AP Physics 1 Summary

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Contents

*Many of these summaries are adapted from Princeton Review's AP Physics C Prep Book.

1 Some Notes

If you want to go to the important stuff, skip this whole section.

1.1 Introduction

This summary includes the main ideas of (almost) every unit in AP Physics 1. This handout should act as a supplement to anything else you're studying, and not your main tool.

Equations that are on the equation sheet are boxed. Please use the equation sheet and this handout to determine which equations you should/shouldn't memorize.

1.2 Contact Me

There may be some typos. If you notice any or have suggestions, please email michel.liao@systemgreen.org.

2 Kinematics

2.1 Definitions

- Position refers to an object relative to a coordinate axis.
- Distance refers to the *total* measure of the ground traveled by an object
- Displacement is how far an object is from where it started: $\Delta x = x_f - x_0$.
- Acceleration is a measure of change in velocity per some unit of time ($\overline{a} = \frac{\Delta v}{\Delta t}$). Acceleration is a *vector*.

2.2 Uniformly Accelerated Motion

- There are 5 kinematics equations pertaining to uniformly accelerated motion (UAM)
  - $\Delta x = \overline{v}t$
  - $\boxed{v = v_o + at}$
  - $\boxed{x = x_0 + vt - \frac{1}{2}at^2}$
  - $\boxed{v^2 = v_0^2 + 2a(x - x_0)}$
  - $\overline{v} = \frac{1}{2}(v_0 + v)$

2.3 Graphs

We can find the slope of a curve for some kinematics graphs:

- The slope of a velocity vs. time graph is acceleration.
- The slope of a displacement vs. time graph is velocity.

We can find the area under the curve for some kinematics graphs:

- The area under the curve of an acceleration vs. time graph is change in velocity.
- The area under the curve of a velocity vs. time graph is displacement.

2.4 Free Fall and Projectiles

- Free fall is when an object is only affected by the force of gravity.
- 2D motion should be analyzed according to its x and y components separately. The x and y components are independent.

3 Newton's Laws of Motion

3.1 Newton's Laws

Newton's Laws, in order, are:

1. Objects will continue in their state of motion unless acted upon by a net force.
2. $\boxed{\sum \vec{F} = m\vec{a}}$ [1]
3. When two objects interact, the force from the first object onto the second object is equal to, and in the opposite direction of, the force the second object exerts on the first object.

3.2 Weight, Normal Force, and Friction

- The weight of an object is *not* the mass of the object. Weight is given by $\vec{F_w} = m\vec{g}$.
- The normal force (F_N or N) is the component of the contact force exerted on an object that is perpendicular to the surface.
- Friction is the component of the contact force exerted on an object that is parallel to the surface.
- The inequality $\boxed{|\vec{F_f}| \leq \mu|\vec{F_N}|}$ gives you the *maximum* force that friction can apply [2] (see the footnote for more details).
  - Static friction occurs when there is no *relative* motion between the object and the surface.
  - Kinetic friction occurs when there is relative motion between the object and the surface.

3.3 Inclined Planes

- Rotate the x-y coordinate axis so that the x-axis and y-axis are parallel and perpendicular, respectively, to the incline (or else your life becomes way harder than it has to be).

[1] In your equation sheet, this is written as $\vec{a} = \frac{\sum \vec{F}}{m}$.

[2] In the case of static friction, we can imagine a box on a surface. The surface will only apply enough static friction force such that the net force remains $0N$. It doesn't make sense for the static friction force to always be equal to $\mu \cdot \vec{F_N}$, or the box may accelerate "backwards" when the forward force isn't equal to the maximum frictional force. Once a forward force exceeds the magnitude of maximum static friction force, the object will start sliding, and static friction becomes kinetic friction.

