AP Physics 1: A Guide to 5.

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July 14, 2024.

0.1: Author's Note.

I'm proud to be among the top 8% of students who scored a 5 on the 2024 AP Physics 1 exam. Recognizing the difficulty of navigating thick textbooks and long videos, I saw the need for a succinct, accessible resource. This led me to create a free AP Physics 1 handbook in collaboration with my non-profit tutoring organization, FamilyFirst Aid CA.

This handbook is tailored for students preparing for the 2025 AP Physics 1 exam. It's one of the few resources updated to reflect the latest course changes, including the new fluids unit (Unit 8). The handbook focuses on the most relevant information and topics for the exam, providing a concise resource for students with a foundational understanding of physics who need quick references, concept clarifications, or essential exam strategies. The content aligns with the College Board's AP Physics 1 curriculum, concentrating on frequently tested material.

Designed to supplement an AP Physics 1 course, this handbook includes simple definitions, example questions, key equations, and essential takeaways, along with brief notes and exam tips.

If you've read this far, you probably have a better attention span than I do, and I'm confident you'll find this handbook beneficial. I hope it serves you well. Enjoy!

0.2: Guide.

This handbook is not intended to be a replacement for an AP Physics 1 class but a supplementary resource to enhance your understanding of the course. Key terms are **bolded**, underlined words highlight critical differences, blue highlights denote example questions, and yellow highlights indicate the most important topics to grasp. Notes marked with "**Note**:" provide tips specifically tailored for the AP Physics 1 exam.

If you're short on time, each unit concludes with "*Key Takeaways*:" summarizing the essential topics needed to grasp the unit's overall framework.

Although the AP Physics 1 exam provides equations and constants, it's beneficial to familiarize yourself with them. The appendix contains examples, essential equations, units, symbols, prefixes, and fundamental constants for your reference.

0.3: 2024-2025 AP Physics 1 Overview.

Unit 1: Kinematics……………………………………………………………………………………………..4
- 1.1 Position, velocity, and acceleration
- 1.2 Equations of kinematics
- 1.3 Vectors
- 1.4 Projectile Motion.

Unit 2: Dynamics………………………………………………………………………………………..……..8
- 2.1 Newton's first law.
- 2.2 Newton's second law.
- 2.3 Newton's third law.
- 2.4 The gravitational field.
- 2.5 Normal force.
- 2.6 Friction force.
- 2.7 Hooke's law.

Unit 3: Work, energy, and power……………………………………………………………………..……..11
- 3.1 Open and closed systems: energy.
- 3.2 Work and mechanical energy.
- 3.3 Conservation of energy and the work-energy principle.
- 3.4 Power.

Unit 4: Linear momentum……………………………………………………………………..………..…..13
- 4.1 Momentum.

4.2 Change in momentum and impulse.
4.3 Conservation of linear momentum.
4.4 Elastic and inelastic collisions.
Unit 5: Torque and rotational dynamics.........15
5.1 Rotational kinematics.
5.2 Connecting linear and rotational motion.
5.3 Torque.
5.4 Rotational inertia.
5.5 Rotational equilibrium and Newton's first law in rotational form.
5.6 Newton's second law in rotational form.
Unit 6: Energy and momentum of rotating systems.........17
6.1 Rotational kinetic energy.
6.2 Torque and work.
6.3 Angular momentum and angular impulse.
6.4 Conservation of angular momentum.
6.5 Rolilng motion.
6.6 Motion of orbiting satellites.
Unit 7: Oscillations.........21
7.1 Defining simple harmonic motion (SHM).
7.2 Frequency and period of SHM.
7.3 Representing and analyzing SHM.
7.4 Energy of simple harmonic oscillators.
Unit 8: Fluids.........23
8.1 Internal structure and density,
8.2 Pressure.
8.3 Fluids and Newton's laws.
8.4 Fluids and conservation laws.

