STUDENT NAME: ________________________

STUDENT NUMBER: ____________________

The University of Western Ontario
Faculty of Engineering Science

ES 1021a – Properties of Materials

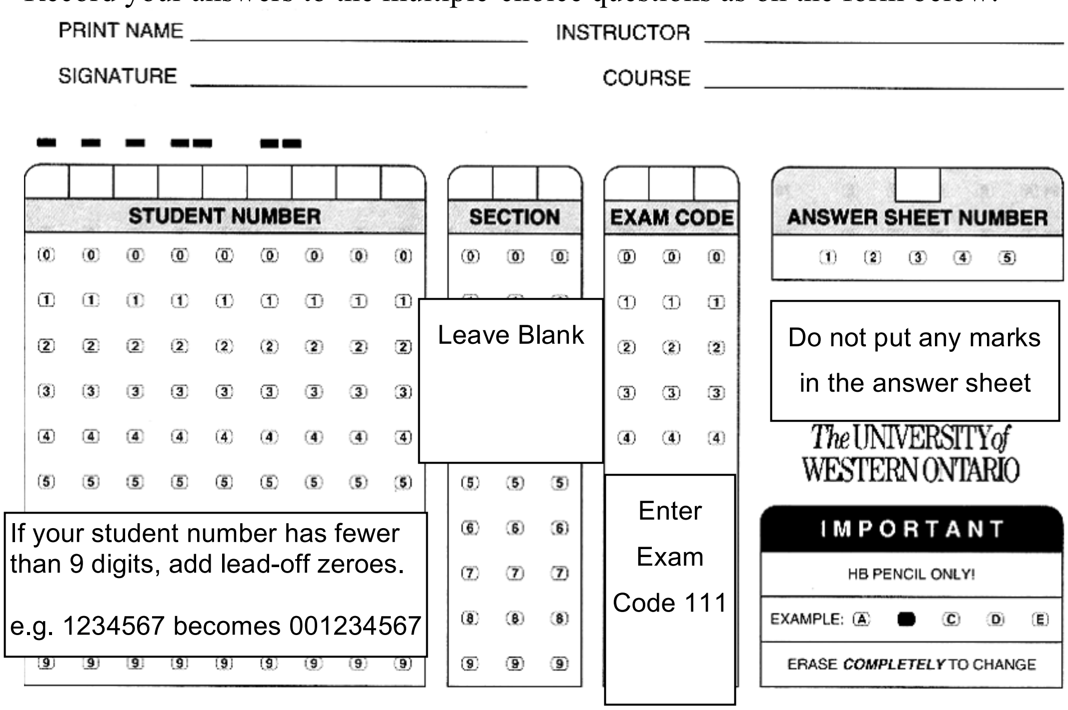
Final Exam
December 17, 2011

Time: 3 hours
Aids: Hand-written 8½” × 11” cribsheet (both sides)
Programmable calculators

Format: 60 Multiple choice questions to be answered on the form provided

UNIVERSITY POLICY STATES THAT CHEATING IS A SCHOLASTIC OFFENSE. THE COMMISSION OF A SCHOLASTIC OFFENSE IS ATTENDED BY ACADEMIC PENALTIES WHICH MIGHT INCLUDE EXPLUSION FROM THE PROGRAM. IF YOU ARE CAUGHT CHEATING, THERE WILL BE NO SECOND WARNING.

Record your answers to the multiple-choice questions as on the form below:


PRINT NAME ____________ INSTRUCTOR ____________
SIGNATURE ____________ COURSE ____________
STUDENT NUMBER
SECTION
EXAM CODE
ANSWER SHEET NUMBER
Leave Blank
Do not put any marks in the answer sheet
If your student number has fewer than 9 digits, add lead-off zeroes.
e.g. 1234567 becomes 001234567
Enter Exam Code 111
The UNIVERSITY of WESTERN ONTARIO
IMPORTANT
HB PENCIL ONLY!
EXAMPLE:
ERASE *COMPLETELY* TO CHANGE

1) The properties of a material in a particular family (e.g. metals, ceramics, …) are similar to other members in the same family because:

   a) Materials in the same family are comprised of the same atoms.
   b) The members of each family are determined by their atomic/molecular structure.
   c) The families are determined by the properties of their members.
   d) All materials have similar properties.
   e) The properties of family members are not similar.

