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Concordia University
Engineering and Computer Science

Department of Mechanical, Industrial & Aerospace Engineering

Name:

Student Number:

MECH 321 – Properties and Failure of Materials

Midterm 2018

Multiple Choice – True/False Answer Sheet

Instructors: Drs. Martin Pugh and Mamoun Medraj

Detach this sheet from the answer book to make your task easier but **ensure that your name and student ID number are on this page as well as on your exam paper. Using a pencil, fill in the boxes below with your answer.**

Q					
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e
11	a	b	c	d	e
12	a	b	c	d	e
13	a	b	c	d	e
14	a	b	c	d	e
15	a	b	c	d	e
16	a	b	c	d	e
17	a	b	c	d	e
18	a	b	c	d	e
19	a	b	c	d	e
20	a	b	c	d	e

Q		
21	T	F
22	T	F
23	T	F
24	T	F
25	T	F
26	T	F
27	T	F
28	T	F
29	T	F
30	T	F

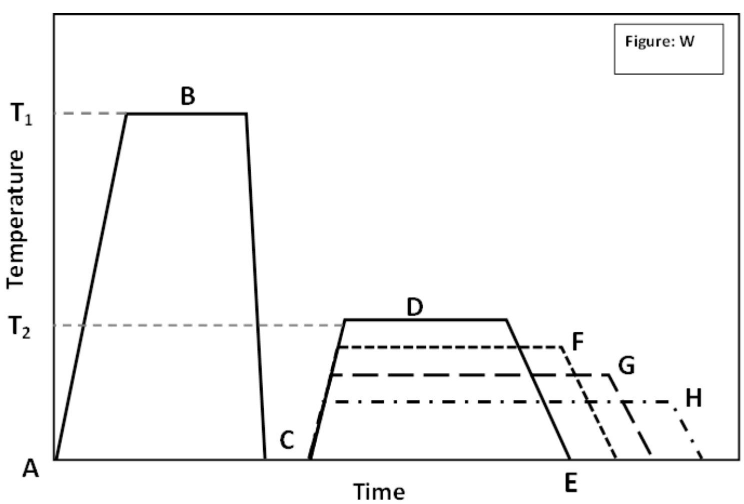
MIDTERM – 2018 **Student Name:** ________________________

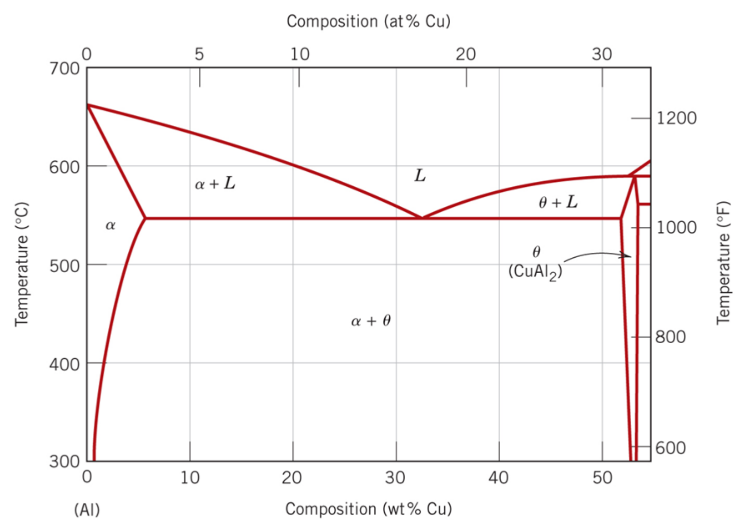
MECH 321 Properties and Failure of Materials **Student Number:** _______________

Answer all questions. For Multiple choice and True/False answers use the detachable sheet. An equation sheet is attached at the end of the exam paper. Questions 1-20, **two** marks each; Questions 21-30, **one** mark each. Hand-in only the answers sheet.