Key Changes for 2024-2025 AP Physics 1

- 8 units - an increase from 7.
- Fluids (previously Unit 1 of AP Physics 2) will now be Unit 8 of AP Physics 1.
- Adding connections between rotational and translational motion.
- Adding specific learning objectives referencing power.
- Adding equations of motion for objects in simple harmonic motion.
- Uncoupling specific science practices from specific learning objectives. In the revised course framework, any learning objective can be tested with any science practice, which allows a greater range of questions to be written to the new framework.
- 40 multiple-choice questions (MCQs)—a decrease from 50 MCQs.
  - Removing multiselect questions.
  - Decreasing Section I (MCQs) time from 90 to 80 minutes.
- 4 free-response questions (FRQs)—a decrease from 5 FRQs.
  - All 4 FRQs will be new question types:
    - Mathematical routines, translation between representations, experimental design and analysis, qualitative/quantitative translation.
    - Increasing Section II (FRQs) time from 90 to 100 minutes.

Unit 1: Kinematics.

Exam Weighting: 10-15%.

1.1 POSITION, VELOCITY, AND ACCELERATION.

Scalar: a quantity with only magnitude.
Vector: a quantity with both magnitude and direction.

Distance: the total length taken from point *A* to point *B*.
Most common units: meters (m).
Scalar quantity.
Displacement: the shortest path from point *A* to point *B*.
Most common units: meters (m).
Used to find the velocity.
Vector quantity.

Example (reference Figure 1.1): Bob ran from point A to point B using the **black** path, traveling a distance of 100 meters. His displacement was only 80 meters.

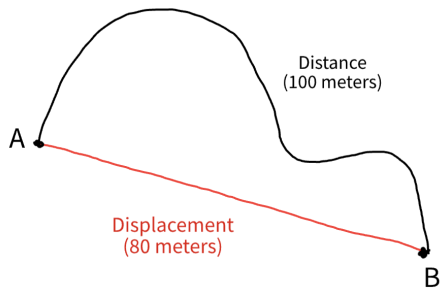


Figure 1.1: Distance vs. Displacement.

Velocity: the rate of change and direction of an object's displacement with respect to time.
Most common units: meters per second (m/s).
Used to find the acceleration.
Vector quantity.
How to calculate: $\frac{displacement}{time}$

Example question 1.1 (reference figure 1.1): Bob ran from point A to point B using the **black** path in 8 seconds. Find his average velocity.

1. His average velocity is found from his displacement and time.
2. His displacement is 80 meters and he took 8 seconds to run from point A to point B.
a. $displacement\ (\Delta x)$ = 80 meters (m)
b. $time\ (t)$ = 8 seconds (sec)
c. $v_a = \frac{displacement}{time}$
3. $v_a = \frac{80\ meters}{8\ seconds}$

v_a = 10 m/s

Note: if units are not in meters or seconds, it is recommended to first convert these magnitudes to meters and seconds.

Acceleration: the rate of change and direction of velocity with respect to time.

Most common units: meters per second per second (m/s^2)
Vector quantity.

How to calculate: $a = \frac{velocity}{time}$

Example question 1.2 (reference figure 1.1): Bob ran from point A to point B using the **black** path in 8 seconds. We found his average velocity, 10 m/s, in the previous example. Find his acceleration.

1. His average acceleration is found from his velocity and time.
2. His average velocity is 10 meters per second and he took 8 seconds to run from point A to point B.

$velocity\ (v_a)$ = 10 m/s

$time\ (t)$ = 8 seconds (sec)

$acceleration\ (a) = \frac{velocity}{time}$

3. $a = \frac{10\ m/s}{8\ seconds}$

$v_a = 1.25\ m/s^2$

1.2 EQUATIONS OF KINEMATICS.

Δx: displacement

v_i: initial velocity

v_f: final velocity

a: acceleration

t: time

$v_f = v_i + at$ — no Δx

$\Delta x = v_i t + \frac{1}{2}at^2$ — no v_f

$v_f^2 = v_i^2 + 2a\Delta x$ — no t

$\Delta x = vt = \frac{1}{2}(v_i + v_f)t$ — no a

Example question 1.3: A car with an initial velocity of 23.7 km/h accelerates at a uniform rate of 0.92 m/s^2 for 3.6 s. Find the final velocity and the displacement of the car during this time.