2) The HCP, FCC and BCC unit cells are shown in Figure 1. The number of close-packed planes in each crystal structure is (HCP, FCC, BCC):

   a) 1, 2, 0
   b) 0, 4, 2
   c) 2, 12, 0
   d) 1, 4, 0
   e) 0, 4, 8

3) Although the density can vary widely within any class of materials, the density of a metal is generally greater than the density of a polymer because:

   a) Atoms are more closely packed in metals than in polymers
   b) Atoms are more closely packed in polymers than in metals
   c) Polymers are usually comprised of lighter, non-metallic elements.
   d) a) and c) are both correct
   e) b) and c) are both correct

4) Archimedes' principle states that:

   a) A mass, submerged in a fluid, experiences a upward force equal to the mass of the column of fluid above it.
   b) A mass, submerged in a fluid, experiences a downward force equal to the mass of the column of fluid above it.
   c) A mass, submerged in a fluid, experiences a upward force equal to the weight of the fluid it displaces.
   d) A mass, submerged in a fluid, experiences a downward force equal to the weight of the fluid it displaces.
   e) The mass of a body is constant.

5) The mass of an object, measured in air, is 25.6 grams. The mass of the same object, submerged in methyl alcohol (ρ=0.79 g/cm^3), is 22.1 grams. The density of the object is:

   a) 0.93 g/cm^3
   b) 1.47 g/cm^3
   c) 3.50 g/cm^3
   d) 5.78 g/cm^3
   e) 9.26 g/cm^3

6) The equilibrium spacing at 0ºK of the atom pair described by the force-distance curve in Figure 2 is:

a) <1.5 nm
b) 1.5 nm
c) 1.8 nm
d) 2.7 nm
e) Not possible to determine from the figure alone.

7) The stiffness of the bond between the pair of atoms described by Figure 2 is characterized by:

a) The value of Fmax.
b) The slope of the curve at F=Fmax
c) The intersection of the curve with the horizontal axis
d) The slope (first derivative) of the curve in the vicinity of F=0
e) The curvature (second derivative) of the curve in the vicinity of $F=F_{max}$

8) "Atoms in a sea of electrons" best describes which type of atomic bonding?

a) Hydrogen Bonding
b) Metallic Bonding
c) Covalent Bonding
d) Ionic Bonding
e) Van der Waal's Bonding

9) If a material is crystalline, it can be characterized as having:

a) Transparency
b) Very high mechanical stiffness.
c) An arrangement of atoms or molecules with short and long-range order.
d) An atomic structure without long-range order
e) None of the above.

10) An amorphous ceramic is best described as being comprised of:

a) Ionically bonded metallic and non-metallic atoms with no long-range order
b) Ionically bonded metallic and non-metallic atoms arranged in a repeating unit cell.
c) Covalently bonded, long-chain molecules held together by van der Waal's forces with or without long-range order.
d) An amorphous, three-dimensional network of covalently bonded molecules.
e) None of the above

11) As it refers to polymers, the term cross-linking means:

a) The process of welding two polymers together
b) The formation of covalent bonds between polymer chains
c) Creating covalent bonds along the "backbone" of the polymer chains
d) The process of converting covalent bonds to van der Waal's bonds.
e) Melting and re-solidifying thermoplastic polymers.

