

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) Newtons' 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