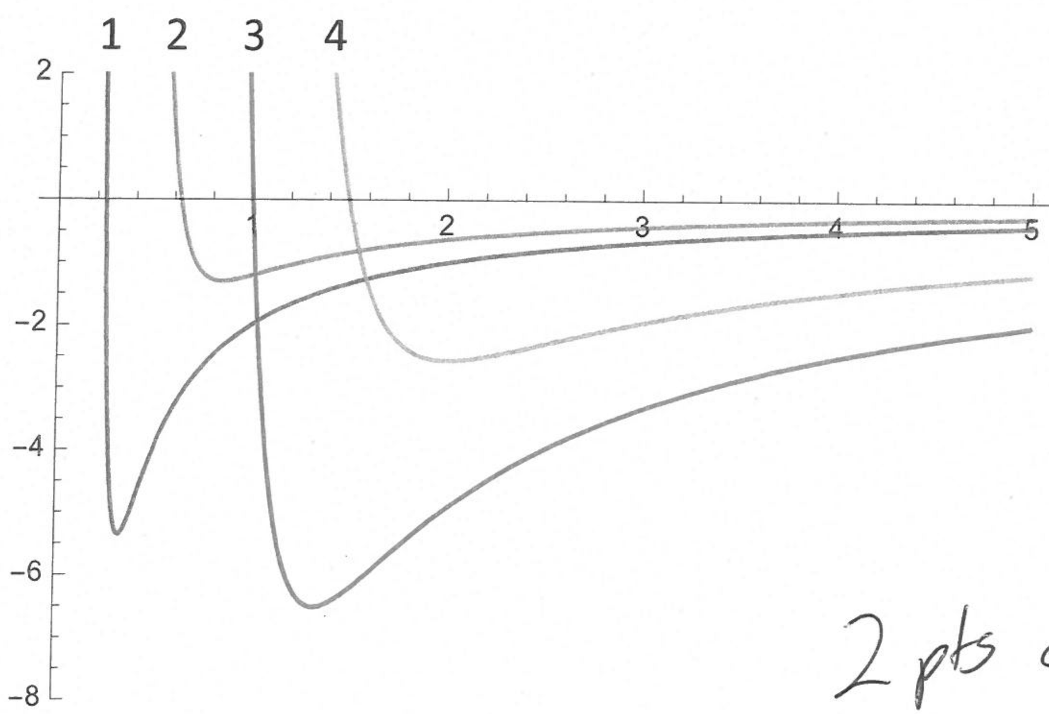
d) the lowest melting temperature? __2__

e) the highest Young's modulus? curvature @ $r_0$ __1__

f) the lowest Young's modulus? __4__

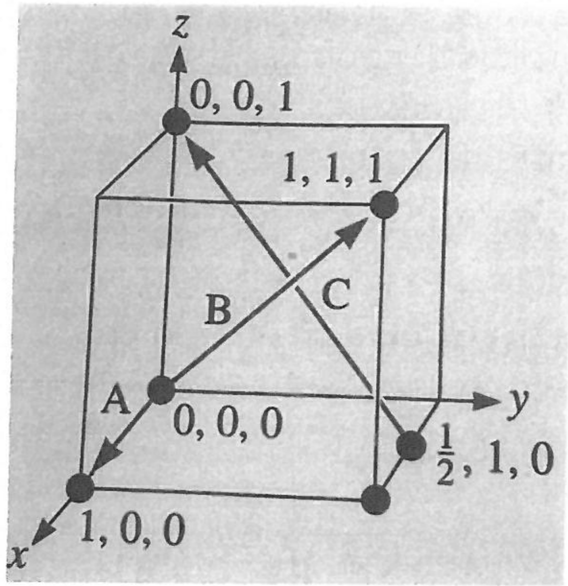
g) the highest thermal expansion coefficient? asymmetry @ $r_0$ __4__ (2)