1. Identify the variables.

v_i = 23.7 km/h, or 6.58 m/s.

a = 0.92 m/s^2

t = 3.6 s

v_f = ?

Δx = ?

2. Set up the equation to find the final velocity during this time.

$v_f = v_i + at$

$v_f = 6.58 + (0.92)(3.6)$

$v_f = 9.892\ m/s$

3. Set up the equation to find the displacement of the car during this time.

$\Delta x = v_i t + \frac{1}{2}at^2$

$\Delta x = (6.58)(3.6) + \frac{1}{2}(0.92)(3.6)^2$

$\Delta x = 29.65\ m$

Note: On the AP Physics 1 test, there are rarely pure kinematic questions or questions where you would just "plug in" numbers. You will often have to apply them conceptually with concepts such as work, power, energy, etc. (Examples on pg.)

1.3 VECTORS.

Vector: a quantity having direction and magnitude.

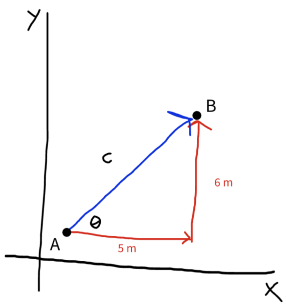


Figure 1.3: Simple vectors.

Example question 1.4 (reference Figure 1.3): Bob walked 5 meters right on the x-axis and 6 meters up on the y-axis. What is the magnitude and the direction of Bob's displacement?

1. Identify the variables.

$\Delta x = 5\,m$

$\Delta y = 6\,m$

$c = ?$

$\theta = ?$

2. Using the pythagorean theorem ($c^2 = \Delta x^2 + \Delta y^2$):

$c^2 = 5^2 + 6^2$

$c = \sqrt{50}$

$c = 7.81\,m$

3. Using trigonometry ($tan\theta = \frac{\Delta y}{\Delta x}$):

$\theta = tan^{-1}(\frac{6\,m}{5\,m})$

$\theta = 50.19^{\circ}$

Note: Pure vector questions like the one above do not appear in the AP Physics 1 exam. But it is still imperative to understand them conceptually because there are a variety of applications for vectors that are tested. Understanding trigonometry and how to get resultant vectors is important in answering 20-30% of the exam.

1.4 PROJECTILE MOTION.

Acceleration of gravity on Earth is a constant: $9.81\,m/s^2$.

Most common notation: $g_E = 9.8\,m/s^2$

Note: the AP Physics 1 Test will allow students to round this to $9.8\,m/s^2$ or $10\,m/s^2$ for simplicity of calculations.

Key Takeaways:

- In a problem, be able to identitfy displacement, initial velocity, final velocity, acceleration, and time.
- Memorize equations of kinematics.
  - $v_f = v_i + at$ — no Δx

- $\Delta x = v_i t + \frac{1}{2}at^2$ — no v_f
- $v_f^2 = v_i^2 + 2a\Delta x$ — no t
- $\Delta x = vt = \frac{1}{2}(v_i + v_f)t$ — no a

- It is recommended to first identify and convert variables to SI base units to figure out which equation of kinematics to use.

Unit 2: Dynamics.

Exam Weighting: 18-23%.

Note: The AP Physics 1 exam has a **lot** of content from Unit 2. The applications of dynamics are spread throughout the test.

2.1 NEWTON'S FIRST LAW.

Every object will remain at rest or in uniform motion in a straight line at a constant velocity unless acted on by a net external force.

2.2 NEWTON'S SECOND LAW.

The acceleration of an object depends on the mass of the object and the amount of force applied.

$F = ma$

force = mass * acceleration

Example question 2.1: A 6.0 kg object undergoes an acceleration of 2.0 m/s^2. What is the magnitude of the external force acting on it? If the same force is applied to a 4.0 kg object, what acceleration is produced?