- There are two components of gravity that act on an object in an inclined plane: the force parallel to the ramp ($mg\sin\theta$) and the force perpendicular to the ramp ($mg\cos\theta$). [3]

3.4 Uniform Circular Motion

- An object undergoes uniform circular motion when its *speed* is constant.
- The velocity vector is *always* tangent to the circle.
- Centripetal acceleration and force points toward the center.

$$\boxed{a_c = \frac{v^2}{r}}$$

- Any force that points toward the center is positive, and any force that points away from the center is negative.
- When an object is at the top of a vertical circle, your acceleration must be at least $a = 9.8\frac{m}{s^2}$.
  - The proof is as follows: Assume we have a roller coaster at the top of a circular loop with mass m. For proof by contradiction, assume that $a < 9.8\frac{m}{s^2}$. Then, we have

$$\begin{aligned} F_N + F_g &= ma \\ F_N &= ma - F_g = m(a-g) \\ F_N &< 0N \end{aligned}$$

    Which is clearly impossible. A normal force that is $0N$ implies that it has no contact with the surface. Therefore, a must be at least $9.8\frac{m}{s^2}$ at the top of a vertical circle. [4]

[3] I recommend that you don't memorize these formulas. Rather, know the definitions of trigonometric functions (SOH CAH TOA).

[4] Remember that acceleration is a vector. The speed of our object does not change, but the direction does.

4 Work, Energy, and Power

4.1 Work

- Work is the product of force and displacement that is parallel to the force: $W = Fx_{\parallel}$.[5]
- Work is positive if the force is in the same direction of displacement. Conversely, work is negative if the force is opposite the direction of displacement.
- The total work done on an object/system is the sum of all work done by every force on the object/system: $W_{\text{total}} = \sum W$.
- The Work-Energy Theorem: $W_{\text{total}} = \Delta K$. A corollary is $\Delta U_g = -W_{\text{by gravity}}$.[6]

4.2 Energy

- Kinetic energy is energy associated with motion: $\boxed{K = \frac{1}{2}mv^2}$.
- Potential energy is stored energy, or the ability of "potentially" moving:[7]
  - $\boxed{\Delta U_g = mg\Delta h}$.
  - $\boxed{U_s = \frac{1}{2}k(\Delta x)^2}$.
  - You cannot have potential energy if you do not include the Earth in your system.[8]
- Conservation of Mechanical Energy occurs when there are no non-conservative forces acting on the system. There are several ways to express conservation of energy:
  - $E_0 = E_f \Rightarrow K_0 + U_0 = K_f + U_f$.
  - $\Delta K = -\Delta U \Rightarrow \Delta K + \Delta U = 0J$.
  - If there are non-conservative forces that do work, then:

$$K_0 + U_0 + W_{\text{other}} = K_f + U_f.$$

[5] Alteratively, work is also the product of displacement and force that is parallel to the displacement, or $W = F_{\parallel}x$.

[6] The distinction between W_{total} and $W_{\text{by gravity}}$ is small, but important.

[7] Potential energy is relative. To make your life easier, choose strategic inital potential energy positions.

[8] The statement isn't exactly correct, but it's a general way to think about things. If you don't include the Earth in your system, then F_g is an external force, which you would add into the left side of your equation (look at the conservation of energy section).

4.3 Power

- Power is the rate at which work is done.[9]
  - $$\boxed{P = \frac{W}{t} = \frac{dW}{dt}}$$
  - $$\boxed{P = \vec{F} \cdot \vec{v}}$$ [10]

[9] The equation sheet has the first equation written as $P = \frac{dE}{dt}$.
[10] This equation involves the dot product. Your velocity must be parallel to your force. (or vice versa).

5 Systems of Particles and Linear Momentum

5.1 Momentum

- Linear momentum is given by the equation

$$\boxed{\vec{p} = m\vec{v}}.$$

- The Law of Conservation of Momentum says that linear momentum is conserved who no external forces act on the system, or $p_0 = p$.
- Elastic collisions conserve *kinetic energy*.[11]
- Generally, for elastic collisions, the relative velocities $(v_2 - v_1)$ after the collision is equal in magnitude and opposite to the relative velocity before the collision $(v_{02} - v_{01})$.
- Inelastic collisions do not conserve kinetic energy. When objects stick together post-collision, the collision is said to be *perfectly* inelastic.

5.2 Impulse

- Impulse is given by the equation

$$\boxed{\vec{J} = \bar{F}\Delta t = \Delta\vec{p}}.$$

[11] Kinetic energy is the key term. In general, every collision conserves energy (energy turns into heat, sound, etc.), but not kinetic energy.