12) The defects depicted in Figure 3 a) are known as:

a) Edge dislocations
b) Vacancies
c) Interstitial defects
d) Substitutional defects
e) Grain boundaries

13) Two specimens of a material with identical cross-sectional areas are prepared so that the second specimen has exactly twice the length of the first. If both specimens are subjected to the same (elastic) tensile load, the ratio of their elongations (ΔL_1:ΔL_2) will be?

a) 1:1
b) 1:2
c) 2:1
d) 1:4
e) 4:1

14) A tensile test specimen (gauge length l=50mm, width w=10mm and thickness, t=2mm) is loaded elastically to 6000N. The gauge length under load is 50.2mm. The strain in the specimen is:

a) 0
b) 0.004
c) 0.2
d) 0.4
e) 1.0

15) The Young's modulus of the material described in Question 14) is:

a) 12 MPa
b) 60 MPa
c) 300 MPa
d) 75 GPa
e) 1500 GPa

16) The material described in Question 14) is known to have a Poisson's ratio of ν=0.3. The width of the specimen when loaded to 6000N is:

a) 8.88 mm
b) 9.988 mm
c) 9.999 mm
d) 10.012 mm
e) 10.10 mm

17) The stress-strain curve for an aluminum alloy is shown in Figure 4. The 0.2% offset yield strength is approximately:

a) 150 MPa
b) 180 MPa
c) 220 MPa
d) 330 MPa
e) 380 MPa

18) The ultimate tensile strength of the aluminum alloy specimen (Figure 4) is approximately:

a) 150 MPa
b) 180 MPa
c) 220 MPa
d) 330 MPa
e) 380 MPa

19) A cube of metal with sides of length 5mm is subjected to a shear force V=400N. The shear stress in the cube is closest to:

a) 0.01MPa
b) 3.2 MPa
c) 16 MPa
d) 80 MPa
e) 10000 MPa

20) The percent change in volume of a piece of steel (E = 200 GPa, G = 80 GPa, K = 165 GPa) subjected to a hydrostatic tensile stress of 100 MPa is:

a) 0.048%
b) 0.061%
c) 0.12%
d) 0.60%
e) 1.65%

21) A composite material is fabricated from 60% E-glass fiber in an epoxy matrix (Table 1). The density of the composite is:

a) 600 kg/m^2
b) 1440 kg/m^2
c) 1860 kg/m^2
d) 2040 kg/m^2
e) 2340 kg/m^2

22) A unidirectional, aligned fibre composite is to be fabricated from a polyester resin and E-glass fibres. (see Table 1) If the volume fraction of fibres is 65%, the Young's modulus of the composite measured parallel to the fibre direction is closest to:

a) 0.5 GPa
b) 1.0 GPa
c) 26 GPa
d) 49 GPa
e) 75 GPa

23) The minimum volume fraction of HM carbon fibres in a polyester matrix (see Table 1) required to achieve a Young's modulus parallel to the fibres of 240 GPa is closest to:

a) 10%
b) 15%
c) 25%
d) 35%
e) 45%

24) Unidirectional, carbon-fibre/epoxy composite material is available in sheet form with a volume fraction of fibres of 60% (see Table 1). If an even number of these sheets are layed-up such that the fibre direction alternates (0°, 90°, 0°, 90°, …), the Young's modulus in the 90° direction is closest to:

a) 1.2 GPa
b) 40 GPa
c) 80 GPa
d) 162 GPa
e) 320 GPa

25) A unidirectional composite of 65% by volume E-glass fibres in epoxy is subjected to a stress of 200 MPa parallel to the fibre direction. The strain in the epoxy is closest to:

a) 0.004
b) 0.040
c) 0.080
d) 0.400
e) There is not enough information to calculate the strain in the matrix.

26) Plastic deformation in thermoplastic polymers is the result of:

a) The motion of dislocations
b) The breaking of polymer chains
c) The sliding and rotation of polymer chains
d) Crack propagation between polymer chains
e) All of the above.

