

## Physical Foundations of Biological Systems

### **1. Measurement and mathematical background**

- (a) Systems of units
- (b) dimensions
- (c) scientific notation
- (d) scientific prefixes
- (e) trigonometry
- (f) logarithms
- (g) vectors and scalars

### **2. Motion (kinematics)**

- (a) displacement
- (b) velocity
- (c) acceleration
- (d) constant acceleration
- (e) free fall motion
- (f) projectile motion

### **3. Newton's laws of motion (dynamics)**

- (a) definitions: mass, momentum, force
- (b) Newton's first law: the principle of inertia
- (c) Newton's second law:  $F=ma$
- (d) Newton's third laws: action/reaction pairs
- (e) Free body diagrams
- (f) Force of gravity (weight)
- (g) Normal force
- (h) Friction force
- (i) Tension force
- (j) Spring force
- (k) Buoyant force
- (l) Drag force
- (m) Centripetal force
- (n) Centripetal acceleration

### **4. Work and energy**

- (a) work done by a constant force
- (b) work done by a non-constant force
- (c) work-kinetic energy theorem
- (d) work and potential energy

- (e) conservation of energy
- (f) power
- (g) machines and mechanical advantage

**5. Linear momentum and collisions**

- (a) conservation of momentum
- (b) elastic and inelastic collisions
- (c) center of mass calculation
- (d) center of mass motion

**6. Rotational motion**

- (a) angular displacement
- (b) angular velocity
- (c) angular acceleration
- (d) rotational inertia
- (e) angular momentum
- (f) torque
- (g) rotational kinetic energy
- (h) conservation of angular momentum

**7. Static equilibrium**

- (a) translational equilibrium
- (b) rotational equilibrium

**8. Oscillatory (periodic) motion**

- (a) angular frequency, frequency, and period of oscillation
- (b) pendulum motion
- (c) mass on a spring

**9. Planetary motion and universal gravitation**

- (a) Kepler's first law
- (b) Kepler's second law
- (c) Kepler's third law
- (d) Newton's universal law of gravitation

**10. Fluids**

- (a) pressure measurement
- (b) hydrostatic pressure
- (c) Archimedes' principle
- (d) Pascal's principle
- (e) continuity equation
- (f) viscosity
- (g) laminar flow, turbulent flow, and Reynolds number
- (h) Streamlines

- (i) Bernoulli's equation
- (j) elastic solids: young's modulus, shear modulus, bulk modulus

### **11. Sound**

- (a) longitudinal (not transverse) waves
- (b) amplitude and volume
- (c) frequency and pitch
- (d) wavelength, frequency, and speed
- (e) intensity of sound and the decibel scale
- (f) superposition principle
- (g) traveling waves vs standing waves
- (h) doppler effect

### **12. Thermodynamics**

- (a) temperature scales
- (b) thermal expansion
- (c) heat capacity
- (d) conduction, convection and radiation of heat
- (e) latent heat
- (f) heat, work and the first law of thermodynamics
- (g) adiabatic process
- (h) isothermal process
- (i) isochoric process
- (j) isobaric process
- (k) closed cycle process
- (l) ideal gas equation of state
- (m) real gas/van der wals equation of state
- (n) partial pressure
- (o) entropy and the second law of thermodynamics
- (p) heat engines and efficiency

### **13. Electrostatics**

- (a) positive and negative electricity
- (b) triboelectricity and charge separation
- (c) conservation of electric charge
- (d) storing charge: capacitance
- (e) conductors and insulators
- (f) coulomb's law
- (g) electric fields
- (h) electric potential
- (i) electric potential energy

- (j) electric dipole moment

#### **14. Electronic circuits**

- (a) electric current
- (b) resistance and resistivity
- (c) insulators, conductors, semiconductors, superconductors
- (d) circuit diagrams
- (e) voltmeters and ammeters
- (f) ohm's law
- (g) Kirchoff's circuit rules
- (h) resistors in parallel
- (i) resistors in series
- (j) joule heating of a resistor
- (k) capacitors in parallel
- (l) capacitors in series
- (m) energy stored in a capacitor
- (n) capacitors with dielectrics
- (o) alternating current and rms voltage
- (p) household wiring

#### **15. Magnetism**

- (a) terrestrial magnetism and magnetic poles
- (b) diamagnetic materials
- (c) ferromagnetism, paramagnetism, Curie temperature
- (d) hard (high coercivity) magnets and soft (low coercivity) magnets
- (e) magnetic fields near permanent magnets
- (f) magnetic fields near wires, loops and helices (1st right hand rule)
- (g) magnetic (lorentz) force on moving charges (second right hand rule)
- (h) magnetic force on current-carrying wires
- (i) the discovery of the electron
- (j) mass spectroscopy

#### **16. Light**

- (a) electromagnetic waves
- (b) producing and detecting electromagnetic waves: antennae and atoms
- (c) speed of light and refractive index
- (d) frequency, color and the visible spectrum
- (e) geometric optics: the ray approximation
- (f) law of reflection
- (g) plane mirrors
- (h) spherical mirrors

- (i) magnification
- (j) law of refraction
- (k) total internal reflection
- (l) convex (converging) lenses
- (m) concave (diverging) lenses
- (n) thin lens equation
- (o) human eyes
- (p) telescopes
- (q) dispersion of light (prisms and rainbows)
- (r) diffraction of light
- (s) interference of light
- (t) polarization of light
- (u) scattering of light

**17. atomic phenomena**

- (a) atomic emission and absorption spectra
- (b) thermal (blackbody) radiation: quantization of energy
- (c) photoelectric effect: quantization of light
- (d) Davisson-Germer experiment: wave particle duality
- (e) Bohr model of the atom: quantization of energy levels
- (f) emission and absorption of light from atoms
- (g) electron spin and the Pauli exclusion principle
- (h) the building-up principle and the periodic table

**18. nuclear phenomena**

- (a) atomic number and mass number
- (b) isotopes
- (c) atomic mass units
- (d) binding energy and mass defect
- (e) nuclear reactions: fusion
- (f) nuclear reactions: fission
- (g) alpha decay
- (h) beta decay
- (i) gamma decay
- (j) radioactive decay half life
- (k) exponential decay