1. Taylor series (truncate for approximations): 
$$F(x) = F(x_0) + \sum F^{(n)}(x_0)(x-x_0)^n/n!$$

Special case — linear approximation: 
$$F(x) \approx F(x_0) + F'(x_0)(x-x_0)$$

Some examples for \( |x| < 1 \):

- \( \sin(x) \approx x \), \( \cos(x) \approx 1 - x^2/2 \), \( e^x \approx 1 + x \)
- \( \ln(1+x) \approx x \), \( (1 + x)^n \approx 1 + nx \)

2. Perturbation method: find the solution iteratively using the solution to the “non-perturbed” (directly solvable) problem as the 0th approximation; corrections for the next approximation are calculated on the basis of the previous one.

3. Solution of the linear differential equation with constant coefficients \( ay'' + by' + cy = 0 \):
$$y = A \exp(\lambda_1 x) + B \exp(\lambda_2 x),$$
where \( \lambda_1,2 \) is the solution of the characteristic equation \( a\lambda^2 + b\lambda + c = 0 \) if \( \lambda_1 \neq \lambda_2 \). If the solution of the characteristic equation is complex, then \( a, b \) and \( c \) are real numbers, then \( \lambda_1,2 = \gamma \pm i\omega \) and
$$y = Ce^{\gamma t}\sin(\omega x + \phi_0).$$

4. Complex numbers:
$$z = a + bi = |z|e^{i\varphi}, \quad \bar{z} = a - bi = |z|e^{-i\varphi},$$
$$|z|^2 = \bar{z}z = a^2 + b^2, \quad \varphi = \arg z = \arcsin \frac{b}{|z|}.$$

Rez = \( (z + \bar{z})/2 \), \( \text{Imz} = (z - \bar{z})/2 \)

5. Cross and dot products of vectors are defined:
$$\vec{a} \cdot \vec{b} = a_b b_a, \vec{a} \times \vec{b} = [a_b b_a].$$

6. Cosine and sine laws:
$$\cos^2 \alpha + \sin^2 \alpha = 1,$$
$$\cos \alpha = \sqrt{1 - \sin^2 \alpha}.$$

7. An angle inscribed in a circle is half of the central angle that subtends the same arc on the circle. Conclusions: hypotenuse of a right triangle is the diameter of its circumscribed; if the angles of a quadrilateral are supplementary, it is a cyclic quadrilateral.

8. Surface area of a triangle \( \frac{1}{2} a b \sin \gamma = \sqrt{p(p-a)(p-b)(p-c)} = abc/4R \).

9. Triangle’s centroid: intersection point of medians, divides medians to 2:1

10. **Vector approach to geometry problems.**

11. Taking derivatives:
$$f(x)' = f'(x) = \frac{f(x+h) - f(x)}{h} \quad (h \to 0),$$
$$\frac{f(x) + f(y)}{2} = f\left(\frac{x+y}{2}\right),$$
$$f(x) = \frac{1}{i/2} e^{ix} \quad (i = \sqrt{-1}).$$

12. Integration: the formulas are the same as for derivatives, but with swapped left-hand-side and rhs (inverse relation), e.g.,
$$\int x^n dx = \frac{x^{n+1}}{n+1}.$$ Special case of the substitution method: 
$$\int f(ax + b)dx = F(ax + b)/a.$$

13. Conic sections: \( a_1 x_1^2 + 2a_2 x_1 x_2 + a_2 x_2^2 + a_1 x + 2a_2 x_2 = 0 \) with \( a_1 = a_2 = 1 \) — parabola; when \( a_1,1 (a_2,2 - a_2)^2 > 0 \) — ellipse, \( a_1,1 (a_2,2 - a_2)^2 = 0 \) — hyperbola, \( a_1,1 (a_2,2 - a_2)^2 < 0 \) — parabola. Ellipse: \( l_1 + l_2 = 2a, \quad \alpha_1 = \alpha_2, \quad A = \pi a b; \) hyperbola: \( l_1 - l_2 = 2a, \quad \alpha_1 + \alpha_2 = \pi b; \quad \alpha = \text{const} = \alpha_1 = \alpha_2 \).

14. Numerical methods. Newton’s iterative method for finding roots \( f(x) = 0 \):
$$x_{n+1} = x_n - f(x_n)/f'(x_n).$$

Trapezoidal rule for approximate integration:
$$\int_a^b f(x)dx \approx \frac{b-a}{2n} [f(x_0) + 2f(x_1) + \cdots + 2f(x_{n-1}) + f(x_n)].$$

15. Derivatives and integrals of vectors: differentiate/integrate each component; alternatively differentiate by applying the triangle rule for the difference of two infinitesimally close vectors.