27) Crystalline ceramics do not experience significant plastic deformation because:

a) The stress required to move dislocations is greater than the fracture stress.
b) The ionic bonds are too strong.
c) Small flaws in the material act as stress concentrators, causing fracture before plastic deformation can occur
d) All of the above
e) None of the above

28) Plastic deformation increases the yield strength of a metal because:

a) the Young's modulus increases.
b) the Young's modulus decreases.
c) the number of vacancies decreases.
d) the number of entangled dislocations increases.
e) the number of substitutional impurities increases.

29) Brass (a Cu-Zn alloy) is stronger than pure copper. This is because:

a) The zinc atoms prevent dislocations from forming
b) The zinc atoms distort the copper lattice
c) The Young's modulus of zinc is higher than that of copper
d) Dislocations are repelled by zinc atoms
e) The copper-zinc bond is stronger than the copper-copper bond

30) A brittle material of $K_{IC} = 10MPa\sqrt{m}$ has an effective strength of 300 MPa when a surface crack is 200μm deep. The effective strength when the flaws are 100μm deep would be approximately:

a) 75 MPa
b) 150 MPa
c) 212 MPa
d) 425 MPa
e) 600 MPa

31) A stress of 200 MPa is enough to cause a piece of low alloy steel to fracture ($K_{IC} = 40MPa\sqrt{m}$, $Y = 1.1$). The depth of the surface flaw in this sample is therefore closest to:

a) 1.1 m.
b) 0.05 cm.
c) 1.05 cm.
d) 0.01 mm.
e) 0.02 mm

32) The plastic zone at the crack tip in a ductile material:

a) Reduces the crack tip stress by crack tip blunting
b) Amplifies the crack tip stress by dislocation generation
c) Increases creep resistance
d) Decreases fatigue life
e) None of the above

33) A tensile sample has a diameter of 5 mm and a surface crack of a depth of 0.2mm. If the far-field tensile stress is 300 MPa, what is the local stress at a location 1mm away from the tip of the crack?
a) 228 MPa
b) 250 MPa
c) 350 MPa
d) 395 MPa
e) 435 MPa

34) What is the critical crack size for a material with a critical strain energy release rate of 1.3 kJ/m², and a Young's modulus of 40 GPa if the applied stress is 50 MPa. (assume Y=1)

a) 6.62×10^{-3} mm
b) 0.22 mm
c) 0.66 mm
d) 2.15 mm
e) 6.62 mm

35) A component with a surface flaw of depth 1.0 mm is subjected to a cyclic stress that varies sinusoidally between 0 and 200 MPa. If the constants are known to be $C = 1\times10^{-4}$ and c = 0.2 (for units of mm/cycle when stress intensity is measured in $MPa\sqrt{m}$), the crack growth rate is approximately:

a) 5.6×10^{-5} mm/cycle
b) 1.6×10^{-4} mm/cycle
c) 2.8×10^{-4} mm/cycle
d) 0.2 mm/cycle
e) 11.2 mm/cycle

36) A copper bar (see Table 1) with a length of 50mm at 20 ºC, is heated to 60 ºC. By how much will the length change?

a) 0.0008 mm
b) 0.04 mm
c) 0.08 mm
d) 0.10 mm
e) 0.40 mm

37) If the copper bar described in Question 36) was clamped to prevent a change in length, the stress in the bar at 100ºC would be approximately: (negative values indicate compressive stress)

a) -144 MPa
b) -96 MPa
c) -48 MPa
d) 96 MPa
e) 4800 MPa

38) A creep test involves the measurement of which two parameters?

a) stress and time
b) stress and strain
c) strain and time
d) strain and ductility
e) stress and Poisson's ratio

39) Choose the correct statement from the list below. When conducting creep experiments, assuming the stress is held constant, as the temperature is increased:

a) Steady-state creep rate will decrease and rupture life will increase.
b) Steady-state creep rate will increase and rupture life will increase.
c) Instantaneous deformation will increase and rupture life will decrease.
d) Instantaneous deformation will decrease and rupture life will decrease.
e) Steady-state creep rate will increase and total creep strain will decrease.

