PAT Formula Sheet for Final Round Revision

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1 Mechanics

1.1 Constant Acceleration Motion

1.1.1 SUVAT equations

$$v = u + at$$

$$s = \frac{(u+v)t}{2}$$

$$s = ut + \frac{at^2}{2}$$

$$s = vt - \frac{at^2}{2}$$

$$v^2 = u^2 + 2as$$

1.1.2 Relationship between acceleration, velocity and displacement

$$\frac{ds}{dt} = v$$

$$\frac{dv}{dt} = a$$

$$\int a\,dt = v$$

$$\int v\,dt = s$$

1.1.3 Newton's 2nd law

$$F = ma$$

$$F = m\frac{dv}{dt}$$

1.1.4 Projectile motion

$$y = x\tan\theta - \frac{gx^2}{2V^2\cos^2\theta}$$

1.2 Resistive force

1.2.1 Proportional model of resistive force

$$f = -kv$$

1.2.2 Air resistance

$$f = \frac{1}{2}c\rho A v^2$$

c: drag coefficient

1.2.3 Terminal speed

$$v_T = \frac{mg}{k} \text{ (proportional model)}$$

$$v_T = \sqrt{\frac{2mg}{c\rho A}} \text{ (air resistance model)}$$

1.3 Spring

1.3.1 Hooke's law

$$F = -kx$$

1.3.2 Energy in a spring

$$E_s = \frac{1}{2}kx^2$$

1.3.3 Combination of springs

$$\frac{1}{k_T} = \frac{1}{k_1} + \frac{1}{k_2} (in\ series)$$

$$k_T = k_1 + k_2 (in\ parallel)$$

1.4 Momentum

$$p = mv$$

1.5 Impulse

$$I = m\Delta v$$

$$F = \frac{dp}{dt} = m\frac{\Delta v}{t}$$

1.6 Linear collision

1.6.1 Conservation of linear momentum

$$m_1u_1 + m_2u_2 + \cdots + m_nu_n = m_1v_1 + m_2v_2 + \cdots + m_nv_n$$

1.6.2 Coefficient of restitution

$$e = \frac{v_r}{u_r} = \frac{v_2 - v_1}{u_1 - u_2}$$

1.7 Energetics

1.7.1 Kinetic energy

$$E_k = \frac{1}{2}mv^2$$

1.7.2 Gravitational potential energy

$$E_p = mgh$$

1.7.3 Conservation of mechanical energy

$$E_{p_1} + E_{k_1} = E_{p_2} + E_{k_2}$$

1.7.4 Work done

$$W = Fs$$

$$W = \int F\, ds$$

1.7.5 Power

$$P = \frac{W}{t} = Fv$$

1.7.6 Relationship between work and energy

$$\sum W = \Delta E_k$$

1.7.7 Potential energy function

$$\mathrm{U}_f - U_i = -\int_{x_i}^{x_f} F_x dx$$

PE can only associate with a conservative force

1.8 Circular motion

$$F = \frac{mv^2}{r} = mr\omega^2$$

$$a = \frac{v^2}{r} = r\omega^2$$

$$v = r\omega$$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

1.9 Simple harmonic motion

1.9.1 SHM equations

$$a = -\omega^2 x$$

$$x = x_0 \sin(\omega t + \emptyset)\ or\ x = x_0 \cos(\omega t + \emptyset)$$

$$v_0 = \omega x_0$$

$$v = v_0 \cos \omega t$$

$$v = \pm\omega\sqrt{x_0^2 - x^2}$$

1.9.2 SHM of a spring

$$T = 2\pi\sqrt{\frac{m}{k}}$$

1.9.3 SHM of a pendulum

$$T = 2\pi\sqrt{\frac{L}{g}}$$

1.9.4 SHM of liquid in U-pipe

$$T = 2\pi\sqrt{\frac{L}{2g}}$$

1.10 Elasticity

1.10.1 Young modulus

$$Y = \frac{F / A}{\Delta L / L_0}$$

1.10.2 Shear modulus

$$S = \frac{F / A}{\Delta x / h}$$

1.10.3 Bulk modulus

$$B = -\frac{\Delta P}{\Delta V / V_0}$$

1.11 Moment

1.11.1 Balance of moment

$$\iota_{clockwise} = \iota_{anticlockwise}$$

$$\iota = L \times F$$

1.11.2 Torque of a couple

$$TC = F \cdot 2L = Fd$$

1.12 Pulley

$$F_{in} = \frac{F_{effective}}{n}$$

n: number of ropes