1. Ductile failure at room temperature is:
   (a) when there is a cup-cone type fracture which starts by the opening of cracks around impurity particles inside the neck.
   (b) when necking to zero radius occurs as long as brittle fracture does not occur.
   (c) when the grains separate from each other along the grain boundaries.
   (d) the kind of failure that usually occurs in as-quenched martensite.
   (e) promoted by increasing the rate of loading.

2. Consider two different types of alloy steels, A and B. Steel A is twice as strong as B. If an attempt is made, at room temperature, to elastically bend a 1.5m long, l cm^2 square cross-section bar of each type of steel;
   (a) A would be easier to bend initially than B.
   (b) B would be easier to bend initially than A.
   (c) There would be no difference in the forces required to bend the bars initially, provided that they were exactly the same length and diameter.
   (d) There would be a difference in the forces required to bring about initial bending, the difference being a function of the yield strengths of the bars rather than the tensile strengths.
   (e) Steel bars cannot be bent at room temperature without snapping.





3. The attached Figure W shows a two-step (T_1 and T_2) heat treatment process starting at A. If this heat-treatment is for precipitation hardening in an Aluminum - 4% copper alloy (partial phase diagram attached) then at point B:
   (a) The temperature, T_1, should be 610°C and there will be a two phase mixture of liquid and the aluminum-rich solid solution, α.
   (b) The temperature, T_1, should be below the *solvus* line, so below 500°C for this composition.
   (c) The temperature, T_1, has to be the above 590°C in order for all the θ ($CuAl_2$) phase to melt.
   (d) The temperature, T_1, has to be the above 660°C in order for all the aluminum-rich solid solution, α and the θ ($CuAl_2$) phase to melt.
   (e) The temperature, T_1, has to be the about the same as the eutectic temperature 550 °C in order for all the θ ($CuAl_2$) phase to dissolve and form just the aluminum-rich solid solution, α.

4. For such an alloy as this Aluminum - 4% copper alloy in the question above, if strengthening by cold-working is also to be used in addition to precipitation hardening, then this cold-working would be carried out at the following stage in Figure W:
   (a) A
   (b) B
   (c) C
   (d) D
   (e) E

5. The process of going from **B** to **C** in Figure W in the precipitation hardening of an Aluminum - 4% copper alloy is called:
   (a) Ageing
   (b) Tempering
   (c) Solutionizing
   (d) Quenching
   (e) Annealing

6. The process that occurs at the temperature, T_2, (**D**) for this Aluminum - 4% copper alloy, in Figure W, involves:
   (a) The transformation of martensite to bainite
   (b) The tempering of the θ ($CuAl_2$) phase
   (c) Softening of the super-hard α phase to form a mixture of α-phase and copper.
   (d) Precipitation of θ ($CuAl_2$) phase from the super saturated α solid solution.
   (e) Maturation of the α phase by fermentation of the wollastonite.

7. In Figure W, F, G and H, represent lower temperature variations of the process, D, that occurs at T_2. For these lower temperature processes, the schematic indicates that a longer time is required. This is because the process occurring in this second stage of the precipitation hardening:
   (a) Is diffusion-based so requires longer times at lower temperature.
   (b) Requires that there be the "same area under the curve" in all treatments as they all require the same energy storage.
   (c) Is a diffusionless treatment that requires a longer time for atoms to move into new positions to form the bainite.
   (d) Requires more time because atoms have to move further due to the grain growth that follows the recrystallization in process "B".
   (e) None of the above.

8. For this Aluminum - 4% copper alloy that is being precipitation hardened, it will have the highest strength and hardness at this point on Figure W:
   (a) A
   (b) B
   (c) C
   (d) D
   (e) E

9. Figure W can also represent the two-stage heat treatment of a carbon steel. If this was the case cooling rapidly from **B** to **C** can:
   (a) Cause the precipitation of large spheroids of cementite.
   (b) Trap the excess carbon atoms in the BCC ferrite solid solution, α.
   (c) Allow diffusion of carbon and iron atoms to form equilibrium phases of ferrite and cementite.
   (d) Trap the excess carbon atoms in the FCC austenite substitutional solid solution, γ.
   (e) Trap the excess carbon atoms in the BCT martensite super saturated solid solution.

