

Q3: a) Design a composite material from E-Glass fibres as reinforcement phase and nylon as a matrix phase. The required in-plane modulus of elasticity of the composite (E_c) is 30 GPa. (5Marks)

b) Compute the in plane shear modulus of the designed glass/nylon lamina by mechanics of materials approach. Hint: $E_{\text{glass}}=72.4$ GPa, ν_{glass} (poisson ratio) = 0.2, $E_{\text{nylon}}=2.7$ GPa, and ν_{nylon} (poisson ratio) = 0.3 . State any assumption(s) made in your calculation. $\frac{1}{G_{12}} = \frac{\nu_f}{G_f} + \frac{\nu_m}{G_m}$ $G = \frac{E}{2(1+\nu)}$ (5Marks)

More

Remix

**UNIVERSITY OF JORDAN
SCHOOL OF ENGINEERING**

Composites and powder technology
Student Name:

Summer II semester (2016-2017)

Midterm Exam
Time: 60 Minutes

Q1: choose the correct answer and summarize your answer in the following table (50 marks)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	

1. Whisker reinforcements are commonly used in
 - a) PMC
 - b) CMC
 - c) SMC
 - d) MMC
2. Sporting goods are common products
 - a) Hand layup process
 - b) Filament winding
 - c) Pultrusion
 - d) Open die process
3. Which of the following statements is true?
 - a) A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other.
 - b) A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are soluble in each other.
 - c) A composite is a structural material that consists of two or more combined constituents that are combined at an atomic level and are soluble in each other.
 - d) A composite is a structural material that consists of two or more combined constituents that are combined at a subatomic level and are not soluble in each other.
4. Not an example for laminar composite
 - a) Wood
 - b) GLARE
 - c) Coatings/Paints
 - d) ARAL
5. Metal matrix composites compared to Polymer matrix composites have
 - a) Low thermal and electrical conductivity
 - b) Higher toughness
 - c) Lower transverse strength
 - d) Lower temperature capability
6. One of the major drawbacks of advanced composite materials is
 - a) their high cost of fabrication
 - b) their low specific elastic modulus
 - c) that they are extremely heavy
 - d) their low specific strength
7. Current service temperature limits for polymers reach
 - a) 350 °C
 - b) 650 °C
 - c) 250 °C
 - d) 170 °C
8. Polymers matrix have covalent bond between the chains is known as
 - a) Thermoplastic matrix
 - b) Thermoset matrix
 - c) elastomer matrix
 - d) Plastic matrix
9. Two directional fiber reinforced composite materials are
 - a) isotropic but not homogeneous
 - b) homogeneous but not isotropic
 - c) both homogeneous and isotropic
 - d) neither homogeneous or isotropic
10. Which of the following composites are replacing metals in pressurized containers?
 - a) Carbon-Carbon
 - b) Graphite-Epoxy
 - c) Boron-Epoxy
 - d) Glass-Epoxy
11. Inter-ply hybrid composites consist of
 - a) two or more different composite systems
 - b) two or more different fibers used in the same ply
 - c) two or more matrix in the same ply
 - d) both a and b
12. Which of the following is a drawback for phenolic resin systems?
 - a) high cost
 - b) low mechanical strength
 - c) high void content
 - d) brittleness
13. What angle plies are used to make a cross-ply laminate?
 - a) 0, 90
 - b) 0, 45, -45, 90
 - c) 0, 90
 - d) 45, -45
14. Which of the following composites are replacing metals in tennis racket?
 - a) Carbon fiber-Carbon
 - b) Carbon fiber-Epoxy
 - c) Glass fiber-Epoxy
 - d) Glass fiber-carbon
15. Maximum fiber volume fraction for circular fibers packing in a hexagonal array is nearly%
 - a) 70
 - b) 79
 - c) 85
 - d) 91
16. Change in matrix properties for a corresponding 1% increase in void content is in the range of
 - a) <2%
 - b) 2%-10%
 - c) 11-20%
 - d) >20%
17. The longitudinal modulus of a lamina is dependent on
 - a) fiber Young's modulus
 - b) matrix Young's modulus
 - c) fiber volume fraction
 - d) all
18. Which of these polymer is least desirable for smoke emission?
 - a) Phenolic
 - b) Epoxy
 - c) Silicone
 - d) Polyimide
19. Specific modulus is given by
 - a) Square root of Young's modulus / density
 - b) Strength / density
 - c) Young's modulus / density
 - d) Square root of strength / density
20. Bullet proof vests use _____ fibers.
 - a) Kevlar fibers
 - b) Carbon fibers
 - c) Glass fibers
 - d) Polyester fibers
21. Which of the following is a drawback for phenolic resin systems?
 - a) high cost
 - b) low mechanical strength
 - c) high void content
 - d) brittleness
22. Which of the following fiber has the highest elastic modulus?
 - a) boron
 - b) Kevlar
 - c) glass
 - d) carbon
23. Has the lowest cost of all commercially available fibers
 - a) E Glass
 - b) S Glass
 - c) X Glass
 - d) Kevlar 49
24. Which of the following is true for composites.