1.13 Mechanical efficiency

$$ME = \frac{P_{out}}{P_{in}}$$

1.14 Mechanical advantage

$$MA = \frac{F_{effective}}{F_{in}}$$

1.15 Continously varying mass and rocket propulsion

$$F_{\text{net}} + v_r \frac{dM}{dt} = M \frac{dv}{dt}$$

$$(v_r = u - v)$$

1.16 Centre of mass

$$\bar{y} = \frac{\int y \, dm}{\sum m}$$

$$\bar{x} = \frac{\int x \, dm}{\sum m}$$

1.17 Centre of mass motion

$$v_{cm} = \frac{p}{M}$$

p: sum of momentum of the system

1.18 Pressure

$$P = \frac{F}{A}$$

1.19 Limiting friction

$$f_{\max} = \mu N$$

1.20 Rotational motion and rigid body

1.20.1 Rotational inertia

$$I = \Sigma\left(m_i r_i^2\right)$$

$$I_{sphere} = \frac{2}{5} m r^2$$

$$I_{rod} = \frac{1}{3} m L^2$$

$$I_{disk} = \frac{1}{2} mr^2$$

$$I_{ring} = mr^2$$

1.20.2 Torque

$$\iota = I\alpha$$

1.20.3 Angular momentum

$$p_a = I\omega$$

$$\sum \tau_{ext} = \frac{dp_a}{dt}$$

1.20.4 Rotational kinetic energy

$$KE_R = \frac{1}{2} I\omega^2$$

1.20.5 Conservation of angular momentum

$$I_1\omega_1 = I_2\omega_2$$

1.20.6 Bullet shoot into rod/child rush on merry-go-round

$$mrv + I_0\omega_0 = I'\omega'$$

$$I' = I_0 + mr^2$$

1.20.7 A sphere rolling down a slope

$$mgh = \frac{1}{2} mv^2 + \frac{1}{2} I\omega^2$$

1.20.8 Constant angular acceleration equations

$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\theta = \omega_f t - \frac{1}{2}\alpha t^2$$

$$\omega_f{}^2 - \omega_0{}^2 = 2\alpha\theta$$

1.20.9 Power

$$P = \tau\omega$$

1.20.10 Work done

$$W = \tau d\theta$$

1.20.11 Precessional motion (motion of gyroscope)

$$\omega_p = \frac{Mgr}{I\omega}$$

1.21 Curvature

$$k = \frac{1}{r}$$

2 Fluid mechanics

2.1 Hydrostatic pressure

$$P = \rho gh + P_0$$

2.2 Force on a dam

$$F = \int_0^H \rho g(H - y)wdy = \frac{1}{2}\rho gwH^2$$

y: distance to the bottom of reservoir

w: length of the dam

2.3 Buoyancy

$$F_B = \rho gV_{displaced}$$

2.4 Bernoulli's equation

$$p_{s_1} + \frac{1}{2}\rho {v_1}^2 + \rho gh_1 = p_{s_2} + \frac{1}{2}\rho {v_2}^2 + \rho gh_2$$

2.5 Relationship between pipe cross-sectional area and speed of flow

$$A_1 v_1 = A_2 v_2$$

2.6 Viscous flow and Reynold number

$$\mathrm{Re} = \frac{F_{inertia}}{F_{viscous}} = \frac{\rho vr}{\mu}$$

(if Re<1000, laminar flow; if 1000<Re<2000, transition stage; if Re>2000, turbulent flow)

2.7 Stroke's law

$$F_D = 6\pi\mu rv$$

$$6\pi\mu rv + \frac{4}{3}\pi r^3 \rho g = mg$$

(when a sphere reaches terminal velocity in a vertical viscous flow)

2.8 Fluid leaking out a bottle from a hole of distance h below surface

$$v = \sqrt{2gh}$$

(derived from Bernoulli's equation)

3 Thermal physics

3.1 Boyle's law

$$P_1V_1 = P_2V_2$$

3.2 Charles's law

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

3.3 Ideal gas law

$$PV = nRT$$

3.4 Absorption of thermal energy

$$Q = cm\Delta T$$

3.5 Average kinetic energy of an ideal gas molecule

$$E_K = \frac{1}{2}m < v^2 >= \frac{3}{2}kT$$

$k = \dfrac{R}{N_A}$ (Avogadro constant)