10. If Figure W represents the two-stage heat treatment of a carbon steel then this steel will have the highest strength and hardness at this point on Figure W:
    (a) A
    (b) B
    (c) C
    (d) D
    (e) E

11. If Figure W represents the two-stage heat treatment of a carbon steel then at point **E** this steel will consist of:
    (a) ferrite and cementite in the form of coarse pearlite
    (b) ferrite and cementite in the form of fine pearlite
    (c) ferrite and cementite in the form of tempered martensite
    (d) austenite and ferrite in the form of spheroidite
    (e) martensite

12. A single crystal of a metal that has the BCC crystal structure is oriented such that a tensile stress is applied in the [010] direction. If the magnitude of this stress is 2.75 MPa, compute the resolved shear stress in the $[\bar{1}\ 1\ 1]$ direction on the (101) plane.
    (a) 0 MPa
    (b) 1.1 MPa
    (c) 1.2 MPa
    (d) 1.4 MPa
    (e) Cannot be solved because the yield strength is missing

13. A large steel plate, with a plain strain fracture toughness of 53 $MPa.m^{1/2}$ has two internal cracks, A and B, which are both oriented perpendicular to the applied tensile load. Crack A has a length of 4 mm and a crack tip radius of 8 μm. Crack B has a crack tip radius of 0.8 mm but has the same stress concentration factor as Crack A. What is the length of crack B?
    (a) 0.2 mm
    (b) 200 mm
    (c) 6 mm
    (d) 400 mm
    (e) 12.6 mm

14. A cylindrical specimen of a metal alloy 48.5 mm long and 9.72 mm in diameter is stressed in tension. A true stress of 393 MPa causes the specimen to uniformly plastically elongate to a length of 57.2 mm. If it is known that the strain-hardening exponent for this alloy is 0.20, calculate the true stress (in MPa) necessary to plastically elongate a specimen of this same material from a length of 48.5 mm to a length of 54.7 mm.
    (a) 253
    (b) 368
    (c) 433
    (d) 529
    (e) 563

15. Using the Table below, which continuous fibre-reinforced epoxy composite with a volume fraction of fibres of 0.6 will have a density less than the Aluminum 7075 alloy?
    (a) only carbon fibre-epoxy
    (b) only Kevlar fibre-epoxy
    (c) only E-glass fibre- epoxy
    (d) carbon fibre-epoxy and Kevlar fibre-epoxy
    (e) carbon fibre-epoxy, Kevlar fibre-epoxy and E-glass fibre epoxy.