16. Curvilinear motion — same as point one, but vectors are to be replaced by linear velocities, accelerations and path lengths.
\[
I_z = \int m(z^2 + y^2) = \int (x^2 + y^2) dm.
\]

6. In a frame where the mass center’s velocity is \( v_c \) (index \( c \) denotes quantities rel. to the mass center):
\[
\vec{L} = L_c = M_\Sigma \vec{R}_c \times \vec{v}_c, \quad K_c = K_\Sigma + M_\Sigma v_c^2/2
\]
\[
\vec{p} = \vec{P}_c + M_\Sigma \vec{v}_c.
\]
7. Steiner’s theorem is analogous (\( b \) — distance of the mass center from rot. axis):
\[
I = I_c + mb^2.
\]
8. With \( \vec{P}_c \) and \( \vec{L} \) from pt. 5, Newton’s 2\textsuperscript{nd} law:
\[
F_\Sigma = d\vec{P}_c/dt, \quad M_\Sigma = d\vec{L}_\Sigma/dt
\]
9. Additionally to pt. 5, the mom. of inertia rel. to the origin \( \theta = \sum m_i r_i^2 \) is useful for calculating \( I_c \) of 2D bodies or bodies with central symmetry using \( 2\theta = I_x + I_y + I_z \).
10. Physical pendulum with a reduced length \( \ell \):
\[
\omega^2(\ell) = g/\ell (1 + 1/ml),
\]
\[
\omega(\ell) = \omega(\ell - l) = \sqrt{g/l}, \quad \ell = l + 1/ml
\]
11. Coefficients for the momenta of inertia: cylinder \( \frac{1}{2} \), solid sphere \( \frac{2}{5} \), thin spherical shell \( \frac{2}{3} \), sphere \( \frac{1}{2} \), rod \( \frac{1}{5} \) (rel. to endpoint \( \frac{1}{2} \)), square \( \frac{1}{2} \).
12. Often applicable conservation laws: energy (elastic bodies, no friction), momentum (no net external force; can hold only along one axis), angular momentum (no net ext. torque, e.g. the arms of ext. forces are 0 (can be written rel. to 2 or 3 pts., then substitutes conservation of lin. mom.).
13. Additional forces in non-inertial frames of ref.: inertial force \( -m\ddot{a} \), centrifugal force \( m\omega^2 R \) and Coriolis force \( 2m\vec{v}_R \times \vec{\Omega} \) (better to avoid it; being \( \parallel \) to the velocity, it does not create any work).
15. Tilted coordinates: for a motion on an inclined plane, it is often practical to align axes along and \( \perp \) to the plane; gravity. acceleration has then both \( x \) and \( y \) components. Axes may also be oblique (not \( \perp \) to each other), but then with \( \vec{v} = v_x \hat{e}_x + v_y \hat{e}_y, \quad v_x \neq \frac{\vec{e}}{x} \) to the \( x \)-projection of \( \vec{e} \).
16. Collision of 2 bodies: conserved are a) net momentum, b) net angular mom., c) angular mom. of one of the bodies with respect to the impact point, d) total energy (for elastic collisions); in case of friction, kin. en. is conserved only along the axis \( \perp \) to the friction force. Also: e) if the sliding stops during the impact, the final velocities of the contact points will have equal projections to the contact plane; f) if sliding doesn’t stop, the momentum delivered from one body to the other forms angle arctan \( \mu \) with the normal of the contact plane.
17. Every motion of a rigid body can be represented as a rotation around the instantaneous center of rotation \( C \) (in terms of velocities of the body points). NB! Distance of a body point \( P \) from \( C \) to the radius of curvature of the trajectory of \( P \).
18. Tension in a string: for a massive hanging string, tension’s horizontal component is constant and vertical changes according to the string’s mass underneath. Pressure force (per unit length) of a string resting on a smooth surface is determined by its radius of curvature and tension: \( N = T/R \). Analogy: surface tension pressure \( p = 2\sigma/R \); to derive, study the pressure force along the diameter.
19. Liquid surface takes equipot. shape (neglecting \( \sigma \)) in incompr. liquid, \( p = p_0 - w, \quad w \)-vol. dens. of pt. en. (for a gas, see X-6).
20. Bernoulli law for incompr. fluid:
\[
p + \frac{1}{2} \rho v^2 + \rho u = \text{const};
\]
\[
in homog. field, the gravit. potential \( \varphi = gh \).
\]
21. Momentum continuity by straight streamlines: \( p + \rho \vec{v} = \text{const} \).
22. Adiabatic invariant: if the relative change of the parameters of an oscillating system is small during one period, the area of the loop drawn on the phase plane (ie. in \( p-x \) coordinates) is conserved with a very high accuracy.
23. For studying stability use a) principle of minimum potential energy or b) principle of small virtual displacement.
24. Virial theorem for finite movement: a) If \( F \propto |r| \), then \( K = (\Pi) \) (time averages); b) If \( F \propto |r|^{-2} \), then \( 2K = -\Pi \).
25. Taylor’s equation \( \Delta v = \ln N \).