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15. Metal matrix composites compared to Polymer matrix composites have

- a) Low thermal and electrical conductivity
- b) Higher toughness
- c) Lower transverse strength
- d) Lower temperature capability

16. GLARE is

- a) Alumina reinforced Glass
- b) Aramid Reinforced Glass
- c) Aluminum Reinforced Glass
- d) Glass Reinforced Aramid

17. Which of the following is true for composites.

- a) easy to repair.
- b) easy to be machined.
- c) tailorable materials for properties
- d) Low cost of fabrication

18. The most common composites are

- a) MMC. b) SMC c) CMC. d) PMC.

19. Which of the following is suitable for high temperature applications (above 1000 °C)

- a) CMC b) SMC c) MMC d) PMC.

20. Thermoplastic polymers have the following type of bonding between the chains

- a) Covalent bond. b) Vanderwaals bond.
- c) Atomic bond. d) none of the above

21. In the automotive industry where short production runs are necessary, polymer matrix composites are manufactured by the process called _____.

- a) filament winding. b) autoclave forming.
- c) resin transfer molding. d) none of the above.

22. Bullet resistant vests mainly use the following fiber.

- a) Boron b) Glass c) Graphite d) Kevlar

23. Specific strength is given by

- A) Square root of Young's modulus / density.
- B) Strength / density.
- C) Young's modulus / density.
- D) Square root of strength / density.

24. Which of these polymer is least desirable for smoke emission?

- a) Phenolic. b) Epoxy c) Silicone d) Polyimide.

25. Disadvantage of carbon fiber

- a) Low strain-to-failure. b) Low impact resistance
- c) High electrical conductivity. d) all of them

26. Has the lowest cost of all commercially available fibers

- A) E Glass.
- B) S Glass
- C) X Glass
- D) Kevlar 49.

27. The reinforcing factor, ξ , used in Halpin-Tsai equation for transverse elastic moduli is dependent on

- A) Young's modulus of fiber
- B) Young's modulus of matrix
- C) packing geometry of fibers
- D) volume fraction of fibers

28. The maximum fiber volume fraction for the packing geometry of circular fibers in a hexagonal array is nearly _____ %

- a) 70 b) 79 c) 85 d) 91

29. The change in matrix dominated properties for a corresponding 1% increase in void content is in the range of

- a) <2% b) 2%-10% c) 11-20% d) >20%

30. Volume fraction of voids is given by

- a) (theoretical minus experimental composite density) / theoretical composite density.
- b) (theoretical minus experimental composite density) / experimental composite density.
- c) (experimental minus theoretical composite density) / theoretical composite density.
- d) (experimental minus theoretical composite density) / theoretical composite density.

31. Which one of the following assumptions does not relate to the classical lamination theory?

- A) Each lamina is orthotropic.
- B) The lamina is thin with only in-plane loads.
- C) Each lamina is elastic.
- D) Slip may occur between lamina interfaces.



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isotropic and aligned glass fiber-reinforced composite consists of 40% of glass fibers having modulus of elasticity of 69 GPa and polyester resin matrix that, when hardened, displays modulus of 3.4 GPa.

→ **A** Compute the modulus of elasticity of this composite in the longitudinal direction

B IF the cross-sectional area is 250 mm^2 and a stress of 50 MPa is applied, compute the magnitude of the Load ^{or} carried by each of the fiber and matrix phase

C Determine the strain that is sustained by each phase when the stress in part b is applied.