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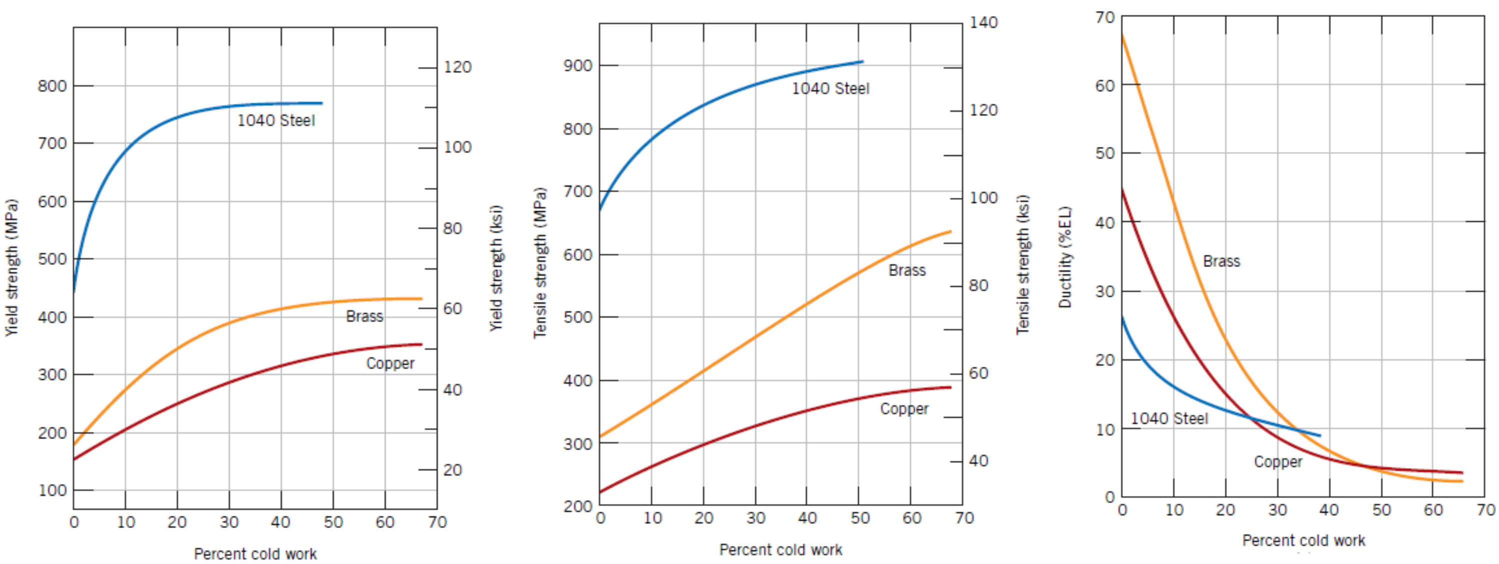
	Density/ Mg.m^{-3}	Tensile Strength/ MPa	Elastic Modulus/ GPa
Aluminum 7075 (T6)	2.84	570	71
Carbon Fibre	1.8	3000	420
Kevlar (49) fibre	1.44	3800	131
E-glass fibre	2.58	3450	72.5
Epoxy resin	1.14	70	3.0

16. The elastic deflection δ, of a beam with square cross-section (t x t) is given by:

$$\delta = \frac{4FI^3}{Et^4}$$

Which fibres from the Table can be used to produce a continuous, unidirectionally reinforced, epoxy composite beam with the same deflection as a similar sized beam of Aluminum 7075 under a force of 1000N (note: assume maximum volume fraction of fibres is 0.75).
   (a) only carbon fibres
   (b) only Kevlar fibres
   (c) only E-glass fibres
   (d) carbon fibres and Kevlar fibres
   (e) carbon fibres, Kevlar fibres and E-glass fibres.

17. Assuming that the stress in the epoxy matrix when the fibres break is 50 MPa in all cases, what volume fractions of carbon fibre and Kevlar fibre are required to give a continuous, unidirectional fibre-epoxy composite material with a tensile strength (in the 0^{o} direction) that is the same as the Aluminum 7075 alloy?
   (a) 57% Carbon fibres, 47% Kevlar fibres
   (b) 65% Carbon fibres, 60% Kevlar fibres
   (c) 18% Carbon fibres, 14% Kevlar fibres
   (d) 21% Carbon fibres, 18% Kevlar fibres
   (e) 9% Carbon fibres, 7% Kevlar fibres.



18. It is necessary to produce a sheet of copper by cold rolling. The final thickness must be 6 mm and the yield strength must be 300 MPa. Using the above figure and assuming that your starting material is fully annealed, the required initial thickness of the sheet is closest to:
   (a) 2.4 mm
   (b) 9.4 mm
   (c) 15 mm
   (d) 20 mm
   (e) 24 mm

19. An application requires a metal alloy with a yield strength of at least 345 MPa, and a ductility of greater than 20%. They can be cold worked if necessary. Of the three alloys in the above figure, which ones can be used?
    (a) 1040 steel only
    (b) brass only
    (c) copper only
    (d) brass and copper
    (e) 1040 steel and brass