3.6 Pressure of ideal gas

$$P = \frac{1}{3}\rho < c^2 >$$

3.7 Internal energy of ideal gas

$$E_{\text{int}} = \frac{3}{2}nRT$$

3.8 Change in internal energy

$$\Delta E_{\text{int}} = nC_V\Delta T$$

C_V : molar specific heat at constant volume

3.9 Linear thermal expansion

$$\Delta L = L_0 \alpha_L \Delta T$$

3.10 Specific latent heat

$$E = mL$$

3.11 Heat transfer

3.11.1 Heat transfer by conduction

$$\frac{dQ}{dt} = kA\frac{\Delta T}{\Delta x}$$

k: conductivity

3.11.2 Heat transfer by convection

$$\frac{dQ}{dt} = hA(T_1 - T_2)$$

h: heat transfer coefficient

3.11.3 Heat transfer by radiation (Stefan-Boltzmann law)

$$\frac{dQ}{dt} = \varepsilon\sigma A(T_1^4 - T_2^4)$$

ε: emissivity σ: Stefan-Boltzmann constant

3.12 First law of thermodynamics

$$Q = \Delta U + W$$

3.13 Adiabatic change ($\Delta U = -W$)

$$P_1 V_1^{\frac{5}{3}} = P_2 V_2^{\frac{5}{3}}$$

3.14 Work done in an isobaric change

$$W = p\Delta V$$

4 Wave

4.1 Period of wave

$$T = \frac{\lambda}{v}$$

4.2 Oscillation formula to wave formula

$x = A\cos(\omega t + \phi)$ (Oscillation)

$y = A\cos(\omega t - kx + \phi)$ (Wave)

$$k = \frac{\omega}{v} = \frac{2\pi}{\lambda}$$

4.3 Speed of waves on strings

$$v = \sqrt{\frac{T}{\mu}}$$

T: tension in the string

μ: mass per unit length

4.4 Rate of energy transfer by sinusoidal waves on strings

$$P = \frac{1}{2}\mu\omega^2 A^2 v$$

4.5 Linear wave equation for a string

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

4.6 Sound wave

4.6.1 Particle displacement in sound waves

$$s(x,t) = s_{\max}\cos(kx - \omega t)$$

4.6.2 Variation in pressure from equilibrium

$$\Delta P = \Delta P_{\max}\sin(kx - \omega t)$$

4.6.3 Speed of sound

$$v = \sqrt{\frac{B}{\rho}}$$

B: bulk modulus ρ: density of medium

4.6.4 Power

$$\Delta P_{\max} = \rho v \omega s_{\max}$$

$$< P >= \frac{1}{2}\rho v \omega^2 A s_{\max}{}^2$$

4.6.5 Intensity

$$I = \frac{1}{2}\rho v \omega^2 s_{\max}{}^2$$

4.6.6 Doppler effect

$$f' = f_0 \frac{v + v_D}{v - v_s} \text{ (Approaching)}$$

$$f' = f_0 \frac{v - v_D}{v + v_s} \text{ (Leaving)}$$

4.6.7 Shock waves/Mach angle

$$\sin\theta = \frac{v}{v_s}$$

4.6.8 Mach number

$$Ma = \frac{v_s}{v}$$

4.7 Doppler effect for light

$$\Delta f = f_0 \frac{v}{c}$$

4.8 Interference

4.8.1 Double slit interference

$$\lambda = \frac{ax}{D}$$

4.8.2 Diffraction gratings

$$n\lambda = d\sin\theta$$

4.8.3 Path difference and construction

$$D = n\lambda, n = 1, 2, 3, \ldots$$

4.8.4 Path difference and deconstruction

$$D = (2n-1)\frac{\lambda}{2}, n = 1, 2, 3, \ldots$$

4.9 Intensity

$$I = \frac{P}{A} (= \frac{P}{4\pi R^2})$$

A: cross-sectional area/sphere surface area

$$I = kA^2$$

A: amplitude

4.10 Beat formula

$$y = y_1 + y_2$$

$$y = (2A\cos(\frac{\omega_1 - \omega_2}{2})t)\bullet\cos(\frac{\omega_1 + \omega_2}{2})t$$

$\frac{\omega_1 - \omega_2}{2}$: angular frequency of signal (periodical change of amplitude)