1. Identify variables.
   m = 6.0 kg
   a = 2.0 m/s^2
   $F = ?$
2. Solve for external force.
   $F = ma$
$F = (6)(2)$
   $F = 12\ N$
3. Identify new variables.
m = 4.0 kg
   a = ?
   $F = 12\ N$
4. Solve for acceleration.
$F = ma$
$\frac{F}{m} = a$
$a = 3\ m/s^2$

2.3 NEWTON'S THIRD LAW.

Whenever one object exerts a force on another object, the second object exerts an equal and opposite force on the first object.

2.4 THE GRAVITATIONAL FIELD.

Mass: total amount of matter in an object.
   Most common units: kilogram (kg).
Weight: the force of gravity on an object.
   Most common units: newton (N).

Force of a planet's gravity (weight of an object):
$F_g = mg$
Weight of an object is in newtons (N).

Example question 2.2: A 6.0 kg object is on Earth. How much does it weigh?

1. Identify variables

$m = 6.0$ kg

$g = 9.8\, m/s^2$

$F_g = ?$

2. Solve

$F_g = (6)(9.8)$

$F_g = 58.8\, N$

2.5 NORMAL FORCE.

The contact force exerted by surfaces to prevent solid objects from passing through each other. Denoted with: F_N

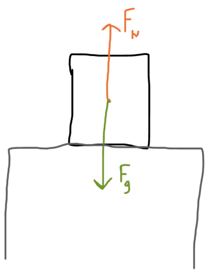


Figure 2.1: Normal force.

Example question 2.2 (reference Figure 2.1): An object weighing 58.8 N is on a table. What is the magnitude of the normal force exerted by the table on the object?

1. Identify the variables.

$F_g = 58.8\, N$

$F_N = ?$

2. By making a FBD (free body diagram), represented by the orange and green force vector arrows, we can see that the normal force and force of gravity acting on the object are equal and opposite. We can then infer that $F_g = F_N$.

3. $F_N = 58.8\, N$

2.6 FRICTION FORCE.

The contact force that is generated by two surfaces that slide against each other. Denoted with: F_k.

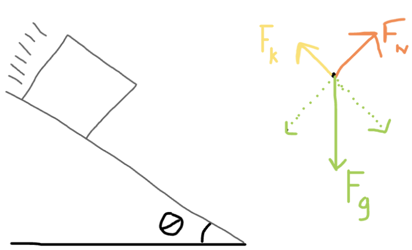


Figure 2.2: Friction force, normal force, gravity force.

Example question 2.3 (reference Figure 2.2): An object of 5.0 kg is on a rough ramp that makes an angle of 32º to the horizontal. The coefficient of kinetic friction between the object and the ramp is $\mu_k = 0.68$. What is the magnitude of the normal force exerted by the ramp by the object? What is the magnitude of the friction force exerted by the ramp?

1. Identify the variables.

$m = 5.0\, kg$

$\mu_k = 0.68$

$\theta = 32º$

$F_N = ?$

$F_g = ?$

$F_k = ?$

2. By making a FBD (free body diagram), represented by the yellow, orange, and green force vector arrows, we can see that $F_g sin\theta = F_N$ and $F_g cos\theta = F_k$.

3. Using Newton's second law, find the force of gravity/weight:

$F_g = mg$

$F_g = (5)(9.8)$

$F_g = 49\ N$

4. $F_g sin\theta = F_N$

$49sin(32) = F_N$

$F_N = 24.96\ N$

5. $F_g cos\theta = F_k$

$49cos(32) = F_k$

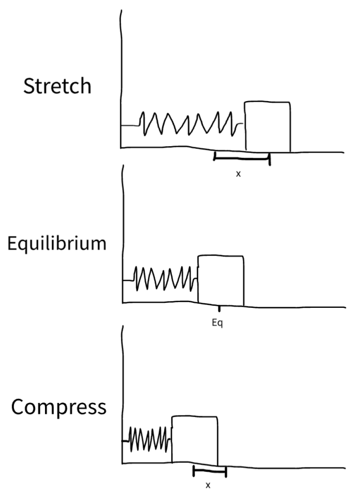
$F_k = 41.55\ N$

2.7 HOOKE'S LAW.

Hooke's Law:

$F_s = k\Delta x$

spring force = spring constant * displacement of spring stretch/compression from equilibrium



Note: Again, for all of the concepts, there are rarely questions that just require you to "plug in" numbers and get a solution. You will have to understand them conceptually and apply them in different ways.

