**School of Engineering and Applied Science (SEAS), Ahmedabad University**

# End Term Exam – May 2025

## CMP670: Sustainable Composites

**Winter Semester: May 01, 2025** **Max. Marks: 100**

**Time: 08:00 AM – 10:00 AM**

Instructions

- Ensure clarity in your explanations.
- Assume missing data where necessary and state assumptions.
- Use neat diagrams and real-world examples wherever relevant.

**Compulsory Question** **[2 x 20]**

1. A unidirectional 60%$V_f$ fiber-reinforced epoxy composite is designed using two different fiber types, glass fiber and jute fiber. The epoxy matrix used has a modulus of 3.45 GPa and a yield strength of 238 MPa. The properties of both the fibers are as,

| Property | Glass Fiber | Jute Fiber |
|---|---|---|
| Diameter (μm) | 10 | 20 |
| Tensile Modulus (GPa) | 72.4 | 30 |
| Tensile Strength, (GPa) | 3.45 | 0.55 |
| Fiber Density (g/cm$^3$) | 2.54 | 1.46 |
| Fiber Strain to Failure (%) | 4.8 | 1.8 |
| Fiber Length (mm) | 5 mm | 5 mm |

(a) Calculate the longitudinal tensile strength assuming glass fibers are continuous and aligned.
(b) For short glass fibers, determine the longitudinal tensile strength considering interfacial shear strengths of 10 MPa. Also, clearly state assumptions about critical fiber length and its impact.
(c) Calculate the critical fiber length for the hemp-epoxy composite.
(d) Calculate the tensile strength of the short hemp-epoxy composite. Assuming identical interfacial shear strengths.
(e) Based on results, compare and comment on the mechanical performance and sustainability of hemp fiber compared to glass fiber for structural applications.

2. A scientist has developed an innovative, low-cost, and environmentally sustainable FRP composite from natural fibers and bio-resin. The material has been proven to meet all essential general-purpose and engineering performance requirements across a wide range of applications. The technology is being offered free of cost to the global community, with

a strong preference for it to be adopted universally for all standard engineering applications, excluding specialized sectors such as aerospace, defense, and other critical exceptions. As a decision-maker responsible for material selection, environmental compliance, and long-term sustainability planning, would you support this universal adoption approach, Yes or No? In any case, justify your answer considering all major and minor decision-making parameters that led to the decision.

**Attempt any FOUR from the following questions.** **[4 x 15]**

3. Explain the hierarchical structure of cellulose fibers. Discuss how its complex structure affects (i) tensile strength and stiffness, (ii) moisture absorption and biodegradability, and (iii) recycling challenges, when used in composites. Also, briefly compare the cellulose fiber with any of the synthetic fibers, highlighting key differences relevant to composite design.
4. Evaluate the comparative sustainability of mechanical recycling, pyrolysis, and solvolysis for FRP waste. Highlight the fiber quality, environmental emissions, scalability, and associated costs.
5. Develop a flowchart for sustainable supply chain management in FRP industries from raw material sourcing to end-of-life (EoL) recycling.
6. (a) Explain the concept of Global Warming Potential (GWP) and Carbon Footprint as applied to FRP composites. How can these help guide material selection and recycling strategies? Give examples using virgin and recycled composites.

**OR**

(b) Discuss the emerging trends in biocomposites and smart recyclable composites. What are their advantages and limitations compared to conventional composites? Give examples of materials and applications.

7. Write short note on any three,
   (i) Design for Disassembly (DfD) principle help reduce carbon footprint and improve recycling rates of composites.
   (ii) Compare the fiber quality obtained by supercritical fluid treatment vs. microwave-assisted solvolysis.
   (iii) Life Cycle Assessment (LCA) can be a powerful tool to assess sustainability. As an example, list and explain its main stages using a recycled GFRP automotive panel.
   (iv) Propose and justify a complete testing strategy covering mechanical and environmental aspects for evaluating recycled FRP composites intended for wind turbine blade reuse.