Math A, B

Math A: 1 ~ 17

Math B: 1 ~ 24, except 5

1. Numbers and expressions
   a. Exponent rules
   b. Factorization / expansion
      ① $(a+b)(a^2-ab+b^2)=a^3+b^3$
   c. Real numbers
   d. First-degree inequality
   e. Absolute values
      ① When $|x|=c$, $x=\pm c$
2. Sets
   a. Sets
      ① $A\cap B$, $A\cup B$, $A\subset B$, $x\in A$
   b. Sufficient and necessary conditions
3. Quadratic equations
   a. Quadratic functions
      ① $y=ax^2+bx+c$
      ② $y=a\left(x+\frac{b}{2a}\right)^2-\frac{b^2-4ac}{4a}$
      ③ $D=b^2-4ac$
   b. Minima, maxima
4. Figures and measurements
   a. Sin, cos, tan
      ① $1+\tan^2\theta=\frac{1}{\cos^2\theta}$
      ② $\sin(90°-\theta)=\cos\theta$
   b. Trigonometric ratios
      ① $\frac{a}{\sin a}=\frac{b}{\sin b}=\frac{c}{\sin c}=2R$
      ② $a^2=b^2+c^2-2bc\cos A$
5. Data analysis
   a. Deviation
      ① $s^2=\overline{x^2}-(\overline{x})^2$
   b. Tendency
6. Number of possible outcomes
   a. Sets
      ① $n(A\cup B)=n(A)+n(B)-n(A\cap B)$
   b. Permutation
      ① ${}_nP_r=\frac{n!}{(n-r)!}$ (Usually written as $P(n,r)$ outside Japan)
      ② $\frac{(n-1)!}{2}$ for circular permutation
   c. Combination
      ① ${}_nC_r=\frac{{}_nP_r}{r!}=\frac{n!}{r!(n-r)!}$ (Usually written as $\binom{n}{r}$ outside Japan)
      ② ${}_nC_r={}_nC_{n-r}$
7. Probability
   a. Properties of probability
      ① $P(A)=\frac{n(A)}{n(U)}$
      ② $P(A)+P(\overline{A})=1$
      ③ $P(A\cup B)=P(A)+P(B)-P(A\cap B)$
   b. Independent trials
      ① ${}_nC_rp^r(1-p)^{n-r}$
   c. Probability with constraints
      ① $P_A(B)=\frac{P(A\cap B)}{P(A)}$
8. Properties of figures
   a. Ceva's theorem
      ① For ΔABC with points R, P, and Q on AB, BC, and CA respectively, $\frac{AR}{RB}\cdot\frac{BP}{PC}\cdot\frac{CQ}{QA}=1$
   b. Menelaus's theorem
   c. Power of a point theorem
9. Properties of integers
   a. Number of divisors
      ① If a natural number $N=p^a\cdot$

$q^b \cdot r^c \cdot \cdots$, then the number of positive divisors $= (a+1)(b+1)(c+1)\cdots$ and the sum of all positive divisors $= (1+p+\cdots p^a)(1+q+\cdots q^b)(1+r+\cdots r^c)\cdots$

b. GCD, LCM
   ① If $a = ga'$ and $b = gb'$, then a' and b' are relative primes of each other, $l = ga'b'$, and $ab = gl$
c. Remainder rules
d. Euclidean algorithm
   ① If $ax + by = c$ and $ap + bq = c$, then $x = bk + p$ and $y = -ak + q$
e. Recurring decimal
f. Positional notation (base 2, 3, 4, …)

10. Miscellaneous expressions
    a. Binomial theorem
       ① $\frac{n!}{p!q!r!}a^p b^q c^r$
    b. Arithmetic mean
       ① If $a > 0$ and $b > 0$, then $a + b \geq 2\sqrt{ab}$ is true and $a + b = 2\sqrt{ab}$ when $a = b$
    c. Roots
       ① $\sqrt{a + b \pm 2\sqrt{ab}} = \sqrt{a} \pm \sqrt{b}$
    d. Properties of complex numbers
       ① $i^2 = -1$
    e. Solutions of functions
       ① If α and β are the two solutions of $ax^2 + bx + c = 0$, then $\alpha + \beta = -\frac{b}{a}$ and $\alpha\beta = \frac{c}{a}$
       ② If α, β, and γ are the three solutions of $ax^3 + bx^2 + cx + d = 0$, then $\alpha + \beta + \gamma = -\frac{b}{a}$ and $\alpha\beta + \beta\gamma + \gamma\alpha = \frac{c}{a}$, and $\alpha\beta\gamma = -\frac{d}{a}$