Key Takeaways:

- Know Newton's second law, or $F = ma$.
- Know Hooke's law, or $F_s = k\Delta x$.
- Before anything, identify the variables and make a free body diagram.
- Understand the vector magnitudes of each force and how they can change with angles.

Unit 3: Work, Energy, and Power.

Exam Weighting: 18-23%.

Note: The AP Physics 1 exam has a **lot** of content from Unit 3. Although this unit may seem short, the applications of energy are spread throughout the test. Thus it is imperative to understand all concepts inside out.

3.1 OPEN AND CLOSED SYSTEMS: ENERGY.

Open Systems: A system that exchanges energy with its surroundings.
Closed Systems: A system that **does not** exchange energy with its surroundings.
Total energy remains constant

Kinetic Energy (KE): Energy of motion.

$KE = \frac{1}{2}mv^2$

kinetic energy = $\frac{1}{2}$ * mass * (velocity^2)

Potential Energy (PE): Store energy due to position (e.g. gravitational potential energy, spring potential energy).

$PE = mgh$

potential energy = mass * gravitational acceleration * height/displacement

3.2 WORK AND MECHANICAL ENERGY.

Work (W): Transfer of energy via force applied over a distance.
Positive work: When force and displacement are in the **same** direction.
Negative work: When force and displacement are in **opposite** directions.
Zero work: When force is perpendicular to displacement.
Gravitational work: Work done against or by gravity.
Spring work: Work done in compressing or extending a spring.

Mechanical Energy: The total of kinetic and potential energy in a system.

$ME = KE + PE$

$ME = \frac{1}{2}mv^2 + mgh$

Work-Energy Theorem: The net work on an object is equal to the change in its kinetic energy.

3.3 CONSERVATION OF ENERGY AND THE WORK-ENERGY PRINCIPLE.

Conservation of energy: In a closed system, the total energy remains constant over time.

$KE_i + PE_i = KE_f + PE_f$

$\frac{1}{2}mv_{initial}^2 + mgh_{initial} = \frac{1}{2}mv_{final}^2 + mgh_{final}$

initial kinetic energy + initial potential energy = final kinetic energy + final potential energy

Work-Energy Principle: The work done on an object by all forces is equal to the change in its kinetic energy.

Example question 3.1: A 3 kg ball is thrown vertically upward with an initial speed of 10 m/s. Calculate the maximum height it reaches and its speed when it returns to the initial height.

1. Identify the variables.

$m = 3\ kg$

$v_{initial} = 10\ m/s$

$h_{maximum} = ?$

$v_{final} = ?$

2. Use the equation for kinetic energy: $KE = \frac{1}{2}mv^2$

$KE = \frac{1}{2}(3)(10)^2$

$KE = 150\,J$

3. Use conservation of energy: $KE_i + PE_i = KE_f + PE_f$

$150 + 0 = 0 + PE_{final}$

4. Use the equation for potential energy: $PE = mgh$

$150 = (3)(9.8)(h)$

$h = 5.1\,m$

5. Use conservation of energy: $KE_i + PE_i = KE_f + PE_f$

$\frac{1}{2}mv_{initial}^2 + mgh_{initial} = \frac{1}{2}mv_{final}^2 + mgh_{final}$

$\frac{1}{2}(3)(0)^2 + (3)g(5.1) = \frac{1}{2}(3)v_{final}^2 + (3)g(0)$

$v_{final} = 10\,m/s$

3.4 POWER.

Power: The rate at which work is done or energy is transferred (how quickly work is done).