→ **Sol:** → $V_F = 0.4$, $V_m = 0.6$, $E_F = 69 \text{ GPa}$, $E_m = 3.4 \text{ GPa}$

$$E_c = E_F V_F + E_m V_m = (69)(0.4) + (3.4)(0.6) = 29.6 \text{ GPa} \quad \boxed{\text{A}}$$

$$A = 250 \text{ mm}^2 \quad \sigma = 50 \text{ MPa} \quad \boxed{\text{C}}$$

B $P = \frac{F}{A} \Rightarrow F = PA = 12500 \text{ N}$

$$\frac{F_F}{F_m} = \frac{E_F}{E_m} V_F = \frac{(69)(0.4)}{(3.4)(0.6)} = 0.9312$$

$$\epsilon_F = \epsilon_m = \frac{\sigma}{E_c} = \frac{50 \times 10^6}{29.6 \times 10^9} = 7.25 \times 10^{-4}$$

$$F_m = 12500$$

$$F_F = (0.9312)(12500) = 11640 \text{ N}$$

$$F_m = 12500 - 11640 = 860 \text{ N}$$

$E_{\text{glass}} = 72 \text{ k Gpa}$ $V_{\text{glass}} = 0.2$ $E_{\text{nylon}} = 27 \text{ Gpa}$

and Nylon 20.2

- Q1 calculate the minimum fraction of fiber in glass fiber/nylon matrix composite necessary to make a composite material with ultimate strength of 1.14 Gpa and ultimate strength of the glass is 1.53 Gpa.

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Q2 Glass fibers in nylon provide reinforcement. If the nylon contains 30% volume fraction of E-glass fiber

Q3 what fraction of the applied stress is carried by the glass fibers?

Q4 compute the in plane shear modulus of a glass/nylon lamina by mechanics of materials approach.

B) Orientation.

C) Shape.

D) All of the above.

22. The material of the fiber directly influences the mechanical performance of a composite

- A) True.
- B) False.

23. Current service temperature limits for polymers reach

- A) 150 °C.
- B) 200 °C.
- C) 350 °C.
- D) 650 °C.

24. Thermoset plastic polymers have the following type of bonding

- A) Covalent bond.
- B) Vanderwaals bond.
- C) Ionic bond.
- D) none of the above

25. The most common fiber shape is

- A) Rectangular.
- B) Triangular.
- C) Circular.

26. Two directional fiber reinforced composite materials are

- A) isotropic but not homogeneous.
- B) homogeneous but not isotropic.
- C) both homogeneous and isotropic.
- D) neither homogeneous or isotropic.

27. Which of the following composites are replacing metals in golf club shafts?

- A) Carbon-Carbon.
- B) Graphite/Epoxy.
- C) Boron/Epoxy.

28. Inter-ply hybrid composites consist of

- A) two or more different composite systems.
- B) two or more different fibers used in the same ply.

D) Kevlar

33. Specific modulus is given by

- A) Square root of Young's modulus / density.
- B) Strength / density.
- C) Young's modulus / density.
- D) Square root of strength / density.

34. Out of the following, which polymer has the highest service temperature?

- A) Polyamide
- B) Polyester
- C) Epoxy
- D) Phenolic

35. Which of these polymer is least desirable for smoke emission?

- A) Epoxy.
- B) Phenolic.
- C) Polyamide.
- D) Silicone

36. Amongst the choices given below, high performance applications in the aerospace industry use

- A) Kevlar 29.
- B) Kevlar 49.

37. Thermoset polymers show which of the following traits

- A) Soften on heating.
- B) Harden on heating.
- C) Decompose on heating.
- D) none of the above

38) Generally for polymer matrix composites, the maximum strain to failure is larger for

- A) the matrix.
- B) the fiber.

39) Electrical contacts used in switches, relays and motors are made of

- A) CMC
- B) PMC
- C) MMC

Why kevlar fibers have low shear resistance? [2]

⇒ because the bonds in the transverse direction are weaker compared to the covalent bonds in the longitudinal direction.
 Longitudinal

What are the three important criteria that the use of fibrous materials as high performance engineering materials is based on?