6 Rotation

6.1 Linear and Angular Quantities

- $s = r\theta$
- $v = r\omega$[12]
- $a_t = r\alpha$[13]

Linear Variables	Angular Equivalent
x	θ
v	ω
a	α
p	L
m	I
F	τ

6.2 Basic Rotation Information

- Rotational inertia is a measure of how difficult it is to change an object's rotational motion. The more concentrated the mass is at the center of the object, the easier it is to cause it to rotate.
- Torque is the ability to cause an object to rotate:

$$\boxed{\tau = r_\perp F = rF\sin\theta}.$$

- Newton's Second Law's rotational equivalent is

$$\boxed{\sum \tau = I\alpha}.$$

- Rotating objects have rotational kinetic energy given by

$$\boxed{K_{\text{rotation}} = \frac{1}{2}I\omega^2}.$$

- If an object is rolling, the rotational kinetic energy is

$$K_{\text{rolling}} = K_{\text{rotation}} + K_{\text{translation}} = \frac{1}{2}I_{\text{cm}}\omega^2 + \frac{1}{2}mv_{\text{cm}}^2.$$

  [14]

[12]This velocity is tangential velocity. This is sort of redundant to say, as all velocity must be tangential in a curving path, but it is important to know that centripetal velocity doesn't exist.

[13]This equation relates to *tangential* acceleration, not centripetal. To find the magnitude of total acceleration, use the equation $a = \sqrt{a_t^2 + a_c^2}$.

[14]Note the emphasis put on the center of mass.

6.3 Angular Momentum

- Angular momentum for a point particle is given by the equation

$$\boxed{L = I\omega}.$$

- Angular momentum for a rigid object is given by

$$L = mvr_{\perp}.$$[15]

- Angular momentum is conserved unless a net external torque acts on the object.

- Know your different types of equilibrium:
  - Translational equilibrium is when the net force is $0N$.
  - Rotational equilibrium occurs when the net torque is $0\frac{kg \cdot m^2}{s^2}$.
  - Equilibrium (by itself) occurs when there is both translational and rotational equilibrium.[16]
  - If an ob ject is at rest, it is in static equilibrium (both translational and rotational).

[15] This is how we find angular momentum in terms of linear momentum.

[16] Remember that when we're in either translational or rotational equilibrium, it doesn't necessarily mean that our velocity or angular velocity is 0. It just means that our velocity/angular velocity is not changing.

7 Oscillations

7.1 Simple Harmonic Motion

- Simple harmonic occurs when there is a restoring force on an object that is proportional for the displacement. The restoring force for a spring is

$$\boxed{F_s = -kx}.$$[17]

- The equation for an object undergoing SHM is

$$\boxed{x = A\cos(2\pi f t)}.$$

- The period is the length of time it takes to copmlete one cycle and frequency is the number of cycles the object completes in one unit of time:

$$\boxed{f = \frac{1}{T} = \frac{\text{cycles}}{\text{time}}}.$$

[17] Remember, x is the length the spring will stretch beyond its natural length (nothing attached to it).

8 Gravitation

8.1 Newton's Law of Gravitation & Circular Orbits

- Newton's Law of Gravitation:

$$\boxed{F_g = \frac{Gm_1m_2}{r^2}}.$$

  Use it in conjunction with $F_g = ma_g$ to arrive at

$$a_g = \frac{Gm_1}{r^2}.$$

- $F_g = F_c$ is very helpful to find the speed of an orbiting object.
-

$$v = \frac{2\pi r}{T}$$

8.2 General Orbits

- Gravitational potential energy is given by

$$\boxed{U_g = -\frac{Gm_1m_2}{r}}.$$

- Mechanical energy and angular moment are conserved for orbits.
- Escape speed is derived when we set our kinetic and potential energy equal to 0.

$$\frac{1}{2}m_1v_{\mathrm{esc}^2} - \frac{Gm_1m_2}{r} = 0$$

  Which gives us

$$v_{\mathrm{esc}} = \sqrt{\frac{2Gm_2}{r}}.$$