$P = \frac{W}{\Delta t}$

power = $\frac{work}{elapsed\ time}$

Key Takeaways:

- Know conservation of energy: $KE_i + PE_i = KE_f + PE_f$
- Grasp the core concepts of energy, work, and power.
- Familiarize yourself with the format and question types from previous AP exams.

Unit 4: Linear Momentum.

Exam Weighting: 10-15%.

Note: Although this unit may seem short, the AP Physics 1 exam does focus on these topics. Although the concepts in this unit in specific may seem elementary, they are applied throughout almost the entire exam.

4.1 MOMENTUM.

Momentum (p): vector quantity defined as the product of an object's mass and its velocity

$p = mv$

$Momentum = mass * velocity$

Most common units: N/s (Newton-seconds) or kgm/s (kilogram-meters per second)

4.2 CHANGE IN MOMENTUM AND IMPULSE.

Impulse (J): the change in momentum of an object when a force is applied over a period of time.

$J = \Delta p = F\Delta t$

$Impulse = Change\ in\ momentum = Force * Time\ interval$

Most common units: Ns

4.3 CONSERVATION OF LINEAR MOMENTUM.

The conservation of momentum states that the total momentum of a closed system remains constant if no external forces act on it.

$p_{initial} = p_{final}$

$m_{initial}v_{initial} = m_{final}v_{final}$

4.4 ELASTIC AND INELASTIC COLLISIONS.

Elastic collisions: collisions in which both momentum and kinetic energy are conserved.
Perfectly elastic collisions: the colliding objects bounce off each other with no energy loss (not realstic).

Inelastic collisions: collisions in which momentum is conserved but **kinetic energy is not**.
Perfectly inelastic collisions: the colliding objects stick together after the collision.

Example question 4.1: Two identical 1 kg balls collide elastically. Ball A is moving at 2 m/s towards Ball B, which is initially at rest. Determine the velocities of both balls after the collision.

6. Identify the variables.

$m_A = m_B = 1\ kg$

$v_{A_{initial}} = 2\ m/s$

$v_{B_{initial}} = 0\ m/s$

$v_{A_{final}} = ?$

$v_{B_{final}} = ?$

7. Use the conservation of momentum: $m_{initial}v_{initial} = m_{final}v_{final}$

$m_A v_{A_{initial}} + m_B v_{B_{initial}} = m_A v_{B_{final}} + m_B v_{B_{final}}$

$(1)(2) + (1)(0) = (1)(v_{A_{final}}) + (1)(v_{B_{final}})$

$v_{A_{final}} + v_{B_{final}} = 2\,kg * m/s$

8. Use conservation of kinetic energy: $\frac{1}{2}m_A v_{A_{initial}}^{\;2} + \frac{1}{2}m_B v_{B_{initial}}^{\;2} = \frac{1}{2}m_A v_{A_{final}}^{\;2} + \frac{1}{2}m_B v_{B_{final}}^{\;2}$

$\frac{1}{2}(1)(2)^2 + \frac{1}{2}(1)(0)^2 = \frac{1}{2}(1)(v_{A_{final}}^{\;2}) + \frac{1}{2}(1)(v_{B_{final}}^{\;2})$

9. Solve equations derived from steps 2 and 3.

$v_{A_{final}} = 0\,m/s$

$v_{B_{final}} = 2\,m/s$

Note: When dealing with collisions, always start with the conservation of momentum equation and then apply energy conservation principles if the collision is elastic.

Key Takeaways:

- Understand the concepts of linear momentum and impulse.
- Apply the law of conservation of momentum to different collision scenarios: $m_{initial}v_{initial} = m_{final}v_{final}$
- Distinguish between elastic and inelastic collisions, and analyze each type accordingly.

Unit 5: Torque and Rotational Dynamics.

Exam Weighting: 10-15%.

5.1 ROTATIONAL KINEMATICS.

Rotational Kinematics: motion of objects that rotate about an object.

Angular displacement (θ): The angle through which an object rotates, measured in radians.
Angular velocity (ω): The rate at which the angular displacement changes with time, measured in radians per second (rad/s)
Angular acceleration (α): The rate at which the angular velocity changes with time, measured in radians per second squared (rad/s^2).