40) Creep deformation becomes an important consideration at which homologous temperature? (recall that Homologous Temperature is defined as T/T_m)

a) 0
b) 0.1
c) 0.4
d) 0.8
e) 1

41) The steady-state creep rate is characterized by the equation:

$$\dot{\varepsilon}_{ss} = A\sigma^n$$

Presented with data of $\dot{\varepsilon}_{ss}$ at various levels of applied stress, the constants *A* and *n* are determined graphically by plotting (*y-axis* vs. *x-axis*):

a) σ vs. $\dot{\varepsilon}_{ss}$: slope = log(n); y-intercept = log(A)
b) $\dot{\varepsilon}_{ss}$ vs. σ : slope = log(A); y-intercept = log(n)
c) $\log(\sigma)$ vs. $\log(\dot{\varepsilon}_{ss})$: slope = n; y-intercept = log(A)
d) $\log(\dot{\varepsilon}_{ss})$ vs. $\log(\sigma)$: slope = A; y-intercept = log(n)
e) $\log(\dot{\varepsilon}_{ss})$ vs. $\log(\sigma)$: slope = n; y-intercept = log(A)

42) A constant-stress creep test is performed at 605K and the steady-state creep rate is measured to be $0.029 s^{-1}$. If the pre-exponential constant is known to be $14 s^{-1}$, the activation energy for the creep process is approximately:

a) 1.6 kJ/mol
b) 8.2 kJ/mol
c) 14.2 kJ/mol
d) 31.1 kJ/mol
e) 45.6 kJ/mol

43) The activation energy for creep of copper is 205 kJ/mol. If the steady-state creep rate measured at 700°C is $0.01 s^{-1}$, the creep rate at 750°C and the same applied stress will be approximately:

a) $0.001 s^{-1}$
b) $0.035 s^{-1}$
c) $0.100 s^{-1}$
d) $0.345 s^{-1}$
e) Can not be determined without more information

44) The specific heat, Cp, of a material is equal to:

a) The absolute melting temperature divided by the density.
b) The creep temperature divided by the density.
c) The rate of steady-state heat transfer
d) The energy required to raise the temperature of a unit mass of the material by one degree.
e) None of the above.

45) The thermal conductivity, λ, of a material characterizes:

a) The temperature difference along the length of a material conducting heat.
b) The mobility of photons in a material
c) The rate of heat flow in a material subjected to a thermal gradient.
d) The energy required to raise the temperature of a unit mass of the material by one degree.
e) None of the above.

46) A shaft is to be used to transmit an alternating normal stress of +/- 600 MPa. Data for the material is given in the diagram shown in Figure 5. The expected fatigue life of the shaft is approximately:

a) < 10,000 cycles
b) 85,000 cycles
c) 850,000 cycles
d) 85,000,000 cycles
e) the shaft would not fail by fatigue

47) A fatigue specimen is subjected to a sinusoidal stress that varies from -25 MPa to 250 MPa. The fatigue ratio that describes this test is:

a) -1
b) -0.1
c) 0
d) 10
e) 275

48) A material with a tensile stress $\sigma_{ts} = 250\,MPa$ will fail in 10^6 cycles when subjected to a cyclic stress of ±50 MPa about a mean stress of zero. What stress range will give the same life if the mean stress is raised to 75 MPa?

a) ± 10 MPa
b) ± 15 MPa
c) ± 23 MPa
d) ± 35 MPa
e) ± 43 MPa

49) The high-cycle fatigue of an aluminum alloy is described by Basquin's law:

$$\frac{\Delta\sigma}{2} = \sigma_a = 480\left(N_f\right)^{-0.12}$$

A component is subjected to a cyclic stress of ±100 MPa for 100,000 cycles about a mean stress of zero. The component is subsequently cycled at ±150 MPa until failure (also at a mean stress of zero). How many additional cycles will be required to cause failure?

a) 12800 cycles
b) 16200 cycles
c) 185000 cycles
d) 275000 cycles
e) 375000 cycles