11. Figures and equations
    a. Triangles
       ① For ΔABO with $O(0,0)$, $A(x_1, y_1)$, and $A(x_2, y_2)$, $S = \frac{1}{2}|x_1 y_2 - x_2 y_1|$
    b. Circles
       ① $x^2 + y^2 = r^2$
       ② For a circle C $x^2 + y^2 = r^2$, the equation of the tangent line is $x_1 x + y_1 y = r^2$ for $P(x_1, y_1)$ on C
    c. Optimization problems

12. Trigonometry
    a. Trigonometric formulas
       ① $\sin(\alpha + \beta) = \sin\alpha\cos\beta + \sin\beta\cos\alpha$, $\cos(\alpha + \beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta$, $\tan(\alpha + \beta) = \frac{\tan\alpha + \tan\beta}{1 - \tan\alpha\tan\beta}$, etc.
       ② $\sin^2\theta = \frac{1-c}{2}$, $\cos^2\theta = \frac{1+c}{2}$, $2\sin\theta\cos\theta = \sin 2\theta$
       ③ $\sin\alpha\cos\beta = \frac{1}{2}\{\sin(\alpha+\beta) + \sin(\alpha-\beta)\}$, etc.
       ④ $\sin A + \cos B = 2\sin\frac{A+B}{2}\cos\frac{A-B}{2}$, etc.
       ⑤ $\sin 3\theta = 3\sin\theta - 4\sin^3\theta$, $\cos 3\theta = -3\cos\theta + 4\cos^3\theta$
       ⑥ Note: sec, csc, and cot are not included in the syllabus

13. Exponential and logarithmic function
    a. Exponential and logarithmic rules
       ① Note: In Japan, log(x) = log

base e ($\ln(x)$) and $\log_{10}(x) =$ log base 10

14. Differential calculus 1
    a. Limit definitions
    b. Basic differentiation
    c. Optimization problems
15. Integral calculus 1
    a. Basic integration
        ① $\int_{\alpha}^{\beta} a(x-\alpha)(x-\beta)dx = -\frac{a}{6}(\beta-\alpha)^3$
        ② Note: Integral calculus 1 does not contain integration by parts
16. Vectors
    a. Dot product (cross product is not included)
    b. Vector geometry (2D and 3D)
        ① If $a\overrightarrow{PA} + b\overrightarrow{PB} + c\overrightarrow{PC} = 0$ for a ΔABC and a point P, $\overrightarrow{AP} = k\left(\frac{n\overrightarrow{AB}+m\overrightarrow{AC}}{m+n}\right)$
        ② For $\vec{p}$ on $\overrightarrow{AB}$, $\vec{p} = (1-t)\vec{a} + t\vec{b}$
        ③ For $\vec{h}$ on ΔABC, $\vec{h} = s\overrightarrow{OA} + t\overrightarrow{OB} + u\overrightarrow{OC}$ $(s+t+u=1)$
17. Sequences
    a. Arithmetic and geometric sequences
    b. Sum of sequences
        ① $S_n = \frac{1}{2}n(a+l)$, $S_n = \frac{1}{2}n(2a+(n-1)d)$, $S_n = a\frac{r^n-1}{r-1} = a\frac{1-r^n}{1-r}$
        ② $\sum_{k=1}^{n} k = \frac{1}{2}n(n+1)$, $\sum_{k=1}^{n} k^2 = \frac{1}{6}n(n+1)(2n+1)$, $\sum_{k=1}^{n} k^3 = \left\{\frac{1}{2}n(n+1)\right\}^2$, etc.
    c. Recurrence
        ① $a_{n+1} = a_n + d$
        ② $a_{n+1} = n(a_n)^m$
        ③ $pa_{n+2} + qa_{n+1} + ra_n = 0$
18. Complex plane
    a. De Moivre's theorem
        ① $(\cos\theta + i\sin\theta)^n = \cos n\theta + i\sin n\theta$
    b. Nth root of 1
        ① $z_k = \cos\frac{2k\pi}{n} + i\sin\frac{2k\pi}{n}$
    c. Geometry on complex plane
        ① $\angle\beta\alpha\gamma = \arg\frac{\gamma-\alpha}{\beta-\alpha}$
19. Curves on a plane
    a. Curves
        ① $y^2 = 4px$
        ② $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ with $F\left(\sqrt{a^2-b^2}, 0\right), F'(-\sqrt{a^2-b^2}, 0)$
        ③ $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$ with $F\left(\sqrt{a^2+b^2}, 0\right), F'(-\sqrt{a^2+b^2}, 0)$
    b. Tangent lines
    c. Parametric curves
        ① $\begin{cases} x = a\sin\theta \\ y = b\cos\theta \end{cases}$ etc.
    d. Polar coordinates
        ① (r, θ)
20. Limits
    a. Limits of r^n
        ① Ex. $\lim_{n\to\infty}\frac{r^n-1}{r^n+1} = -1$ when $|r| < 1$, $= 0$ when $r = 1$, and $= 1$ when $|r| > 1$
    b. Limits of sequences
        ① Ex. $a_{n+1} = \frac{2a_n-3}{a_n-4}$, $\lim_{n\to\infty} a_n$
        ② Ex. $\frac{1}{\sqrt{1}+\sqrt{3}} + \frac{1}{\sqrt{3}+\sqrt{5}} + \cdots + \frac{1}{\sqrt{2n-1}+\sqrt{2n+1}} + \cdots$