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$\omega^2 = \omega_0^2 + 2a\Theta$

As you can tell, these are derived from the standard kinematic equations but:

- velocity (v) as angular velocity (ω).
- displacement (Δx) as angular displacement (θ).
- acceleration (a) as angular acceleration (α).

5.2 CONNECTING LINEAR AND ROTATIONAL MOTION.

Rotational motion can be connected to linear motion through the radius of the circular path

Linear displacement: $s = r\Theta$
Linear velocity: $v = r\omega$
Linear acceleration: $a = ra$

5.3 TORQUE.

Torque (τ) is how much a force acting on an object causes that object to rotate. The point where the object rotates is called the axis of rotation.
$\tau = rFsin\theta$
$Torque = radius * Force * sin\, of\, angle\, between\, force\, and\, lever$
Most common units: Newton-meter (Nm)

Example question 5.1: A force of 10 N is applied at a distance of 0.5 m from the axis of rotation. What is the torque produced?

10. Identify the variables.
$F = 10\, N$
$r = 0.5\, m$
$\theta = 90º$
$\tau = ?$
11. Plug in variables:
$\tau = rFsin\theta$
$\tau = (0.5)(10)sin90$
$\tau = 5\, Nm$

Note: Pay attention to the direction of the applied force and the angle at which it is applied when calculating torque.

5.4 ROTATIONAL INERTIA.

Rotational Inertia: the resistance of an object to change its state of rotational motion.
Momentum of Inertia: Depends on the mass distribution relative to the axis of rotation.

For a point mass: $I = mr^2$

Note: Familiarize yourself with common moments of inertia for various shapes, as they frequently appear in exam problems.

5.5 ROTATIONAL EQUILIBRIUM AND NEWTON'S FIRST LAW IN ROTATIONAL FORM.

Rotational Equilibrium occurs when the net torque acting on a system is zero, meaning there is no angular acceleration.

Newton's First Law for Rotation: An object at rest or in uniform rotational motion will remain so unless acted upon by a net external torque.

5.6 NEWTON'S SECOND LAW IN ROTATIONAL FORM.

Newton's Second Law for Rotation: relates the net torque acting on an object to its angular acceleration.

$\tau_{net} = I\alpha$

$Torque = Moment\ of\ inertia * Angular\ acceleration$

Example question 5.2: Calculate the angular velocity of a rotating disk with a moment of inertia of 2 kg·m² when subjected to a net torque of 4 Nm for 3 seconds.

1. Identify the variables.

$I = 2\,kg * m^2$

$\tau = 4\,Nm$

$t = 3\,s$

$\omega_0 = 0\,rad/s$

$\alpha = ?$

$\omega = ?$

2. Use these equations: $\tau_{net} = I\alpha$ and $\omega = \omega_0 + at$.
3. Using Newton's Second Law for Rotation, find the angular acceleration of the rotating disk:

$\tau = I\alpha$

$4 = (2)(\alpha)$

$\alpha = 2\ rad/s^2$

4. Using rotational kinematics, find the angular velocity of the rotating disk:

$\omega = \omega_0 + \alpha t$

$\omega = 0 + 2(3)$

$\omega = 6\,rad/s$

Key Takeaways:

- Understand the relationship between linear and rotational motion.
- Grasp the concept of rotational inertia and how it affects an object's resistance to changes in rotational motion.
- Be able to apply Newton's laws and kinematics to rotational systems.
- Know how to find torque: $\tau = rFsin\theta$

Unit 6: Energy and Momentum of Rotating Systems.

Exam Weighting: 5-8%.

Note: Before reading, keep in mind that the AP Physics 1 exam comprises very little content from this unit. This handbook will very briefly go through this unit, but it is imperative to understand centripetal motion and circular motion as a concept for Unit 5.

6.1 ROTATIONAL KINETIC ENERGY.

Rotational kinetic energy: the energy due to the rotation of an object and its part of its total kinetic energy.

