Physics 2311 Physics I (Mechanics)

Equation list for Exam II

Chapter 7 Work and Energy

Work: $W = F\Delta r\cos\theta = F_{\parallel}\Delta r = \vec{F}\cdot\vec{r}$ (for a constant force)

Work: $W = \int \vec{F}\cdot d\vec{r}$

Force by a spring (Hooke's Law): $F_s = -kx$

Work done by a spring: $W = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2$

Work – kinetic energy theorem: $W_{net} = K_f - K_i = \Delta K$

Gravitational Potential Energy (near surface of Earth): $U_g = mgy$ (y increases upward, g >0)

Potential Energy of a Spring: $U_s = \frac{1}{2}kx^2$

Potential energy change due to an external force: $W_{ext} = U_f - U_i = \int_{x_i}^{x_f} \vec{F}_{ext}\cdot d\vec{r}$

Work by a conservative, internal force: $W_{intern} = U_i - U_f = -\Delta U$

Mechanical energy: $E_{mech} = K + U$

Obtain a force from a potential energy function: $F_x = -\frac{dU}{dx}$

Chapter 8 Conservation of Energy

For a non-isolated system, $\Delta E_{system} = \Sigma T$ where $\Delta E_{system} = \Delta K + \Delta U + \Delta E_{intern}$

and $\Sigma T = W + Q + T_{MW} + T_{MT} + T_{ET} + T_{ER}$ are transfer energies.

For an isolated system, $\Delta E_{system} = 0$

For an isolated system with only mechanical energy: $\Delta E_{mech} = 0 = \Delta K + \Delta U$

For a non-isolated system with friction: $\Delta E_{mech} = +\Sigma W_{other\ forces} - f_k d$

For a non-isolated system with no change in potential energy, and friction and other forces are present: $\Delta K = \Sigma W_{other\ forces} - f_k d$

Internal energy change of a closed system with friction: $\Delta E_{intern} = f_k d$

For an isolated system with changes in potential energy and friction: $\Delta E_{mech} = -f_k d$

Power: $P = \frac{dE}{dt}$

Power expended by a force: $P = \vec{F}\cdot\vec{v}$

Average power by a force that did work W: $P_{avg} = \frac{W}{\Delta t}$

Chapter 9. Linear momentum and collisions

Linear momentum: $\vec{p} = m\vec{v}$

Momentum and force: $\vec{F}=\frac{d\vec{p}}{dt}$

Conservation of momentum: $\vec{p}_{tot}=constant$ or $\Sigma\vec{p}_{j,initial}=\Sigma\vec{p}_{j,final}$

Impulse: $\vec{I}=\Delta\vec{p}$ or $\vec{I}=\int\vec{F}_{net}dt$

Types of collisions (all obey conservation of momentum):

a) elastic: kinetic energy is conserved

b) inelastic: kinetic energy is not conserved

c) perfectly inelastic: kinetic energy is not conserved and particles stick together

Center of mass for discrete masses:

$$x_{com}=\frac{\Sigma m_i x_i}{M_{tot}} \quad \text{and} \quad y_{com}=\frac{\Sigma m_i x_i}{M_{tot}}$$

Center of mass for continuous, extended masses:

$$\vec{r}_{CM}=\frac{1}{M}\int\vec{r}\,dm$$

For a system of particles:

$$\vec{p}_{tot}=M_{tot}\vec{v}_{CM}$$

Chapter 10. Rotation of a Rigid Object

Angular position: $\theta=\frac{s}{r}$ (where s is arclength)

Angular speed: $\omega=\frac{d\theta}{dt}$

Angular acceleration: $\alpha=\frac{d\omega}{dt}$

Relate to translational quantities: $v=r\omega$, $a_t=r\alpha$ and $a_c=\frac{v^2}{r}=r\omega^2$

Angular kinematic equations for constant angular acceleration:

$$\omega_f=\omega_i+\alpha t$$

$$\theta_f=\theta_i+\omega_i t+\frac{1}{2}\alpha t^2$$

$$\omega_f^2=\omega_i^2+2\alpha(\theta_f-\theta_i)$$

$$\theta_f=\theta_i+\frac{1}{2}(\omega_i+\omega_f)t$$

Rotational kinetic energy: $K_R=\frac{1}{2}I\omega^2$

Moment of inertia: $I=\Sigma m_i r_i^2$ (for discrete masses)

Moment of inertia: $I=\int r^2 dm$ (for continuous masses)

Mass density: linear mass density, λ , surface mass density, σ , volume mass density ρ

Parallel-axis theorem: $I=I_{CM}+MD^2$

Torque: $\tau=rF\sin\theta$ gives the magnitude. (Direction given by Right Hand Rule.)

Torque: $\tau_{net}=I\alpha$

Total kinetic energy: $K_{tot}=K_{trans}+K_{rot}$

For an object that rolls without slipping:

$$\Delta s = R\Delta\theta$$
$$v_{CM} = R\omega$$
$$a_{CM} = R\alpha$$

Chapter 11 Angular Momentum

Torque as vector cross product: $\vec{\boldsymbol{\tau}} = \vec{\boldsymbol{r}} \times \vec{\boldsymbol{F}}$
Angular momentum of a particle: $\vec{\boldsymbol{L}} = \vec{\boldsymbol{r}} \times \vec{\boldsymbol{p}}$
Relate angular momentum to torque: $\sum \vec{\boldsymbol{\tau}} = \frac{d\vec{\boldsymbol{L}}}{dt}$
Angular momentum of an extended object: $L = I\omega$
Conservation of angular momentum: for a closed system, $\frac{d\vec{\boldsymbol{L}}}{dt} = 0$

Chapter 12 Static Equilibrium and Elasticity

The two conditions of static equilibrium:
1) $\sum \vec{\boldsymbol{\tau}}_{ext} = 0$
2) $\sum \vec{\boldsymbol{F}}_{ext} = 0$