V Oscillations and waves
1. Damped oscillator:
\[
\ddot{x} + 2\gamma \dot{x} + \omega^2 x = 0 (\gamma < \omega_0).
\]
Solution of this equation is (cf. 1.2):
\[
x = x_0 e^{-\gamma t} \sin(\sqrt{\omega^2 - \gamma^2} - \omega_0 t).
\]
2. Eq. of motion for a system of coupled oscillators:
\[
x_i = \sum_j a_{ij} x_j.
\]
3. A system of \( N \) coupled oscillators has \( N \) different eigenmodes when all the oscillators oscillate with the same frequency \( \omega_0 \), \( x_j = x_0 \sin(\omega_0 t + \phi_0) \), and \( N \) eigenfrequencies \( \omega_i \) (which can be multiple, \( \omega_i = \omega_0 \)). General solution (with \( 2N \) integration constants \( x_i, \phi_i \)) is a superposition of all the eigenmodes:
\[
x_j = \sum_i X_i x_0 \sin(\omega_i t + \phi_i + j) ,\quad j = 0, 1, ..., N-1,
\]
4. If a system described with a generalized coordinate \( \xi \) (cf IV-2) and \( K = \mu \xi^2/2 \) has an equilibrium state at \( \xi = 0 \), for small oscillations \( \Pi(\xi) \approx \kappa \xi^2/2 \) [where \( \kappa = \Pi''(0) \)] so that \( \omega^2 = \kappa/\mu \).
5. The phase of a wave at pt. \( x, t \), is \( \varphi = kx - \omega t + \phi_0 \), where \( k = 2\pi/\lambda \) is a wave vector. The phase velocity is \( v_\varphi = \sqrt{k/x} \) and group velocity \( v_g = d\omega/dk \).
6. For linear waves (electromagn., w., small-ampl. sound- and water w.) any pulse can be considered as a superpos. of sinusoidal waves; a standing w. is the sum of two identical counter-propagating w.:
\[
e^{-i(kx-\omega t) + e^{-i(kx-\omega t)} = 2e^{-i\omega t} \cos kx},
\]
7. Speed of sound in a gas \( \frac{c_s}{c_s} = \sqrt{(\partial p/\partial \rho)_{\text{adiab}}} = \sqrt{\gamma p/\rho} = \nu \sqrt{\gamma/3} \).
8. Speed of sound in elastic material \( c_s = \sqrt{E/\rho} \).
9. Sp. of waves in shallow (\( h \ll \lambda \)) water: \( v = c_0 / \sqrt{h} \); in a string: \( v = \sqrt{T/m_i} \).
10. Doppler’s effect: \( \nu = \nu_0 \frac{1 + v/c_0}{1 - v/c_0} \).
11. Huygen’s principle: wavefront can be constructed step by step, placing an imaginary wave source in every point of previous wave front. Results are curves separated by distance \( \Delta t = c_0 \Delta t \), where \( \Delta t \) is time step and \( c_0 \) is the velocity in given point. Waves travel perpendicularly to wavefront.