- ① diameter size relative to length
 small diameter with respect to grain size.
- ② high aspect ratio
 on surface area high amount of load transferred to fibers through interface
- ③ Flexibility of fiber
 high degree of flexibility

Mention five properties for kevlar fibers?

- ① high tenacity
- ② Low creep
- ③ high young's modulus
- ④ Low elongation at break (~3.5%)
- ⑤ hard to dye, w/ weak solution dyed

Which type of glass fibers is most commonly used in the fiber-reinforced plastics (FRP) industry?

⇒ E-glass because the cheapest.

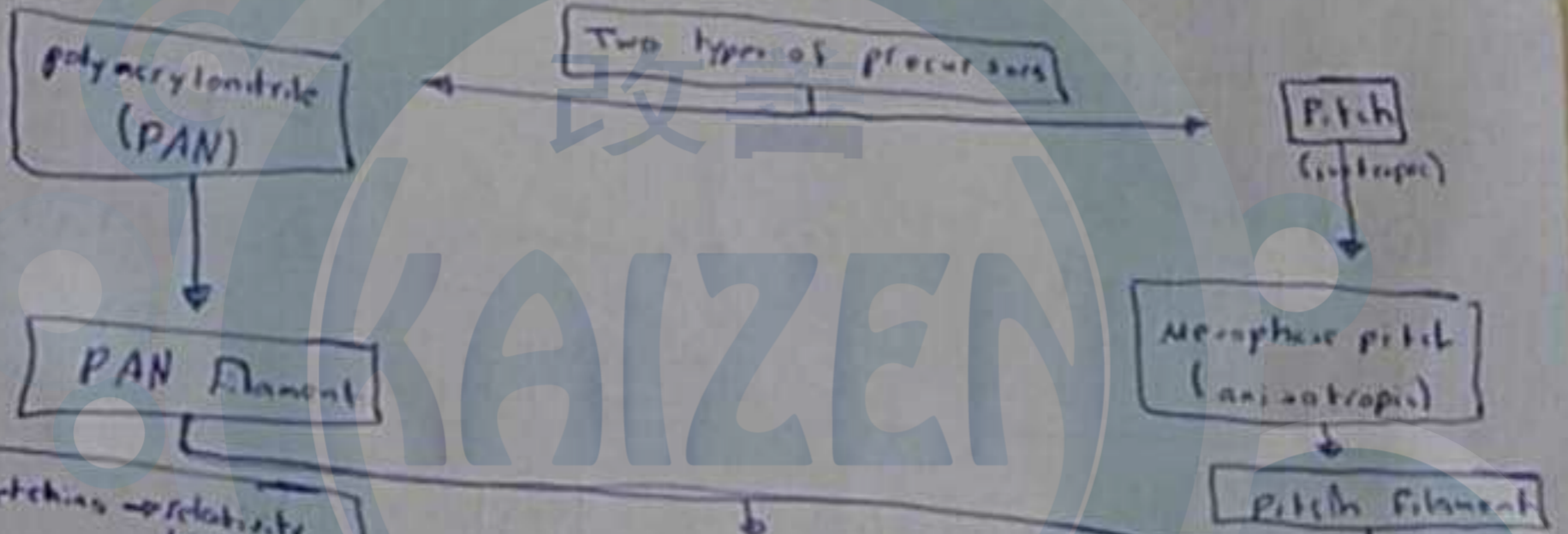
~~...~~

~~...~~
50% CB 20%
3-4% 11 20%

اساتو

اساتو

Sketch - - - manufacturing process of carbon fibers?



- Without stretching → relatively high modulus (50-60 GPa)
- With stretching → improved strength carbon fibers

relatively low modulus (between 200 and 300 GPa)
 high-strength carbon fibers

Q10) Sketch the fabrication process of glass fiber

⊗ glass is dry mixed in furnace (oven) at 1370°C .

then the molten glass is extruded to form $\sim 10\text{Nm}$ in diameter filaments, the filaments are then individually coated with ~~size~~ size (lubricants, anti static agents, binder...) and then are binded together to form a strand.