③ Ex. Fractals

c. Trigonometric limits

① $\lim_{x\to 0}\frac{\sin x}{x}=1$

21. Differential calculus 2

a. Chain rule

b. Limits of e

① $\lim_{h\to 0}(1+h)^{\frac{1}{h}}=e$

c. Implicit differenciation

d. Mean-value theorem

e. L'Hospital's rule

f. Optimization problems

g. Differentiation of parametric functions

h. Approximation

① If $h \approx 0$, then $f(a+h) \approx f(a) + f'(a)h$

② If $x \approx 0$, then $f(x) \approx f(0) + f'(0)x$

22. Integral calculus 2

a. Integration by parts

b. Trigonometric integration

c. Volume

d. Integration of parametric functions

e. Length of a curve

① $L=\int_a^b \sqrt{1+y'^2}$

② $L=\int_a^b \sqrt{\left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2}\,dt$ for a parametric function

*Note 1: The "matrix" section was removed from the syllabus a few years ago, but there is a chance it will come back in the next years (2024~25 or so).

*Note 2: I did not add much detail for obvious contents such as for exponential and logarithmic functions and calculus.

Japanese

1. Section A
    a. JLPT N5 ~ N4
2. Section B
    a. JLPT N3 ~ N2
3. Section C
    a. JLPT N2 ~ N1
    b. Additional proverbs and expressions not covered in JLPT

JLPT N5 →	30/300	≈ 10%
JLPT N4 →	60/300	≈ 20%
JLPT N3 →	120/300	≈ 40%
JLPT N2 →	190/300	≈ 60%
JLPT N1 (100/180 ~ 130/180) →	220/300	≈ 70%
JLPT N1 (130/180 ~ 150/180) →	220/300	≈ 80%
JLPT N1 (160/180+) →	270/300	≈ 90%+

(Including lucky guesses)

Chemistry

*Note: Numbers or formulas with a ✤ sign must be memorized.

1. Constituent particles of matter
    a. Simple substances
    b. Compounds
    c. Allotropes
        ① SCOP (sulfur, carbon, oxygen, phosphorous)
    d. (First) ionization energy
2. Chemical formulas
    a. Molecular weight / formula weight
    b. Avogadro's number
        ① $6.02 \cdot 10^{23}$ ✤
    c. Standard state
        ① The volume of any (ideal) gas is 22.4L ✤ at standard state, and standard state always means 101 kPa at 0C°✤
3. Chemical bonds and crystals
    a. Ion, covalent, metallic bonds and intermolecular bonds (van der Waals force, hydrogen bond)
    b. Electronegativity
    c. Molecular polarity
    d. NaCl, CsCl, diamond, body-centered cubic lattice, face-centered cubic lattice, and hexagonal close-packed structure
        ① Number of atoms per unit cube, coordination number, and atomic packing factor ✤
4. States of matter
    a. Vapor pressure
    b. Vapor-liquid equilibrium
    c. Ideal gas law
    d. Differences of ideal and real gas
5. Solution
    a. Henry's law
    b. Concentration
        ① Mass percent concentration (%)
        ② Mole-concentration (mol/L)
        ③ Molar concentration (mol/kg)
    c. Osmotic pressure
        ① $\Pi = cRT$
    d. Colloids
        ① Size of colloid particles: 10^{-9}~10^{-7}m ✤
        ② Tyndall effect
        ③ Brownian movement
        ④ Electrophoresis
    e. Hydrophobic and hydrophilic colloids
        ① Coagulation
        ② Salting out
        ③ Dialysis
        ④ Sol, gel
6. Chemical reactions and energy
    a. Enthalpy
        ① Enthalpy of formation
        ② Enthalpy of dissolution
        ③ Enthalpy of neutralization
    b. Binding energy
    c. Hess's law
7. Reaction speed
    a. Activation energy
    b. Catalysis
    c. Chemical equilibrium
    d. Le Chatelier's principle
    e. Equilibrium constant
8. Acid and base
    a. Arrhenius's theory
    b. Bronsted-Lowry's theory
    c. pH