$\frac{\omega_1 + \omega_2}{2}$: angular frequency of the carrier wave

4.11 Malus's law of polarisation

$$I = I_0 \cos^2 \theta$$

θ: angle between the transmission axes of the analyser and polarizer

4.12 Ultrasound used in medical imaging

4.12.1 Acoustic impedance

$$Z = \rho c$$

4.12.2 Proportion of incident wave energy reflected

$$\frac{I_{ref}}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

5 Circuit

5.1 DC circuit

5.1.1 Resistance

$$R = \frac{\rho L}{A}$$

5.1.2 Ohm's law

$$R = \frac{V}{I}$$

5.1.3 Kirchhoff's laws

5.1.3.1 Kirchhoff's first law

$$\sum I_{in} = \sum I_{out}$$

5.1.3.2 Kirchhoff's second law

$\sum e.m.f = \sum p.d$ (in any loop)

5.1.4 Connect in series

$$I = I_1 = I_2 = \ldots = I_n$$

$$V = V_1 + V_2 + \ldots + V_n$$

$$R = R_1 + R_2 + \ldots + R_n$$

5.1.5 Connect in parallel

$$I = I_1 + I_2 + \ldots + I_n$$

$$V = V_1 = V_2 = \ldots = V_n$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$$

5.1.6 Charge

$$Q = It$$

$$Q = \int I dt$$

5.1.7 Power

$$P = VI = \frac{V^2}{R} = I^2 R$$

5.1.8 Energy

$$W = VIt = QV$$

5.1.9 Maximum power on load

$$r = R$$

R: load resistance r: internal resistance of power supply

5.2 AC circuit

5.2.1 Periodical change of current

$$I = I_0 \sin(\omega t)$$

5.2.2 Root-mean-square value of current/potential difference

$$I_{RMS} = \frac{I_0}{\sqrt{2}}$$

$$V_{RMS} = \frac{V_0}{\sqrt{2}}$$

5.2.3 Average power

$$P_{mean} = \frac{1}{2} P_{\max} = I_{RMS} V_{RMS}$$

5.2.4 Transformer

$$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

Step/turn ratio: $\frac{N_P}{N_S}$

$$V_P I_P = V_S I_S$$

5.3 Capacitor

5.3.1 Capacitance

$$C = \frac{\varepsilon A}{d}$$

5.3.2 Capacitance of a sphere

$$C_s = 4\pi\varepsilon_0 R$$

5.3.3 Charge in a capacitor

$$Q = CV$$

5.3.4 Energy in a capacitor

$$E = \frac{1}{2} C V^2$$

5.3.5 Charing a capacitor

$$I = I_0 e^{-\frac{t}{RC}}$$

$$V = V_f (1 - e^{-\frac{t}{RC}})$$

$$Q = Q_f (1 - e^{-\frac{t}{RC}})$$

5.3.6 Discharging a capacitor

$$I = I_0 e^{-\frac{t}{RC}}$$

$$V = V_0 e^{-\frac{t}{RC}}$$

$$Q = Q_0 e^{-\frac{t}{RC}}$$

5.3.7 Time constant

$$\tau = RC$$

5.3.8 Combining capacitors

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_n} \text{ (in series)}$$

$$C = C_1 + C_2 + \ldots + C_n \text{ (in parallel)}$$

5.4 Operational amplifier

5.4.1 Open-loop voltage gain

$$G_0 = \frac{V_{out}}{V_{in}}$$

5.4.2 Gain of inverting amplifier

$$G = -\frac{R_f}{R_{in}}$$

5.4.3 Gain of non-inverting amplifier

$$G = 1 + \frac{R_1}{R_2}$$

5.5 Inductor

5.5.1 RL circuit

5.5.1.1 Effect on current when a switch is closed

$$I = \frac{\varepsilon}{R}(1 - e^{-Rt/L})$$

ε: EMF of power supply

5.5.1.2 Time constant

$$I = \frac{\varepsilon}{R}(1 - e^{-t/\tau})$$

$$\tau = \frac{L}{R}$$

5.5.1.3 Effect on current when a switch is opened

$$I = \frac{\varepsilon}{R} e^{-t/\tau} = I_i e^{-t/\tau}$$

5.5.2 Energy in magnetic field

$$U_B = \frac{1}{2} L I^2$$

5.5.3 Energy density in inductor

$$u_B = \frac{U_B}{V}$$

V: volume of inductor

5.5.4 LC circuit

5.5.4.1 Total energy stored in circuit

$$U = U_E + U_B$$

$$\frac{Q^2}{2C} + \frac{1}{2} L I^2 = \frac{{Q_{\max}}^2}{2C}$$

5.5.4.2 Oscillations in circuit

$$Q = Q_{\max} \cos(\omega t + \phi)$$

$$\omega = \frac{1}{\sqrt{LC}}$$

5.5.5 RLC circuit

$$Q = Q_{\max} e^{-Rt/2L} \cos \omega_d t$$

$$\omega_d = \left[\frac{1}{LC} - (\frac{R}{2L})^2 \right]^{\frac{1}{2}}$$

6 Field

6.1 Electric field

6.1.1 Electric field strength

$$E = \frac{F}{Q}$$

$$E = \frac{V}{d}$$

(for uniform electric field)