20. A cylindrical specimen of an unknown metal with a diameter of 8 mm is elastically stressed in tension by a stress of 312 MPa. A reduction in the specimen diameter of $5x10^{-3}$ mm is measured. Compute Poisson's ratio for this material if its modulus of elasticity is 140 GPa.
    (a) 0.13
    (b) 0.28
    (c) 0.35
    (d) 0.43
    (e) 0.50

For these True/False questions, use the detachable answer sheet:

21. The critical resolved shear stress represents the minimum shear stress required to initiate slip in a single crystal.
22. Fine-grained metals are tougher than coarse-grained metals of the same composition.
23. During a torsion test, ductile materials fail perpendicular to the axis of the testpiece whereas brittle materials fail in a helical fashion perpendicular to the maximum tensile stresses.
24. If the properties of a material depend on the crystallographic direction along which the property is measured, then the material is isotropic.
25. Any metal that is heated above its recrystallization temperature will recrystallize.
26. Hollomon's equation describing the relationship between true stress and true strain obtained for a metal using a tensile test can be used in mechanical deformation processes that involve mainly compression such as forging.
27. When a positive (⊥) dislocation and a negative (T) dislocation meet on the same slip plane, they annihilate each other to produce a region of perfect crystal arrangement.
28. The recrystallization temperature is normally higher for a pure metal than for its alloys.
29. In ductile metals, sharp cracks are blunted by localized plastic deformation whereas in brittle materials such as ceramics the cracks stay sharp hence causing higher stress concentration.
30. For most metals there is a linear relationship between the Brinell Hardness and the tensile strength.

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MECH 321

Equation Sheet

$$U_r = \frac{\sigma_y^2}{2E} \qquad \varepsilon_T = \ln\left(\frac{l_i}{l_o}\right) \qquad \varepsilon_{eng} = \left(\frac{l_i - l_o}{l_o}\right) = \frac{\Delta l}{l_o} \qquad \sigma_T = k\varepsilon_T^n \text{ (uniform plastic)} \qquad \sigma_T = \sigma(1+\varepsilon)$$

$$\varepsilon_T = \ln(1+\varepsilon) \qquad \tau = \frac{M_T r}{J} \qquad \gamma = \frac{r\theta}{L} \qquad \sigma_r = \sigma_o + kd^{-1/2} \qquad \tau_r = \sigma\cos\lambda\cos\phi$$

$\rho_c = V_f \rho_f + (1-V_f)\rho_m$

$$L_c = \frac{\sigma_f d}{2\tau_c} \qquad E_{c1} = E_f v_f + E_m v_m$$

$$E_{c2} = \frac{E_f E_m}{E_f(1-v_f) + E_m v_f} \qquad \sigma_{c2} \approx \frac{\sigma_m}{2} \qquad \sigma_{cl}^* = \sigma_m^{'}(1-V_f) + \sigma_f^* V_f$$

$$\sigma_{cd}^* = \sigma_f^* V_f \left(1 - \frac{\ell_c}{2\ell}\right) + \sigma_m^{'}(1-V_f) \qquad \sigma_{cd'}^* = \frac{\ell\tau_c}{d} V_f + \sigma_m^{'}(1-V_f)$$

$$\sigma_{max} = 2\sigma_o\left(\frac{a}{\rho}\right)^{1/2} \qquad k_t = \frac{\sigma_{max}}{\sigma_o} \qquad \sigma_c = \sqrt{\frac{2E\gamma_s}{\pi a}} \text{ (brittle)} \qquad B \geq 2.5\left[\frac{K_{1c}}{\sigma_y}\right]^2$$

$$\sigma_c = \sqrt{\frac{2E(\gamma_s + \gamma_p)}{\pi a}} \text{ (plastic)} \qquad G_c = \frac{K_{1c}^2}{E} \qquad K_{IC} = Y\sigma\sqrt{\pi a}$$