d. Neutralization
   ① Phenolphthalein (pH ≥ 7)
   ② Methyl orange (pH ≤ 7)

9. Oxidation and reduction
   a. Oxidizer, reducing agent
   b. Battery
      ① Primary, secondary
      ② Voltaic battery
      $-Zn|H_2SO_4aq|Cu+$, reaction on each side ✤
      ③ Daniell cell
      $-Zn|ZnSO_4aq|CuSO_4aq|Cu+$, reaction on each side ✤
      ④ Manganese battery
      ⑤ Lead-acid battery
      $-Pb|H_2SO_4aq|PbO_2+$, reaction on each side ✤
   c. Ionization tendency
      ① From bigger to smaller, Li K Ca Na Mg Al Zn Fe Ni Sn Pn (H_2) Cu Hg Ag Pt Au ✤
   d. Electrolysis
   e. Faraday's law
      ① 96500 C/mol

10. Periodic table
   a. Elements in group 1,2, 13 ~ 18 must be memorized in order (top to down) ✤
   b. Transition elements and their characteristics
   c. Main group elements and their characteristics

11. Non-metals
   a. Halogens
   b. Contact process ✤
   c. Haber bosch process ✤
   d. Ostwald process ✤
   e. Solvay or ammonia-soda process ✤
   f. Oxoacid

12. Metals
   a. Alkali metals
   b. Alkaline earth metals
      ① In Japan, only Ca, Sr, Ba, and Ra are considered alkaline earth metals due to their distinctive characteristics compared to Be and Mg. ✤
   c. Aluminum
      ① Production of aluminum, bauxite, aluminum oxyde
   d. Hydroxide
   e. Complex ions
      ① $[Ag(NH_3)_2]^+$, straight line ✤
      ② $[Cu(NH_3)_4]^{2+}$, square ✤
      ③ $[Zn(NH_3)_4]^{2+}$, tetrahedron ✤
      ④ $[Fe(CN)_6]^{3-}$, octahedron ✤

13. Inorganic substances
   a. Storage methods
      ① Na, K, P, CaO, CaC_2, NaOH, $AgNO_3$, HF
   b. The production method, collecting method, color, odor, acidity, solubility, and other characteristic features of the following gases must be memorized
      ① H_2, O_2, Cl_2, HCl, HF, H_2S, SO_2, NO_2, NO, CO_2, CO, NH_3 ✤
   c. Precipitation

14. Aliphatic compounds
   a. Hydrocarbons
      ① Alkane, cycloalkane
      ② Alkene, cycloalkene
      ③ Alkyne
   b. The formula, naming, hydrolysis, acidity, and other characteristics of the following functional groups

must be memorized

① $-OH$, $-O-$, $-CHO$, $=CO$, $-COOH$, $-COO-$, $-NH_2$, $-NO_2$, $-SO_3H$ ♣

c. Isomers
   ① Geometric, optical, stereoisomer
d. Alcohol
   ① Primary, secondary, tertiary
   ② Monohydric, dihydric, trihydric
e. Ether
f. Ester
g. Carboxylic acid
h. Oils and fats and soap
   ① Detergent
   ② Surface active agent

15. Aromatic compounds
   a. Phenol
   b. Aromatic carboxylic acid
   c. Aniline
   d. Pharmaceuticals
      ① Sulfonamides
      ② Antibiotics
   e. Dye, azo compounds