h) the lowest thermal expansion coefficient? __1__



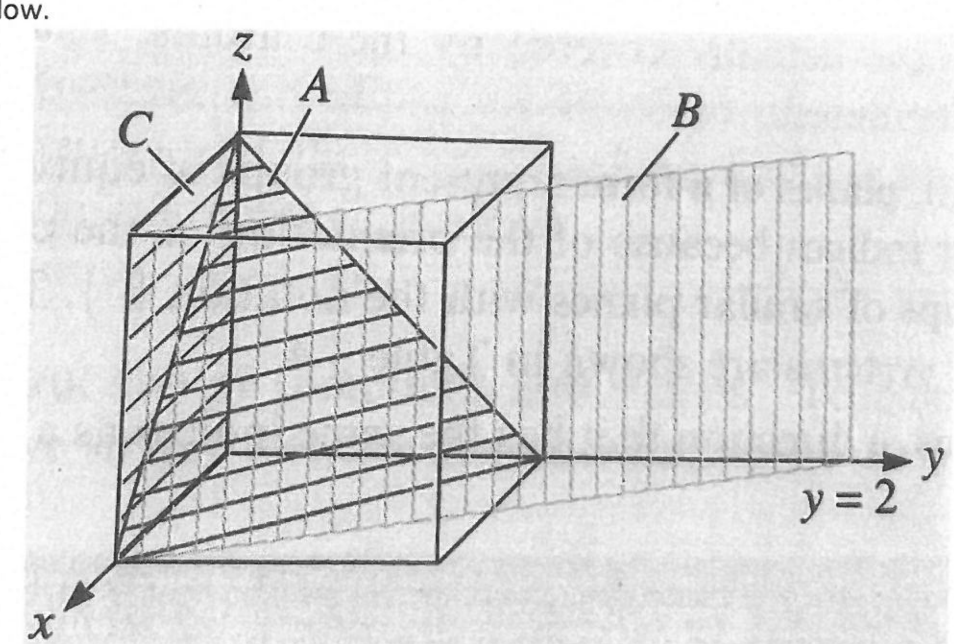

2 pts each
16 max

2. Determine the [hkl] indices for the vectors A, B, and C; shown with respect to a unit cell in the figure below.




A: [100]
B: [111]
C: [$\bar{1}\bar{2}$2]

Determine the Miller indices for the planes A, B, and C; shown with respect to a unit cell in the figure below.




A: (111)
B: ($\bar{2}\bar{1}$0) or (210)
C: (010)

3 pts each
18 max

3. Fill in the blank with the letter of the most appropriate answer.

A. dislocation
B. grain boundary
C. slip plane
D. slip direction
E. interstitial impurity
F. substitutional impurity
G. vacancy
H. Young's modulus
I. elongation at failure
J. engineering strain
K. Poisson's ratio
L. yield strength

a. Point defect involving a small atom inserted between the matrix atoms E

b. Planar interface between two crystals B

c. Linear defect in a crystal A

d. Plane on which a dislocation moves easily C

e. Lattice site where an atom is missing G

f. Equal to ratio of stress to strain under small tensile deformations H

g. Stress at which significant plastic deformation begins L

h. Point defect in which one type of atom replaces another on the lattice F

i. Equal to the change in length of a sample divided by its initial length J

j. Ratio of the lateral strain to the axial strain in tensile deformation K

4. A plate of iron is used to limit the escape of carbon from a furnace at 720 C. The concentration of carbon just inside the furnace is held constant at 500 g/m$^3$, and is zero outside. After steady-state diffusion has been established through the plate, it is determined that the total flux of carbon is J = 2.5 x 10$^{-9}$ kg/m$^2$-s.

$D = D_o \exp(-Q_d/RT)$

For carbon diffusing in iron,

$D_o = 1.1\ 10^{-6}$ m$^2$/s
$Q_d$ = 87.4 kJ/mol
R=8.314 J/mol-K

a) What is the diffusion coefficient for carbon in iron at this temperature?

b) What is the thickness of the iron plate?

c) What would be the diffusion coefficient for carbon in iron at 800 C?

d) What would be the carbon flux if the furnace temperature was raised to 800 C?

a) $T_K = 720 + 273 = 993$

$D = D_o \exp(-Q/RT) = 2.78 \times 10^{-11}\ m^2/s$

b) $J = -D\left(\frac{\partial C}{\partial X}\right) = -D\left(\frac{\Delta C}{\Delta X}\right)$