Sketch the fabrication process of glass fibre

① glass is dry mixed in furnace (oven) at 1370°C
 ② then the molten glass is extruded to form ~ 10mm in diameter filaments. The filaments are then individually
 coated with size (lubricants, antioxidants, agents, binders) and then are banded together to form a strand



① Polymer matrix composite
 High strength
 High modulus
 High resistance

② Metal Matrix composite
 High strength
 High modulus
 High resistance

③ Ceramic matrix composite
 High strength
 High modulus
 High resistance

Mention five of the composite materials disadvantages:

- ①
- ②
- ③
- ④
- ⑤

③

Characteristics of composite material



2 2 2 2

7

35 Marks and 1 hour 15 minutes
المدة 1 ساعة و 15 دقيقة

2

sketch - manufacturing process of carbon fibers?

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sketch relation between the modulus and ~~angle~~ crystalline orientation angle for fiber?

TEAM

المدة 1 ساعة و 15 دقيقة

matrix material ✓

119 (11/2/2021)

Structural material that consists of two or more combined constituents that are combined at a microscopic level and are not soluble in each other.

2 prepreg ✓

are not the final product. We impregnate strands with matrix to form partially cured prepreg which are flexible and easy to form to the final form.



3 strands:

absorbable or unwound glass fiber based prepreg

4 GLARE ✓

is a FRP laminate consisting of thin aluminum sheet and unidirectional / bi-directional epoxy-fiber or glass. mainly used in aerospace industries.

5 whiskers ✓

are virtually flaw-free, crystaline perfection, single crystals that have exceptionally high strength to weight ratios but are very expensive and impractical to use.

6

Matrix composite (matrix)

Composite material:

is a structural material that consists of two or more combined constituents that are combined at a microscopic level and are not soluble in each other

Whiskers:

are virtually flaw-free, crystalline perfection, single crystals that have exceptionally high strength to weight ratios but are very expensive and impractical to use

critical size of fiber

1) small diameter with respect to its grain size

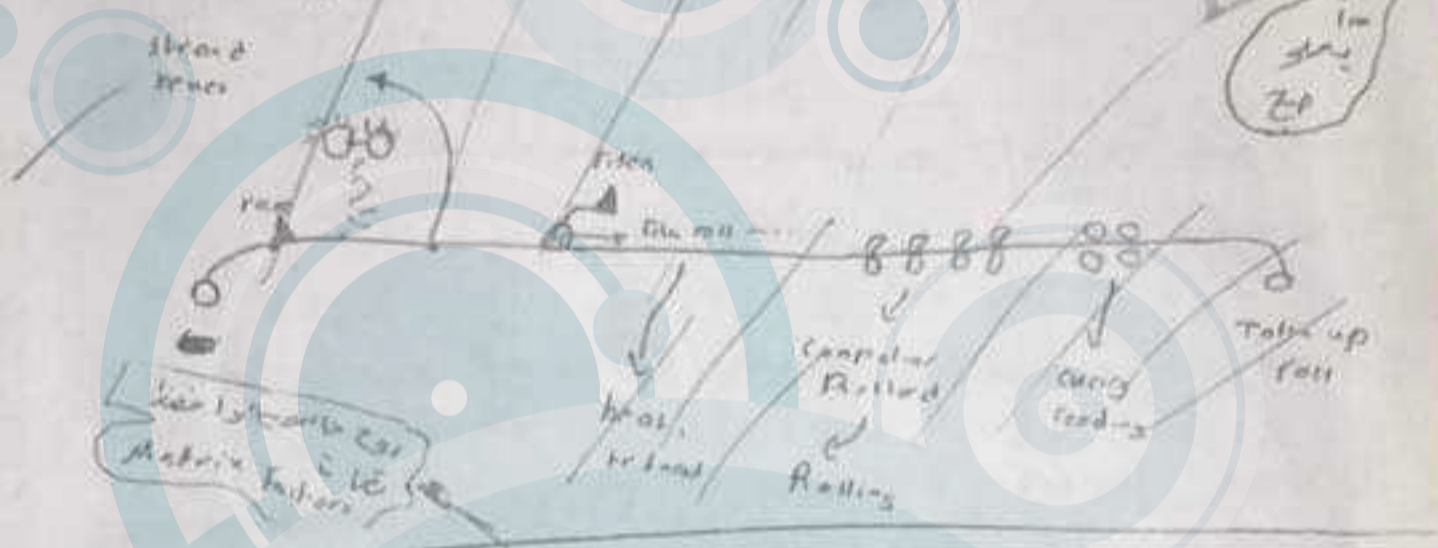
light degree of flexibility of fiber

3) high aspect ratio which allows height of the applied level

المستوى الذي يمكنه التحمل

~~المستوى الذي يمكنه التحمل~~

Describe the manufacturing process of sheet molding compound and indicate the treatment in each step.