16. Natural polymers
   a. Sugar
      ① Monosaccharide
      ② Polysaccharide
   b. Amino acid
      ① Zwitterions
      ② Ninhydrin reaction
   c. Protein
      ① Peptide bond
      ② Biuret test
      ③ Xanthoprotein reaction
      ④ Enzyme
   d. Nucleic acid
      ① DNA, RNA
      ② Ribose, deoxyribose

17. Artificial polymers
   a. Fibers
      ① Rayon
      ② Acetate
      ③ Nylon (polyamide)
      ④ Vinylon
      ⑤ Acrylic fiber
      ⑥ Polyester
   b. Synthetic resin (plastic)
      ① Polyethylene
      ② Polyvinyl acetate
      ③ Phenolic resin
      ④ Urea resin
      ⑤ Polyethylene terephthalate
   c. Rubber
      ① Natural rubber (latex)
      ② Synthetic rubber, vulcanization

Physics

1. Constant acceleration motion
   a. V-t graph
      ① $v = v_0 + at$
      ② $x = v_0 t + \frac{1}{2}at^2$
      ③ $v^2 - {v_0}^2 = 2ax$
   b. Potential energy
      ① $\frac{1}{2}mv^2$
      ② Mgh
   c. Relative velocity
2. Equilibrium of forces
   a. Action-reaction law
   b. Friction
   c. Forces
      ① mg
      ② kx
      ③ ρVg
   d. Spring
      ① $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2},\ k = k_1 + k_2$
   e. Center of mass
      ① $x_G = \frac{m_1x_1 + m_2x_2 + m_3x_3 + \cdots}{m_1 + m_2 + m_3 + \cdots}$
3. Laws of motion
   a. Newtonian equation of motion
      ① $\vec{F} = m\vec{a}$
   b. Conservation of energy and work
      ① $U = \frac{1}{2}kx^2$
      ② $W = Fl$
4. Movements with resistance
   a. Friction
      ① $\mu' N$
   b. Air resistance
      ① kv
5. Conservation of momentum
   a. Momentum and impulse
      ① $m\vec{v}$
      ② $\vec{F} \cdot \Delta t$
   b. Coefficient of restitution and collision
      ① $V' - v' = -e(V - v)$
6. Circular motion and universal gravitation
   a. Circular motion
      ① $T = \frac{2\pi}{v} = \frac{2\pi}{\omega}$
      ② $a = \frac{v^2}{r} = r\omega^2$
      ③ $F = m\frac{v^2}{r} = mr\omega^2$
   b. Universal gravitation
      ① $f = G\frac{Mm}{r^2}$
      ② $U = -G\frac{Mm}{r}$
   c. Kepler's law
      ① $\frac{1}{2}rv = \text{constant}$
      ② $T^2 = ka^3$
   d. Escape velocity
      ① $\frac{1}{2}m{v_0}^2 + \left(-G\frac{Mm}{r}\right) \geq 0$
7. Harmonic motion and pendulum
   a. Simple harmonic motion
      ① $x = A\sin\omega t$
      ② $v = A\omega\cos\omega t,\ v_{max} = A\omega$
      ③ $T = \frac{2\pi}{\omega}$
   b. Spring pendulum
      ① $T = 2\pi\sqrt{\frac{m}{k}}$
   c. Pendulum
      ① $T = 2\pi\sqrt{\frac{l}{g}}$
      ② $g' = g + a$ in an elevator
      ③ $g' = \sqrt{g^2 + a^2}$ in a car
8. Temperature and heat
   a. Heat capacity
      ① $Q = mc\Delta t$
      ② $Q = C\Delta t$

b. Thermal efficiency

① $e = \frac{W}{Q_{in}} = \frac{Q_{in}-Q_{out}}{Q_{in}} < 1$

9. Motion of particles and change in state

a. Equation of state and laws of gas

① $PV = nRT$

② $pS = p_0S + Mg$

b. Movement of particles

① $\frac{1}{2}m\overline{v^2} = \frac{3R}{2N_A}T = \frac{3}{2}nRT$

② $\Delta U = nC_V\Delta T$

③ $W = p\Delta V = nR\Delta T$

c. Change in state

① $C_V = \frac{3}{2}R,\ C_P = C_V + R$

② $pV^\gamma = \text{constant},\ \gamma = \frac{C_P}{C_V}$

③ $Q = \Delta U + W$

10. Properties of waves

a. Y-t and y-x graphs

① $y = A\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

b. Fixed end and free end reflection

c. Interference

① $|l_1 - l_2| = m\lambda$ or $= \left(\frac{1}{2} + m\right)\lambda$

d. Sound waves

① String: $v = \sqrt{\frac{S}{\rho}},\ f_m = \frac{m}{2l}\sqrt{\frac{S}{\rho}}$ $(m = 1,2,3,\cdots)$