$$E = -\frac{d\phi}{dr}$$

6.1.2 Particle acceleration in electric field

$$QV = \frac{1}{2}mv^2$$

6.1.3 Coulomb's law

$$F = \frac{kQ_1Q_2}{R^2}$$

$$k = \frac{1}{4\pi\varepsilon_0}$$

6.1.4 Electric field potential energy

$$EPE = \frac{kQ_1Q_2}{R}$$

6.1.5 Electric field potential

$$V = \frac{kQ}{R}$$

6.1.6 Electric flux

$$\Phi_E = EA_\perp$$

6.1.7 Gauss's law

$$\Phi_E = \frac{q}{\varepsilon_0}$$

6.2 Gravitational field

6.2.1 Newton's gravitational law

$$F_g = \frac{Gm_1m_2}{R^2}$$

6.2.2 Gravitational potential energy

$$GPE = -\frac{Gm_1m_2}{R}$$

6.2.3 Gravitational potential

$$\phi = -\frac{GM}{R}$$

6.2.4 Gravitational field strength

$$E = \frac{GM}{R^2}$$

6.2.5 Newton's shell theorem

$$g' = \frac{GMr}{R^3}$$

M: mass of planet r: radius to core R: radius of planet

6.3 Magnetic field

6.3.1 Magnetic force on a straight charge-carrying wire

$$F = I\vec{L} \times \vec{B}$$

6.3.2 Magnetic force on a point charge

$$F = q\vec{V} \times \vec{B}$$

6.3.3 Magnetic field produced by a charge-currying wire

$$B = \frac{\mu_0 I}{2\pi r}$$

6.3.4 Magnetic field inside a solenoid with current

$$B = \mu_0 n I$$

n: number of turns per unit length

6.3.5 Magnetic field at the centre of a coil with current

$$B = \frac{\mu_0 I}{2r}$$

6.3.6 Magnetic flux

$$\phi = BA$$

6.3.7 Induced E.M.F

$$EMF = -\frac{d\phi}{dt} N$$

6.3.8 Induced E.M.F in a straight conductor

$$E.M.F = L\vec{v} \times \vec{B}$$

6.3.9 Induced E.M.F in a rotating straight rod

$$EMF = \frac{1}{2} vBL$$

6.3.10 Speed Selector

$$vBd = V$$

6.3.11 Cyclotron

$$R = \frac{mv}{qB}$$

6.3.12 Hall's effect

$$V_H = \frac{BI}{net}$$

t: thickness of the material

6.3.13 Ampere's law

$$\sum Bds = \mu_0 I$$

6.3.14 Inductance

6.3.14.1 Self-inductance

$$L = \frac{N\phi}{I}$$

L: inductance

6.3.14.2 Self-induced emf

$$\varepsilon_L = -L\frac{dI}{dt}$$

6.3.14.3 Mutual inductance (mutual inductance of coil 2 with respect to coil 1)

$$M_{12} = \frac{N_2\phi_{12}}{I_1}$$

6.3.14.4 Mutual-induced emf

$$\varepsilon_2 = -M_{12}\frac{dI_1}{dt}$$

$$\varepsilon_1 = -M_{21}\frac{dI_2}{dt}$$

6.3.15 Torque on current loop

6.3.15.1 Magnetic dipole moment

$$\mu = NIA$$

N: number of coils

Direction: perpendicular to the plane

6.3.15.2 Magnetic moment

$$\tau = \mu \times B = \mu B \sin\theta$$

6.3.15.3 Magnetic potential energy

$$U = -\mu \bullet B = -\mu B \cos\theta$$

7 Optics

7.1 Reflection

$$\theta_{inc} = \theta_{ref}$$

$$v_O = v_I$$

$$d_O = d_I$$

7.2 Refraction

7.2.1 Snell's law

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

7.2.2 Critical angle

$$\sin\theta_1 = \frac{n_2}{n_1}$$

7.2.3 Refractive index

$$n = \frac{c_{vac}}{v_{med}}$$