What are the **Fiber Factors** that affect their mechanical performance in composite material? Q4

- Length
- material
- orientation
- shape

Which of the reinforcement type is basically two-dimensional particles? Q5

→ Flakes

Draw comparison between thermoplastics and thermosets polymer Matrices

	Thermoplastics	Thermosets
Manufacturing cost	high	Low
shelf life	high long	short
Quality control	Easier simpler/high	more complex/low
Toughness and density	Toughness high	Toughness low
shrinkage	Low	high
property variation	- depends on conditions - less stable mechanical and thermal stability	- depend on conditions - more stable mechanical and thermal stability

low of mechanical of thermal stability

but more stable mechanical of thermal stability

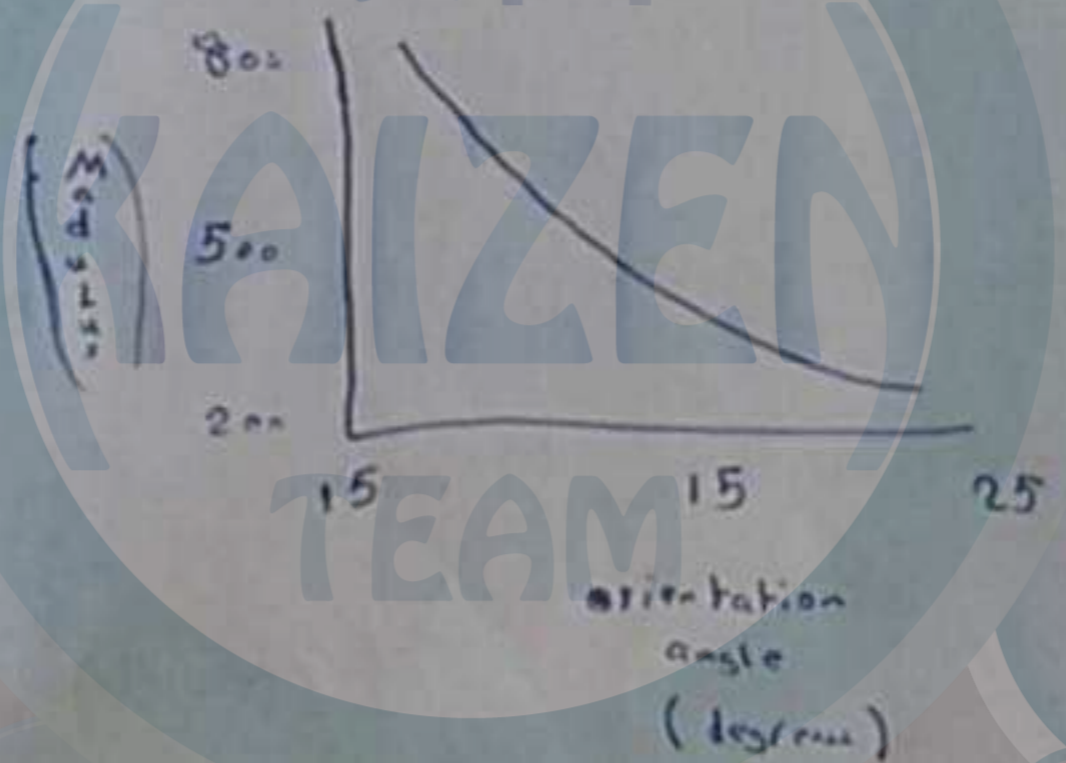
- With stretching or
improved strength
carbon fibers

relatively
high-modulus
(200-600 GPa)

pitch filament
↓
Relatively low-modulus (between 200 and 300 GPa)
- high-strength carbon fibers

sketch

relation between the modulus and ~~pitch~~ crystalline orientation
angle for kevlar fiber?