VI Geometrical optics.
1. Fermat’s principle: waves path from point \( A \) to point \( B \) is such that the wave travels the least amount.
2. Snell’s law:
\[
sin \alpha_1/\sin \alpha_2 = n_2/n_1 = n_1/n_2.
\]
3. If refraction index changes continuously, then we imaginarily divide the media into layers of constant \( n \) and apply Snell’s law. Light ray can travel along a layer of constant \( n \), if the requirement of total internal reflection is marginally satisfied, \( n' \ll n/r \) (where \( r \) is the curvature radius).
4. If refraction index depends only on \( z \), the photon’s mom. \( p_x, p_y \), and en. are conserved:
\[
k_x, k_y = \text{Const.}, \quad [\vec{k}/n = \text{Const.} \]
5. The thin lens equation (pay attention to signs):
\[
1/a + 1/b = 1/f = D.
\]
6. Newton’s eq. \( (x_1, x_2 \text{ — distances of the image and the object from the focal planes}) \):
\[
x_1f_1 = x_2f_2 = f^2.
\]
7. Parallax method for finding the position of an image: find such a pos. for a pencil’s tip that it wouldn’t shift with resp. to the image when moving perpendicularly the position of your eye.
8. Geometrical constructions for finding the paths of light rays through lenses: a) ray passing the lens center does not refract; b) ray || to the optical axis passes through the focus; c) after ref., initially || rays meet at the focal plane; d) image of a plane is a plane; these two planes meet at the plane of the lens.
9. Luminous flux \( \Phi \) [unit: lumen (lm)] measures the energy of light (emitted, passing a contour, etc), weighted according to the sensitivity of an eye. Luminous intensity [candela (cd)] is the luminous flux (emitted by a source) per solid angle: \( I = \Phi/\Omega \). Illuminance [lux (lx)] is the luminous flux (falling onto a surface) per unit area: \( E = \Phi/S \).
10. Gauss theorem for luminous flux: the flux through a closed surface surrounding the point
1. Diffraction — method based on Huygens’ principle: if obstacles cut the wavefront into fragment(s), the wavefront can be divided into small pieces which serve as imaginary point-like light sources; the wave amplitude at the observ. site will be the sum of the contributions of these sources.

2. Two slit interference (the slit width $d \ll a, \lambda$): angles of maxima $\varphi_{\text{max}} = \arcsin(n\lambda/a)$, $n \in \mathbb{Z}$; $I \propto \cos^2(k \frac{a}{2} \sin \varphi)$, where $k = 2\pi/\lambda$.

3. Single slit: angles of minima $\varphi_{\text{min}} = \arcsin(n\lambda/d)$, $n \in \mathbb{Z}$, $n \neq 0$. NB! the central maximum is double-wide. $I \propto \sin^2(k \frac{a}{2} \sin \varphi) / \varphi$.

4. Diffraction grating: the main maxima are $2\varphi$, that angle, the center of one point falls onto the polarization planes.

5. Brewster’s angle: reflected and refracted rays are $\perp$; reflected ray is completely polarized; incidence angle tan $\varphi_B = n$.

6. Diff. with optical elements: no need to calculate optical path lengths through lenses, prisms etc.: work simply with images. Particular conclusion: biprism gives the same diff. as a double slit.

16. Optical fibres: Mach-Zehnder interferometer is analogous to a double-slit diffraction; circular resonator — to Fabry-Perot interferometer; Bragg filters work similarly to the X-ray case. Single-mode fibres: $\Delta n/n \approx \frac{1}{2} (\lambda/a)^2$.

VII Wave optics

1. Fabry-Pérot interferometer: two parallel semitransp. mirrors with large reflectivity $r$ ($1-r \ll 1$). Resolving power of a prism: $\Delta \varphi = \frac{\varphi}{n} = \frac{\varphi}{n} (\lambda/\sin \varphi)$.

2. Kirchoff’s laws:

   
   
   $\sum_{\text{node}} I = 0, \quad \sum_{\text{contour}} U = 0$

3. Kirchoff’s laws: $\sum R_i$, $R_{\text{series}} = \sum R_i$, $R_{\text{parallel}} = \sum R_i^{-1}$.


5. AC: apply pts. 1-4 while substituting $R$ with $Z$: $Z_R = R$, $Z_C = 1/\omega C$, $Z_L = \omega L$, $\varphi = \arg Z$, $U_{\text{eff}} = |Z|I_{\text{eff}}$

6. P = $|U||I| \cos(\arg Z) = \sum R_i^2 R_i$. $P$ = $|U||I| \cos(\arg Z) = \sum R_i^2 R_i$. $P$ = $|U||I| \cos(\arg Z) = \sum R_i^2 R_i$.

7. Energy conservation for electric circuits: $\Delta W + Q = Uq$, where $q$ is charge which has crossed a potential drop $U$; work of emf is $A = \int E \, \text{ds}$.