② Open pipe: $f_m = \frac{mV}{2l}$ $(m = 1,2,3,\cdots)$

③ Closed pipe: $f_m = \frac{mV}{4l}$ $(m = 1,3,5,\cdots)$

e. Doppler effect

① $f' = \frac{V-u}{V-u}f_o$

f. Beat

11. Light waves

a. Properties of light

① $n = \frac{c}{v}$

② $n_{12} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$

③ $n_1\sin\theta_1 = n_2\sin\theta_2$

b. Lenses

① $\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$

② $m = \left|\frac{b}{a}\right|$

c. Young's experiment

① $\lambda m = \frac{dx}{l}$

d. Newton's rings

① $d = \frac{r^2}{2R}$

12. Electrostatic force and electric field

a. Formulas and laws

① $F = k\frac{Qq}{r^2}$

② $E = k\frac{Q}{r^2}$

③ $V = k\frac{Q}{|r|}$

④ $N = 4\pi kQ = \frac{Q}{\varepsilon_0}$

⑤ $U = qV$

13. Capacitor

a. Capacitor laws

① Note: In Japan, capacitors are called "condensers"

② $Q = CV$

③ $C = \varepsilon\frac{S}{d}$

④ $U = \frac{1}{2}QV$

⑤ $F = \frac{CV^2}{2d}$

b. Conservation of electric power

14. DC circuit

a. Current laws
   ① $I = Senv$
   ② $V = RI$
   ③ $V = E - rl$

15. Electric current and magnetic field
   a. Magnetic field
      ① $H = \frac{I}{2\pi r},\ H' = \frac{I}{2r},\ H'' = nI$
      ② $B = \mu H$
      ③ $eE = evB$
      ④ $E = vB$

16. Electromagnetic induction
   a. Induction laws
      ① $V = -N\frac{\Delta\varphi}{\Delta t}$
      ② $V = Blv_{\perp} = Blv\cos\theta$
   b. Self and mutual induction
      ① $V = -L\frac{\Delta I}{\Delta t}$
      ② $V' = -M\frac{\Delta I}{\Delta t}$
      ③ $U = \frac{1}{2}LI^2$

17. AC circuit
   a. Generator of AC
      ① $V = V_0 \sin\omega t$
      ② $\varphi = BS\cos\omega t$
   b. AC circuit
      ① $V = RI$
      ② $V = \omega LI$
      ③ $V = \frac{1}{\omega C}I$
      ④ $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$
   c. Resonance circuit
      ① $T = 2\pi\sqrt{LC}$
      ② $\frac{1}{2}LI^2 = \frac{1}{2}CV^2$

18. Electrons and lights
   a. Electron in a magnetic field
      ① $F = eE$
      ② $\frac{1}{2}mv_0^2 + eV = \frac{1}{2}mv^2$
      ③ $a = \frac{eE}{m}$
      ④ $f = evB$
   b. Wave-particle duality of light
      ① $E = hv$
      ② $hv = W + \frac{1}{2}mv^2$
      ③ $\lambda = \frac{c}{v}$
   c. X-rays
      ① $\lambda = \frac{hc}{eV}$
   d. Compton effect
   e. Bragg's law
      ① $2d\sin\theta = n\lambda\ (n = 1,2,3,\cdots)$

19. Atoms and nuclei
   a. Hydrogen atom
      ① $m\frac{v^2}{r} = k\frac{ee}{r^2}$
      ② $2\pi r = n\frac{h}{mv}\ (n = 1,2,3,\cdots)$
      ③ $E = -\frac{ke^2}{2r}$
   b. Release of light
      ① Lyman series
      ② Balmer series
      ③ Paschen series
      ④ $\frac{1}{\lambda} = R\left(\frac{1}{n'^2} - \frac{1}{n^2}\right)$
   c. Radioactive decay
      ① $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T}}$
   d. Properties of atoms and energy
      ① $E = mc^2$