7.2.4 Real depth

$$n = \frac{d_{real}}{d_{appr}}$$

7.3 Imaging

7.3.1 The lens equation

$$\frac{1}{f} = \frac{1}{d_O} + \frac{1}{d_I}$$

7.3.2 Linear magnification

$$m = \frac{h_I}{h_O} = -\frac{d_I}{d_O}$$

7.3.3 Angular magnification

$$M = \frac{\theta_I}{\theta_O}$$

7.3.4 Power of a lens

$$P = \frac{1}{f}$$

7.3.5 Magnification of a magnifying glass

$$M_{near} = \frac{d_I}{f} + 1$$

$$M_{\inf} = \frac{D}{f}$$

7.4 Resolution

7.4.1 Rayleigh's criterion

$$\theta = 1.22\frac{\lambda}{d}$$

7.4.2 Resolvance of diffraction gratings

$$R = \frac{\lambda}{\Delta\lambda} = Nm$$

N: number of slits illuminated m: order number

7.5 Attenuation

$$ATT = 10\log_{10}\frac{I}{I_0}$$

8 Quantum and nuclear physics

8.1 Photoelectric effect

8.1.1 Energy of a photon

$$E_p = hf$$

8.1.2 Work function

$$\phi = hf_0$$

8.1.3 Maximum kinetic energy of the electron

$$hf = \phi + KE_{\max}$$

8.1.4 Stopping potential difference

$$V = \frac{hf - \phi}{e}$$

8.2 De Broglie wavelength

$$mv\lambda = h$$

8.3 Energy level

8.3.1 Bohr Model for a nucleus with *Z* protons

$$E_n = \frac{-Z^2 R}{n^2}$$

n=1 for ground state

8.3.2 De-excitation of electron

$$hf = E_1 - E_2$$

8.3.3 De-excitation route

$$n = {}^{N}C_2$$

N: number of lines presented

n: number of possible de-excitation lines

8.4 Einstein's mass-energy equation

$$E = mc^2$$

8.5 Pair production

$$hf = 2mc^2$$

8.6 Angular momentum of electron in stationary state

$$mvr = \frac{nh}{2\pi}$$

8.7 Radioactive decay

8.7.1 Radioactive decay formula

$$N = N_0 e^{-\lambda t}$$

8.7.2 Decay constant

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$$

8.7.3 Activity

$$A = \frac{\Delta N}{\Delta t} = -\lambda N$$

8.7.4 Decay equilibrium

$$A_1 = A_2$$

$$\lambda_1 N_1 = \lambda_2 N_2$$

8.8 Relationship between radius of nucleus and nucleon number

$$R = R_0 Z^{\frac{1}{3}}$$

R_0 : Fermi radius

8.9 Nuclear density

$$\rho = \frac{3u}{4\pi R_0^3}$$

8.10 Application of nuclear physics

8.10.1 X-Ray intensity equation

$$I = I_0 e^{-\mu x}$$

8.10.2 Linear absorption

$$\mu = \frac{\ln 2}{x_{\frac{1}{2}}}$$

9 Astronomy

9.1 Distance between foci

$$d = \sqrt{j^2 - r^2}$$

j: radius of major axis r: radius of minor axis

9.2 Kepler's second law

$$r_1 v_1 = r_2 v_2$$

9.3 Kepler's third law

$$T^2 = \frac{4\pi^2}{GM} R^3$$

9.4 Escape velocity of the Earth

$$v_{esc} = \sqrt{\frac{2GM}{r}}$$

9.5 Apparent brightness of a star

$$b = \frac{L}{4\pi d^2}$$

d: distance from the star to observer

9.6 Luminosity

$$L = 4\pi R^2 T^4 \sigma$$

9.7 Mass-luminosity relation

$$L = kM^{3.5}$$

9.8 Wien's law

$$T = \frac{2.9 \times 10^{-3}}{\lambda_{\max}}$$