$\Delta C = 500\ \frac{g}{m3}$, so $\Delta X = 0.0056\ m = 5.6\ mm$
$= \frac{-D}{J}\Delta C$

c) $D_2 = 6.12 \times 10^{-11}\ m^2/sec$ @ $800C = 1073K$

d) $J_2 = D_2\left(\frac{\Delta C}{\Delta X}\right) = 5.5 \times 10^{-9}\ \frac{kg}{m^2\text{-}sec}$

4 pts each, 16 max

5. The stress-strain response for a cast iron sample is shown in the two enclosed figures of stress in Pa vs. strain (the second one is focused on the small strain region) and the table below. Calculate or estimate: $E = \sigma / \varepsilon$

a) the tensile modulus initial slope ~ $1.8 \times 10^{11}$ Pa = 180 GPa

b) the 0.2% offset yield stress $2.7 \times 10^{8}$ Pa ~ 270 MPa

c) the 0.5% total strain yield stress $3.0 \times 10^{8}$ Pa ~ 300 MPa

d) the strain at failure 0.18 ~ 18%

e) the tensile strength $4.0 \times 10^{8}$ Pa = 400 MPa

f) the modulus of resilience $\sigma_y^2 / 2E \approx 200 \times 10^{3}$ Pa = 200 kPa

g) the energy to failure ~$3.2 \times 10^{8}$ Pa (0.18) $\approx 5.8 \times 10^{7}$ Pa = 58 MPa

h) the shear modulus

$$G = \frac{E}{2(1+\nu)}$$

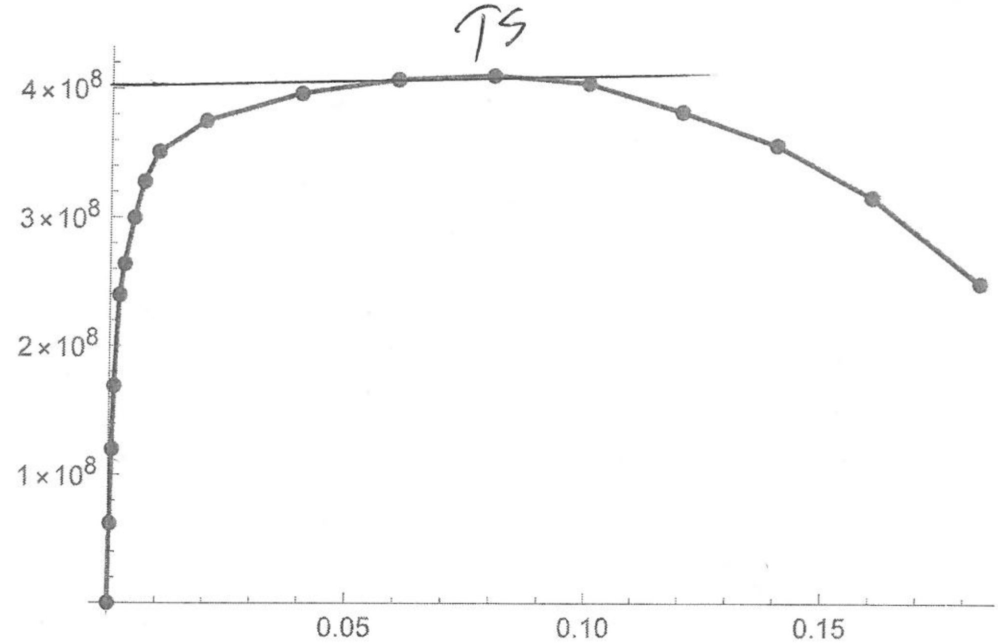
guess $\nu \sim 0.3$ gives $G \sim 69$ GPa

| Stress (Pa) | Strain |
|---|---|
| 0.00E+00 | 0.00E+00 |
| 6.21E+07 | 3.33E-04 |
| 1.20E+08 | 6.67E-04 |
| 1.69E+08 | 1.00E-03 |
| 2.17E+08 | 1.51E-03 |
| 2.40E+08 | 2.00E-03 |
| 2.64E+08 | 3.00E-03 |
| 3.00E+08 | 5.00E-03 |
| 3.28E+08 | 7.00E-03 |
| 3.51E+08 | 1.00E-02 |
| 3.75E+08 | 2.00E-02 |
| 3.96E+08 | 4.00E-02 |
| 4.07E+08 | 6.00E-02 |
| 4.10E+08 | 8.00E-02 |
| 4.04E+08 | 1.00E-01 |
| 3.82E+08 | 1.20E-01 |
| 3.56E+08 | 1.40E-01 |
| 3.16E+08 | 1.60E-01 |
| 2.49E+08 | 1.83E-01 |