8. Kirchoff’s laws: $\sum R_i$, $R_{\text{series}} = \sum R_i$, $R_{\text{parallel}} = \sum R_i^{-1}$. $P$ = $|U||I| \cos(\arg Z) = \sum R_i^2 R_i$.

9. Resonance: $\Delta \varphi = \frac{\varphi}{n} (\lambda/\sin \varphi)$.

10. Magnetic inductance: magnetic flux through a contour $\Phi_1 = L_1 I_1 + L_2 I_2$ ($I_2$ — current in a second contour. Theorems: $L_{12} = L_{21} \equiv M$, $M \leq \sqrt{L_1 L_2}$.

IX Electromagnetism

1. Faraday’s law: $\oint \vec{E} \, \text{ds}$, $\oint \vec{E} \cdot \vec{d}S = 0$, $\oint \vec{E} \cdot \vec{d}S = 0$, $\oint \vec{E} \cdot \vec{d}S = 0$. $\oint \vec{E} \cdot \vec{d}S = 0$.

2. Gauss’s law: $\oint \vec{B} \cdot \vec{d}S = 0$, $\oint \vec{B} \cdot \vec{d}S = 0$. $\oint \vec{B} \cdot \vec{d}S = 0$.

3. Magnetic field caused by current element: $\vec{B} = \frac{\mu_0 I}{4\pi} \frac{\vec{r}}{r^3}$.
18. Forces acting on a dipole: $F = (\vec{E}d')^*$, $F = (\vec{B}d')^*$; interaction between 2 dipoles: $F \propto r^{-4}$.  
19. Point charge as a magn. dipole: $d_μ = Φ × τ^2/B$ is an adiab. inv. (see IV-20).  
20. Electric and magnetic images: grounded (superconducting for magnets) planes act as mirrors. Field of a grounded (or isolated) sphere can be found as a field of one (or two) fictive charge(s) inside the sphere. The field in a planar waveguide (slit between metallic plates) can be obtained as a superposition of electromagnetic plane waves.  
21. Ball’s (cylinder’s) polarization in homogeneous (electric) field: supersonic, of homogeneously charged (+p and −ρ) balls (cylinders), $d ≡ E$.  
23. Inside a superconductor and for fast processes inside a conductor $B = 0$ and thus $I = 0$ (current flows in surface layer — skin effect).  
24. Charge in homog. magnetic field $\vec{B} = B\hat{z}$ moves along a cycloid with drift speed $v = E/B = F/eB$; generalized mom. is conserved $p_z = mv^2 - Bq_y$, $p_y = mv_y + Bzq$, as well as gen. angular mom. $L' = L + B\hat{z}q_z$.  
25. MHD generator (a — length along the direction of $\vec{E}$): $E = \nu B\hat{a}$, $r = \rho a/Be$.  
26. Hysteresis: S-shaped curve (loop) in $B$-$H$-coordinates (for a coil with core also $B$-$I$-coord.: the loop area gives the thermal energy dissipation density per one cycle).  
27. Fields in matter: $\vec{B} = ε_0ε_E\vec{E} = ε_0\vec{E} + \vec{P}$, where $\vec{P}$ is dielectric polarization vector (volume density of dipole moment); $\vec{H} = \vec{B}/μ_0 = \vec{B}/μ_0 - \vec{J}$, where $\vec{J}$ is magnetization vector (volume density of magnetic moment).  
28. In an interface between two substances $E_1$, $D_n (= εE_2)$, $H_τ (= B_τ/μ)$ and $B_n$ are continuous.  
30. For $μ > 1$, field lines of $B$ are attracted to the ferromagnetic (acts as a potential hole, cf. pt. 28).  
31. Current density $\vec{j} = ne\vec{v} = σ\vec{E} = \vec{E}/ρ$.  
32. Lenz’s law: system responds so as to oppose changes.  