Q3: a) Design a composite material from E-Glass fibres as reinforcement phase and nylon as a matrix phase. The required in-plane modulus of elasticity of the composite (E_c) is 30 GPa. (5Marks)

b) Compute the in plane shear modulus of the designed glass/nylon lamina by mechanics of materials approach. Hint: $E_{\text{glass}}=72.4$ GPa, ν_{glass} (poisson ratio) = 0.2, $E_{\text{nylon}}=2.7$ GPa, and ν_{nylon} (poisson ratio) = 0.3 . State any assumption(s) made in your calculation. $\frac{1}{G_{12}} = \frac{\nu_f}{G_f} + \frac{\nu_m}{G_m}$ $G = \frac{E}{2(1+\nu)}$ (5Marks)

More

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- B) Polyethylene Metal Composition.
C) Polymer Matrix Composite.
17. The acronym SMC stands for
A) Sheet Molding Compound.
B) Strong Metal Composite.
C) Structural Metal Composite.
18. Composites are easy to repair.
A) False.
B) True.
19. The most common composites are
A) Metal Matrix Composites.
B) Polymer Matrix Composites.
C) Ceramic Matrix Composites.
20. The most common fibers used in polymer composites are
A) glass, steel, and kelvar.
B) glass, steel, and aluminum.
C) glass, carbon, and kelvar.
21. What fiber factors contribute to the mechanical performance of a composite?
A) Length.
B) Orientation.
C) Shape.
D) All of the above.
22. The material of the fiber directly influences the mechanical performance of a composite.
A) True.
B) False.
23. Current service temperature limits for polymers reach
A) 150 °C.
C) both a and b.
D) none of the above.
29. A typical example of thermoplastic matrix include
A) phenolics.
B) polyethylene.
C) polyesters.
30. Which of the following is a drawback for phenolic resin systems?
A) low mechanical strength
B) high cost.
C) brittleness.
D) high void content.
31. Aramid fibers are made up of the following elements
A) Carbon, Hydrogen, and Oxygen.
B) Hydrogen, Oxygen and Nitrogen.
C) Carbon, Hydrogen, and Nitrogen
D) Carbon, Hydrogen, Oxygen and Nitrogen.
32. Bullet resistant vests mainly use the following fiber.
A) Boron
B) Glass
C) Graphite
D) Kevlar
33. Specific modulus is given by
A) Square root of Young's modulus / density.
B) Strength / density.
C) Young's modulus / density.
D) Square root of strength / density.
34. Out of the following, which polymer has the highest service temperature?
A) Polymide
B) Polyimide

Q2. Aramid fibres are the most common use

1. good resistance to chemical solution
2. aromatic chain with tow panels
3. directional

Aral refer to composite material that consist of AL sheet and Aramid epoxy element

Q3 mention the 3 letter type of glasses

E, S, C

there diff. ...

Q2) F/L sheet and Aramid epoxy element

Q3) mention the 3 differ type of glasses

E, S, C

there differ chemical composition and mechanical properties [E, S, C] and chemical properties

Q4) sketch the process of manufacturing glass and mention the important parameter

Sol.

above $1370^{\circ}C$



Size coating \rightarrow continuous fiber

OR discontinuous fiber OR prepreg (layer sheet matrix-resin)

Q5) what the role of the size

+ type of Fibers:

- 1) Whistlers
- 2) wire
- 3) Fiber with fine diameter

+ type of polymer matrix:

- 1) Thermoplastic \rightarrow linear branch
- 2) Thermosets \rightarrow cross link

گپس/ گلاس جی بی جی

E S C

What- the ^{mat} of the size ?

- 1) reaction effect
- 2) eliminate the static friction

Aramid Fibers most common used ?

