Review

Physics 231

fall 2007

Main issues

- ✓ Kinematics - motion with constant acceleration
  1 D motion, 2D projectile motion, rotational motion
- ✓ Dynamics (forces)
- ✓ Energy (kinetic and potential) (translational or rotational motion when details are not important)
- ✓ Momentum and systems of particles (collisions, systems of objects)
- ✓ Equilibrium (equations from equilibrium conditions)
- ✓ Gravitation (mostly motion of planets and satellites)
- ✓ Periodic motion (SHM, springs, pendulum)
- ✓ Fluids (pressure, force, principle of buoyancy)

Problem solving

- ✓ Phase 1: You have to understand the problem
- ✓ Phase 2: Devising a plan
- ✓ Phase 3: Carrying out the plan
- ✓ Phase 4: Looking back

Practical advise (phase 1)

- ✓ Start from the statement of the problem. If you cannot understand the problem, try to restate the problem
- ✓ Visualize the problem as a whole as clearly and as vividly as you can. Draw a diagram.
- ✓ Isolate the principal parts of your problem. Do not concern yourself with details for the moment. Go through the principal parts of your problem
- ✓ Good questions: What is the unknown? What are the data? What is the condition?

  Is the condition sufficient to determine the unknown? Or is it insufficient? Or redundant? Or contradictory?

Practical advise (phase 2)

- Devising a plan is a heuristic reasoning (includes: evaluating possible answers or solutions, trial and error)
- Examine principal parts, details and their connections. Consider them from various sides, combine them differently. Seek connections with you formerly acquired knowledge.
- Examine your guess.
- Look at the unknown. Try to think of a familiar problem having the same or similar unknown.
- You may be obliged to consider auxiliary problems if an immediate connection cannot be found

Phase 3: Carrying out the plan

- ✓ This phase is easier than the first two, what we need is mainly patience.
- ✓ Practical advise: follow you plan and check each step

Practical advise (phase 4)

- ✓ Check the result using formerly acquired knowledge (including common sense!).
- ✓ Problem “in letters” are susceptible of more tests than “problems in numbers”.
- ✓ Can we derive the result differently?

Kinematics

1D motion (for free fall $a = -g$)

$$\begin{cases} v &= v_0 + at \\ x &= x_0 + v_0 t + \frac{1}{2} a t^2 \end{cases}$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

2D projectile motion

$$\begin{cases} v_x &= v_{x0} \\ x &= x_0 + v_{x0} t \\ v_y &= v_{y0} - g_y t \\ y &= y_0 + v_{y0} t - \frac{1}{2} g t^2 \end{cases}$$

Dynamics

Second Newton's Law $\vec{F}_{net} = m\vec{a}$

for 1D/2D motion: $F_{net,x} = ma_x, \quad F_{net,y} = ma_y$

for uniform circular motion: $F_{net,r} = mv^2 / r$

Forces:

Gravitational force	$\vec{F}_g = m\vec{g}$
Normal force	$N = mg\cos(\theta) + F_{\text{external}}$
Tension	T
Frictional force	$f_s = \mu_s N$ and $f_k = \mu_k N$
Spring force	$\vec{F}_e = -k\vec{x}$

Energy

Kinetic energy $K = \frac{1}{2}mv^2$

Change in kinetic energy $\Delta K = K_f - K_i = W = F \cdot d \cos\vartheta$

Gravitational potential energy $U(y) = mgy$

Elastic potential energy $U(x) = \frac{1}{2}kx^2$

Conservation of Mechanical Energy

$K_i + U_i = K_f + U_f$

Conservation of Energy (friction involved)

$K_i + U_i = K_f + U_f + f_k(x_f - x_i)$

Power : $P = \frac{dW}{dt} = \frac{\Delta W}{\Delta t} = Fv$

Rotational kinematics, dynamics & energy

rotational and translational motion: $\theta = \frac{s}{r} \quad \omega = \frac{v}{r} \quad \alpha = \frac{a}{r}$

period $T = \frac{2\pi r}{v} = \frac{2\pi}{\omega}$, frequency $f = \frac{1}{T} = \frac{\omega}{2\pi}$

$$\begin{cases} \omega = \omega_0 + \alpha t \\ \theta = \theta_0 + \omega_0 t + \alpha t^2 / 2 \end{cases}$$

$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$$

torque $\tau = r F \sin(\phi)$

Second Newton's law $\tau_{net} = I\alpha$ (where I is rotational inertia)

Total kinetic energy $K = \frac{1}{2} m v_{cm}^2 + \frac{1}{2} I_{cm} \omega^2$

Work and power: $W = \tau(\theta_2 - \theta_1) \quad P = \tau\omega$

Moment and Impulse

Linear momentum $\vec{p} = m\vec{v}$, 2nd Newton's Law $\vec{F}_{net} = m\vec{a} = \dfrac{d\vec{p}}{dt}$

Impulse : $\vec{J} = \vec{p}_f - \vec{p}_i = \vec{F}_{ave}\Delta t$

Conswrvation of linear momentum : $\vec{F}_{net} = 0$ then $\vec{p}_i = \vec{p}_f$

Elastic collision : $\vec{p}_i = \vec{p}_f$ and $E_i = E_f$

Inelastic collision : $\vec{p}_i = \vec{p}_f$ and $E_i \neq E_f$

Angular momentum : particle $\vec{L} = \vec{r} \times \vec{p}$, rigid body $\vec{L} = I\vec{\omega}$

Conservation of angular momentum : for $\tau_{net} = 0$ $\vec{L} = const$

System of particles

Center of mass $\vec{r}_{CM} = \dfrac{m_1\vec{r}_1 + m_2\vec{r}_2 + \ldots}{m_1 + m_2 + \ldots} = \dfrac{1}{M}\sum_{i=1}^{n} m_i\vec{r}_i$