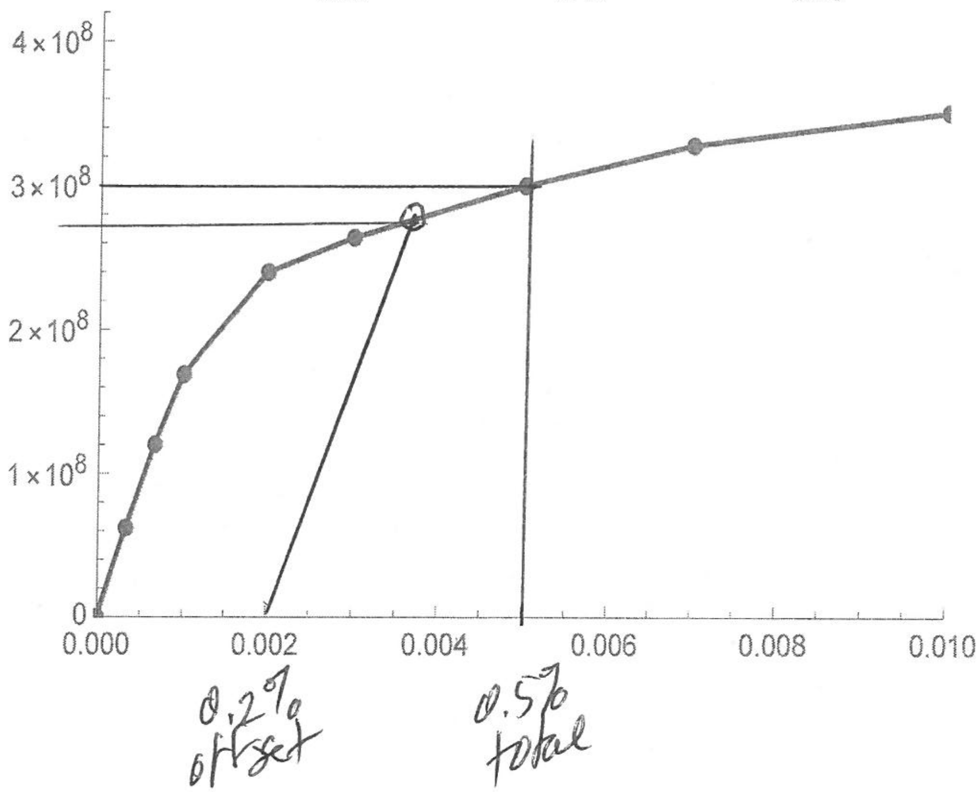
2 pts each

16 max

# Version A



TS
4×10^8
3×10^8
2×10^8
1×10^8
0.05
0.10
0.15

4×10^8
3×10^8
2×10^8
1×10^8
0
0.000
0.002
0.004
0.006
0.008
0.010
0.2%
offset
0.5%
total

6. Fill in the blank with the letter of the most appropriate answer.

A) radius of gyration
B) polydispersity index
C) step-growth polymerization
D) chain growth polymerization
E) syndiotactic polymer
F) isotactic polymer
G) polyester
H) polyamide
I) polyethylene
J) block copolymer
K) graft copolymer

a. polymer with controlled chirality (all the same) F

b. reaction involving a dibase with a diacid C

c. formed by the reaction of a diamine with a diacid H

d. polymer having extended sequences of one monomer followed by sequences of another monomer J

e. measure of the breadth of the distribution in molecular sizes of a polymer B

f. reaction involving an initiation step followed by chain propagation D

g. can be prepared by free radical polymerization I

h. polymer with controlled chirality (alternating) E

i. formed by the reaction of a diacid with a dialcohol G

l. polymer formed by appending side chains composed of one monomer to the backbone of a chain formed from another monomer K

k. estimate of the overall size of a polymer chain A