50) At one point during a fatigue test, the rate of crack growth is measured as 0.57mm/cycle. If the constants are known to be A = 0.30, and m = 0.2 (for crack growth in mm/cycle), what is the cyclic stress intensity?

a) 1.3 MPa√m
b) 9.5 MPa√m
c) 14 MPa√m
d) 18 MPa√m
e) 25 MPa√m

51) The maximum permitted strain amplitude that would allow a component to survive 1000 cycles under fully reversed plastic loading is approximately (C=0.1, c=0.5):

a) 1.0×10^{-4}
b) 1.2×10^{-3}
c) 3.2×10^{-3}
d) 0.25
e) Cannot be determined without more data

52) The resistivity of pure copper at room temperature is $1.7\times10^{-8}\ \Omega\cdot m$. The conductivity of pure copper at room temperature is:

a) $5.9\times10^{5}\ \Omega^{-1}\cdot m^{-1}$
b) $1.7\times10^{7}\ \Omega^{-1}\cdot m^{-1}$
c) $5.9\times10^{7}\ \Omega^{-1}\cdot m^{-1}$
d) $1.7\times10^{8}\ \Omega^{-1}\cdot m^{-1}$
e) Not enough information to determine.

53) The resistance (at room temperature) of a 200m length of pure copper wire (see Question 52) with a diameter of 1mm is:

a) $2.6\times10^{-16}\ \Omega$
b) 0.00034 Ω
c) 0.0034 Ω
d) 4.3 Ω
e) 340 Ω

54) The power lost when 2.0A flows along the length of the wire described above is approximately:

a) 6.8×10^{-8} W
b) 2.2 W
c) 8.6 W
d) 17 W
e) 430 W

55) A material carries a current density of 2.5 A/m^2 under an electric field of 110 V/m. The conductivity of the material is approximately:

a) $3.6\times10^{-3}\ \Omega^{-1}\cdot m^{-1}$
b) $2.3\times10^{-2}\ \Omega^{-1}\cdot m^{-1}$
c) $32\ \Omega^{-1}\cdot m^{-1}$
d) $44\ \Omega^{-1}\cdot m^{-1}$
e) $275\ \Omega^{-1}\cdot m^{-1}$

56) The resistance of two wires: one a metal and the other an intrinsic semiconductor is measured at different temperatures near room temperature. The expected behaviour for the resistance is: as the temperature increases, the resistance:

	Metal	Semiconductor
a)	increases	increases
b)	increases	decreases
c)	decreases	decreases
d)	decreases	increases
e)	remains unchanged for both materials	

57) Choose the best statement to finish this sentence: A diode in forward bias will permit an electrical current to flow because…:

a) Electrons are free to move towards the positive terminal
b) Positive holes are free to move towards the negative terminal
c) The forward bias puts the diode in the exhaustion range
d) The charge carriers recombine at the p-n junction
e) The holes and electrons are created at the p-n junction and move to each end of the device.

58) Devices made from extrinsic semiconductors are typically used in the exhaustion range because:

a) The electrical conductivity is at its minimum
b) The electrical conductivity is at its maximum
c) The electrical conductivity is approximately independent of temperature
d) No more electrons can be promoted to the conduction band
e) All valence electrons have been promoted to the conduction band

59) An n-type semiconductor is known to have an electron concentration of 3×10^{18} m^{-3}. If the electron drift velocity is 100 m/s in an electric field of 500 V/m, the conductivity of the material is closest to: $\left(|e| = 1.6\times10^{-19}\right)$

a) $0.096\ \Omega^{-1}m^{-1}$
b) $0.68\ \Omega^{-1}m^{-1}$
c) $2.40\ \Omega^{-1}m^{-1}$
d) $5.00\ \Omega^{-1}m^{-1}$
e) $48\ \Omega^{-1}m^{-1}$

60) The answer to this question is e) – Enjoy your holidays!