Second Newton's Law for a system of particles

$$\vec{F}_{net} = M\vec{a}_{CM}$$

for $\vec{F}_{net} = 0 \quad \vec{v}_{CM} = 0, \quad \vec{r}_{CM} = const$

Equilibrium

Two Conditions for Equilibrium : $\vec{F}_{net} = 0$ and $\vec{\tau}_{net} = 0$

in physics 231 for most problems $\begin{cases} F_{net,x} = 0 \\ F_{net,y} = 0 \\ \tau_{net,z} = 0 \end{cases}$

Choose ONE object in a time for consideration

Draw a free-body diagram
(show ALL forces acting ON that object)

Choose (wisely) a coordinate system and resolve forces in their components

“Generate” equilibrium equations using the conditions for equilibrium

Gravitation

Newton's Law of gravitation $F = G\frac{m_1 m_2}{r^2}$

The free-fall acceleration $g = \frac{GM}{R^2}$

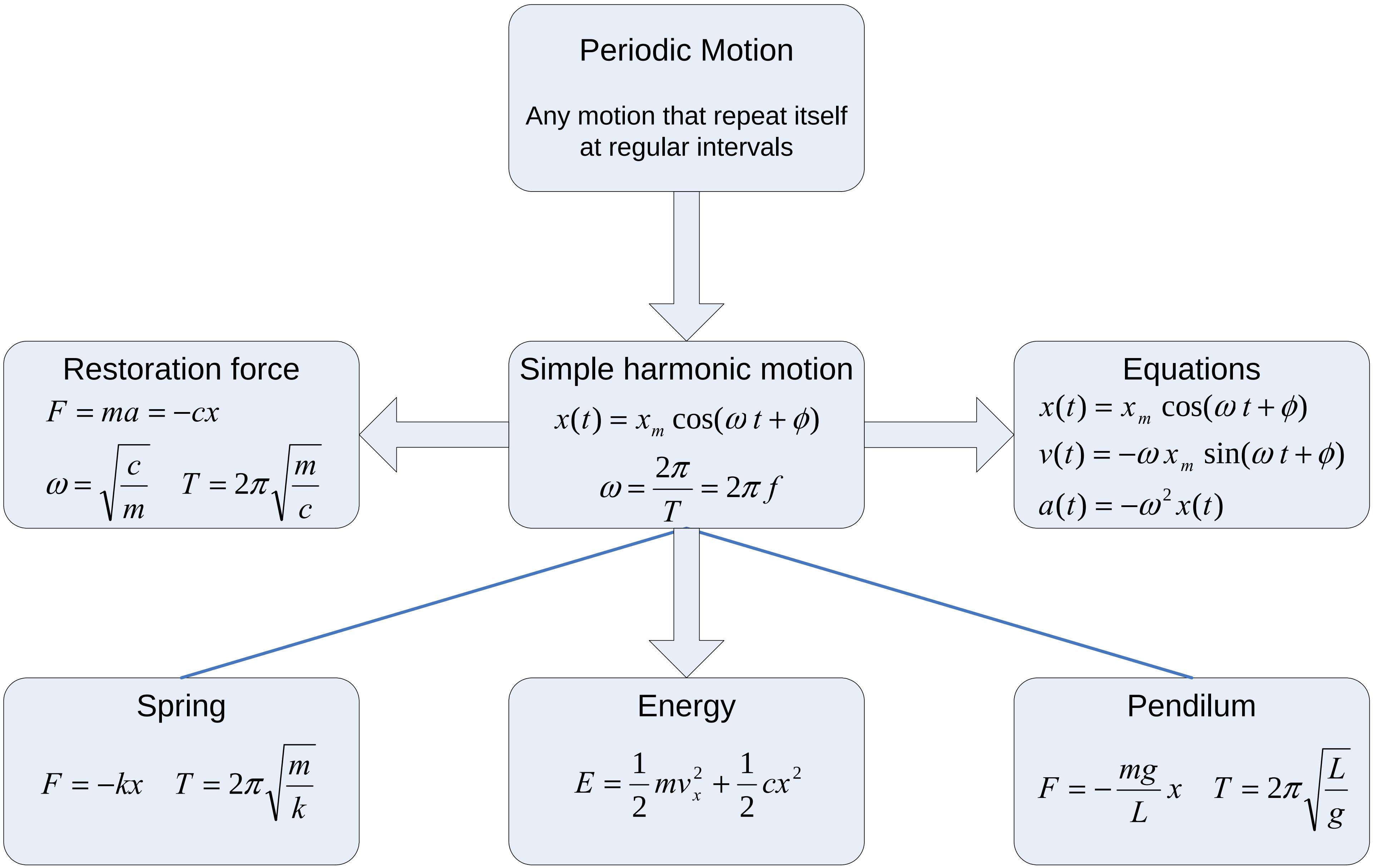
for $M = \rho V = \rho \frac{4\pi}{3} R^3$ then $g = \frac{4\pi}{3} G\rho R$

Gravitational potential energy $U = -\frac{GMm}{R}$

Escape speed: $v_i = \sqrt{\frac{2GM}{R}}$

Orbital motion: $v_c = \sqrt{\frac{GM}{R+h}}$ and $T = \frac{2\pi}{\sqrt{GM}}(R+h)^{3/2}$

Periodic motion



Fluids

Density $\rho = \frac{m}{V}$

Pressure $p = \frac{F}{A}$

Pressure at depth $h: p = p_0 + \rho g h$

Pascal's principle $: F_0 = F_i \frac{A_0}{A_i}$

Archimedes' principle of buoyancy $F_b = m_f g = \rho_f V g$