Biomedical Engineering Cheatsheet

A quick reference guide for key concepts, formulas, and techniques in biomedical engineering, covering biomechanics, biomaterials, bioinstrumentation, and bioimaging.

Biomechanics

Stress and Strain

Stress (σ)	Force per unit area: $\sigma = F/A$ Where: F = Force (N) A = Area (m^2) Units: Pascals (Pa) or N/m^2
Strain (ε)	Change in length per unit length: $\varepsilon = \Delta L/L_0$ Where: ΔL = Change in length (m) L_0 = Original length (m) Strain is dimensionless.
Young's Modulus (E)	Measure of stiffness: $E = \sigma/\varepsilon$ Units: Pascals (Pa) or N/m^2
Shear Stress (τ)	Force acting parallel to the surface per unit area: $\tau = F/A$ Units: Pascals (Pa) or N/m^2
Shear Strain (γ)	Change in angle: $\gamma = \Delta x/L_0$ Where: Δx = Displacement (m) L_0 = Original length (m) Strain is dimensionless.
Shear Modulus (G)	Measure of resistance to shear deformation: $G = \tau/\gamma$ Units: Pascals (Pa) or N/m^2

Viscoelasticity

Viscoelastic materials exhibit both viscous and elastic characteristics when undergoing deformation.

Key Concepts:

- **Creep**: Time-dependent deformation under constant load.
- **Stress Relaxation**: Time-dependent decrease in stress under constant strain.
- **Hysteresis**: Energy loss during loading and unloading cycle.

Common Models:

- **Maxwell Model**: Represents a spring and dashpot in series.
- **Kelvin-Voigt Model**: Represents a spring and dashpot in parallel.

Fluid Mechanics

Reynolds Number (Re)	Predicts flow regime: $Re = (\rho v L)/\mu$ Where: ρ = Density (kg/m^3) v = Velocity (m/s) L = Characteristic length (m) μ = Dynamic viscosity (Pa·s) $Re < 2300$: Laminar flow $Re > 4000$: Turbulent flow
Viscosity (μ)	Measure of a fluid's resistance to flow. Units: Pascal-seconds (Pa·s)
Poiseuille's Law	Describes laminar flow in a cylindrical tube: $Q = (\pi r^4 \Delta P)/(8 \mu L)$ Where: Q = Flow rate (m^3/s) r = Radius of the tube (m) ΔP = Pressure difference (Pa) μ = Dynamic viscosity (Pa·s) L = Length of the tube (m)

Biomaterials

Material Properties

Biocompatibility	The ability of a material to perform with an appropriate host response in a specific application.
Biodegradability	The ability of a material to degrade or be absorbed in the body.
Surface Properties	Surface energy, roughness, and chemical composition affect protein adsorption and cell adhesion.
Mechanical Properties	Tensile strength, compressive strength, Young's modulus, and Poisson's ratio determine structural integrity.

Types of Biomaterials

Metals:

- Stainless steel, titanium alloys, cobalt-chromium alloys.
- Used in implants, prosthetics, and surgical instruments.

Ceramics:

- Alumina, zirconia, hydroxyapatite.
- Used in bone grafts, dental implants, and coatings.

Polymers:

- Polyethylene, polypropylene, silicone, poly(lactic acid) (PLA), poly(glycolic acid) (PGA).
- Used in sutures, drug delivery systems, and tissue engineering scaffolds.

Composites:

- Combination of two or more materials (e.g., carbon fiber reinforced polymers).
- Used in load-bearing implants.

Biomaterial Degradation

Hydrolysis	Chemical breakdown of a material due to reaction with water.
Enzymatic Degradation	Breakdown of a material by enzymes present in the body.
Oxidation	Chemical degradation due to reaction with oxygen.
Corrosion	Electrochemical degradation of metals.

Bioinstrumentation

Sensors and Transducers

Strain Gauge	Measures strain by detecting changes in electrical resistance.
Thermistor	Measures temperature by detecting changes in electrical resistance.
Pressure Transducer	Measures pressure by converting it into an electrical signal.
Electrode	Measures electrical potential differences (e.g., ECG, EEG).

Signal Processing

Amplification
Filtering
Analog-to-Digital Conversion (ADC)
Digital Signal Processing (DSP)

Common Instruments

Electrocardiograph (ECG)	Records electrical activity of the heart.
Electroencephalograph (EEG)	Records electrical activity of the brain.
Electromyograph (EMG)	Records electrical activity of muscles.
Blood Pressure Monitor	Measures arterial blood pressure.

Bioimaging

Imaging Modalities

X-ray	Uses electromagnetic radiation to create images of bones and dense tissues.
Computed Tomography (CT)	Uses X-rays to create cross-sectional images of the body.
Magnetic Resonance Imaging (MRI)	Uses magnetic fields and radio waves to create detailed images of soft tissues.
Ultrasound	Uses sound waves to create real-time images of organs and tissues.
Positron Emission Tomography (PET)	Uses radioactive tracers to visualize metabolic activity in the body.

Image Processing

Image Enhancement
Image Segmentation
Image Registration
Image Reconstruction

Contrast Agents

Iodine-based	Used in CT scans to enhance the visibility of blood vessels and organs.
Gadolinium-based	Used in MRI to enhance the visibility of soft tissues and blood vessels.
Microbubbles	Used in ultrasound to enhance the visibility of blood flow and tissue perfusion.