### X Thermodynamics  
1. $pV = \frac{mRT}{2}$  
2. Internal energy of one mole $U = \frac{1}{2}RT$.  
3. Volume of one mole at standard cond. is $22.4\text{ l}$.  
4. Adiabatic processes: slow as compared to sound speed, no heat exchange: $pV^\gamma = \text{Const.}$ (and $TV^{-1} = \text{Const.}$).  
5. $γ = c_p/c_v = (i + 2)/i$.  
6. Boltzmann’s distribution: $ρ = ρ_0e^{-\frac{h\nu}{kT}}$.  
7. Maxwell’s distribution (how many molecules have speed $v$) $≈ e^{-\frac{mv^2}{2kT}}$.  
8. Atmosphere: pressure of $\Delta p ≡ p$, then $\Delta p = p_0h\Delta$.  
9. $p = \frac{1}{2}mv_0^2 = nkT$, $v = \sqrt{3kT/m}$, $ν = v/nS$.  
10. Carnot’s cycle: 2 adiabats, 2 isotherms. $η = (T_1 - T_2)/T_1$; derive using $S$-$T$-coordinates.  
11. Heat pump, inverse Carnot: $η = \frac{T_1 - T_2}{T_1}$.  
13. I law of thermodynamics: $SU = δQ + δA$.  
14. II law of thermodynamics: $\Delta S ≥ 0$ (and $η_{\text{real}} ≤ η_{\text{Caront}}$).  
15. Gas work (look also p. 10) $A = \frac{1}{2}pV^\gamma$, adiabatic: $A = \frac{i}{2}(\Delta p^V)$.  
16. Dalton’s law: $p = \sum p_i$.  
17. Boiling: pressure of saturated vapour $p_0 = ρ_0$ at the interface betw. 2 liquids: $p_0 + p_2 = p_1$.  
18. Heat flux $P = k\delta\frac{AT}{l}$ (k thermal conductivity); analogy to DC circuits ($P$ corresponds to $I$, $AT$ to $U$, $k$ to $1/l$).  
19. Heat capacity: $Q = \int c(T)dT$. Solids: for low temperatures, $c ∝ T^3$; for high $T$, $c ∝ 3Nk$, where $N$ — number of ions in crystal lattice.  
20. Surface tension: $U = S\sigma$, $F = \sigma r$, $p = 2\sigma/R$.  
22. Wien’s law: $f_{\text{max}} = Ak_BT/h$ ($A ≈ 2.8$, $λ_{\text{max}} = hc/Ak_BT$ ($A' ≈ 5$).  

### XI Quantum mechanics  
1. $p = \hbar\kappa = h/\lambda$, $E = hω = hν$.  
2. Interference: as in wave optics.  
3. Uncertainty: (as a math. theorem): $ΔpΔx ≥ h$, $ΔEΔt ≥ h$, $ΔωΔt ≥ h$.  
4. Spectra: $hν = E_n = E_n$; width of spectral lines is related to lifetime: $Γ ≡ h$.  
5. Oscillator’s (e.g. molecule) en. levels (with eigenfrequency $ν_n$): $E_n = (n + \frac{1}{2})hν_0$. For many eigenfrequencies: $E = \sum ϵ_n\rho_ν$.  
6. Tunnelling effect: barrier $Γ$ with width $l$ is easily penetrable, if $Γ ∝ h$, where $Γ = l/\sqrt{2\tau}$.  
7. Bohr’s model: $E_n ∝ -1/n^2$. In a (classically calculated) circular orbit, there is an integer number of wavelengths $λ = h/me$.  
8. Compton effect — if photon is scattered from an electron, photon’s $∆λ = h/(m - pν)/c^2$.  

### XII Kepler laws  
1. $F = GMm/r^2$, $\Pi = -GMm/r$.  
2. Gravitational interaction of 2 point masses (Kepler’s law): trajectory of each of them is an ellipse, parabola or hyperbola, with a focus at the center of mass of the system. Derive from R.-L. v. (pt 9).  
3. Kepler’s II law (conserv. of angular mom.): for a point mass in a central force field, radius vector covers equal areas in equal times.  
4. Kepler’s III law: for two point masses at elliptic orbits in $r^2$-force field, revolution periods relate as the longer semiaxes to the power of $\frac{3}{2}$: $T_2^3/T_1^2 = a_2^3/a_1^3$.  
5. Full energy $(K + II)$ of a body in a gravity field: $E = -GMm/2a$.  

### XIII Theory of relativity  
1. Lorentz transforms (rotation of 4D space-time of Minkowski geometry), $γ = 1/\sqrt{1-v^2/c^2}$.  
2. $x' = (x- vt)/\gamma$, $y' = y$, $t' = γ(t - vx/c^2)$.  
3. $p_x' = p_x - p_v/c\gamma$, $m' = m/(1 - v^2/c^2)$.  
4. Length of vector: $s^2 = c^2t^2 - x^2 - y^2 - z^2$.  
5. Adding velocities: $w = (u + v)/(1 + u v/c^2)$.  
6. Doppler effect: $ν' = ν_0/(1-ν_0/c)(1+v/c)$.  

* marks an advanced material.  
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