- 1) good resistance to abrasion
- 2) " " " " organic solvents
- 3) non-conductive
- 4) no melting point, degradation starts from 500°C

- (a) Reinforcement
(b) Matrix
(c) Can't define
(d) Both are of equal strength

4. Usually stronger constituent of a composite is

- (a) Matrix
(b) Reinforcement
(c) Both are of equal strength
(d) Can't define

5. Last constituent to fail in fiber reinforced composites

- (a) Matrix
(b) Fiber
(c) Both fails at same time
(d) Can't define

6. Size range of dispersoids used in dispersion strengthened composites

- (a) 0.01-0.1 μm
(b) 0.01-0.1 nm
(c) 0.01-0.1 mm
(d) 0.01-0.1 m

7. Al-alloys for engine/automobile parts are reinforced to increase their

- (a) Strength
(b) Wear resistance
(c) Elastic modulus
(d) Density

8. Longitudinal strength of fiber reinforced composite is mainly influenced by

- (a) Fiber strength
(b) Fiber orientation

- (c) Magnesium
(d) Zinc
(g) Graphite

11. ARALL is

- a) Alumina reinforced Aramid
b) Aramid Reinforced Layer
(c) Aluminum Reinforced Aramid
d) None of these

12. GLARE is

- a) Aramid Reinforced Glass
(b) Aluminum Reinforced Glass
c) Alumina reinforced Glass
d) Glass Reinforced Aramid

13. One of the major drawbacks of advanced composite materials is

- A) their low specific strength.
B) that they are extremely heavy.
C) their low specific elastic modulus
(D) their high cost of fabrication.

14. What is a composite?

- A) Recycled waste.
B) A chemical reaction.
(C) A structural material consisting of two or more constituents.
D) A monolithic material

15. E-glass type of fiber is used for

- A) electrical applications.
B) emission applications.
(C) environmental applications.

16. The acronym PMC stands for

- (A) Polymer Metal Composition.

UNIVERSITY OF JORDAN
SCHOOL OF ENGINEERING

Composites and powder technology
Student Name:

second summer semester (2016-2017)

Final Exam
Time: 60 Minutes

Q1: choose the correct answer and summarize your answer in the following table (31 marks)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31															

- The three most common types of fibers used in composites are glass, aramids, and graphite. Of these, which are transversely isotropic?
a) glass and graphite. b) glass and aramids.
c) aramids and graphite.
- If the applied stress is greater than the longitudinal tensile strength, for which volume fraction of fibers is it possible for the composite to take a greater load?
a) critical fiber volume fraction.
b) minimum fiber volume fraction.
c) maximum fiber volume fraction.
- Generally for ceramic matrix composites, the maximum strain to failure is larger for
a) the fiber.
b) the matrix.
- The component in a unidirectional polymeric matrix composite which carries the largest percentage of a uniaxial applied load along the fibers is
a) the fibers.
b) the matrix.
c) the particles and matrix share the load equally.
d) Can't define.
- Mechanical properties of fiber-reinforced composites depend on
a) Properties of constituents b) Interface strength
c) Fiber length, orientation, and volume fraction
d) All the above.
- Composite materials are classified based on:
a) Type of matrix b) Size and shape of reinforcement
- Rule-of-mixture provides _____ bounds for mechanical properties of fiber composites.
a) Lower b) Upper c) Both d) None
- Mechanical properties of fiber-reinforced composites depend on
a) Properties of constituents b) Interface strength
c) Fiber length, orientation, and volume fraction
d) All the above.
- In open mold process, mold release agent (silicone, polyvinyl alcohol, fluorocarbon, or sometimes, plastic film) is first applied to increase the product quality.
A) True
B) False
- Electrical contacts used in switches, relays and motors are made of
A) PMC
B) CMC
C) MMC
- Which of the following is not a characteristic of a composite
a) high fatigue strength
b) High specific strength
c) High specific modulus
d) Isotropic
- Which of the following statements is false?
a) Composites do not have a high combination of strength and fracture toughness compared to metals.
b) Composites do not necessarily give higher performance in all the properties used for material selection.
c) Composites do have a high combination of strength and fracture toughness compared to metals
d) Repair of composites is not a simple process.
- Choose the Reinforcement used in Metal matrix composites
a) Al
b) Mg
c) Ti
d) Cu
- Choose the matrix used in PMC composites
a) Copper b) Aluminium c) Epoxy
d) Titanium
- both
- none



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* What are the effects of void content on the Mechanical properties of composite materials?

- ① Lower toughness strength
- ② Lower compression strength
- ③ Lower (micro) strength
- ④ Lower reinforcement strength
- ⑤ Lower stiffness strength

* sketch the pultrusion process and indicate the treatment in each step.