$K_{rot} = \frac{1}{2}I\omega^2$

$Rotational\ kinetic\ energy = \frac{1}{2} * Moment\ of\ inertia * Angular\ velocity$

Example question 6.1: A solid disk with a mass of 2 kg and a radius of 0.5 m is spinning at 10 rad/s. Calculate its rotational kinetic energy.

1. Identify the variables.

$m = 2\,kg$

$r = 0.5\,m$

$\omega = 10\,rad/s$

$I = ?$

$K_{rot} = ?$

2. Use these equations: $I = \frac{1}{2}mr^2$ and $K_{rot} = \frac{1}{2}I\omega^2$.
3. Find the moment of inertia.

$I = \frac{1}{2}mr^2$

$I = \frac{1}{2}(2)(0.5)^2$

$I = 0.25\,kg * m^2$

4. Find the rotational kinetic energy.

$K_{rot} = \frac{1}{2}I\omega^2$

$K_{rot} = \frac{1}{2}(0.25)(10)^2$

$K_{rot} = 12.5\,J$

6.2 TORQUE AND WORK.

Torque and work in rotational systems follow similar principles to linear systems but invovle rotational quantities.

$W = \tau\Theta$

$Work = Torque * Angular\ displacement$

Example question 6.2: A force of 20 N is applied tangentially to the edge of a wheel with a radius of 0.3 m, causing it to rotate through an angle of 2 radians. Calculate the work done by the force.

1. Identify the variables.

$F = 20\,N$

$r = 0.3\,m$

$\Theta = 2\,rad$

$\tau = ?$

$W = ?$

2. Use these equations: $\tau = Fr$ and $W = \tau\theta$.

3. Find the torque.

$\tau = Fr$

$\tau = (20)(0.3)$

$\tau = 6\, Nm$

4. Find the work.

$W = \tau\theta$

$W = 6(2)$

$W = 12\, J$

6.3 ANGULAR MOMENTUM AND ANGULAR IMPULSE.

Angular Momentum (L): the rotational equivalent of linear momentum and is conserved in a closed system.

$L = I\omega$

$Angular\ Momentum\ =\ Momentum\ of\ inertia\ *\ Angular\ velocity$

$L = mvr$

$Angular\ Momentum\ =\ mass\ *\ velocity\ *\ radius$

Angular Impulse (ΔL): change in angular momentum.

$\Delta L = \tau\Delta t$

$Angular\ Impulse\ =\ Torque\ *\ Change\ in\ time$

6.4 CONSERVATION OF ANGULAR MOMENTUM.

The Conservation of Angular Momentum states that the total angular momentum remains constant if no external torque acts on a system.

Example question 6.3: A figure skater with a moment of inertia of 2 kg·m² spins at 5 rad/s. If she pulls her arms in and reduces her moment of inertia to 1 kg·m², what will her new angular velocity be?

1. Identify the variables.

$I_{initial} = 2\, kg * m^2$

$\omega_{initial} = 5\, rad/s$

$I_{final} = 1\, kg * m^2$

$\omega_{final} =?$

2. Use the equation for angular momentum: $L = I\omega$

3. Find the initial angular momentum.

$L_{initial} = I_{initial}\omega_{initial}$

$L_{initial} = (2)(5)$

$L_{initial} = 10\, kg * m^2/s$

4. Apply the conservation of angular momentum.

$L_{final} = I_{final}\omega_{final} = 10\, kg * m^2/s$

$10 = (1)\omega_{final}$

$\omega_{final} = 10\, rad/s$

6.5 ROLLING MOTION.

Rolling motion involves both translational and rotational motion. The kinetic energy of a rolling object is the sum of its translational and rotational kinetic energies.

$K_{total} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$Total\ kinetic\ energy\ = \frac{1}{2} * mass * velocity^2 + \frac{1}{2} * moment\ of\ inertia * angular\ velocity^2$

Example question 6.4: A solid sphere of mass 1 kg and radius 0.2 m rolls without slipping at a speed of 3 m/s. Calculate its total kinetic energy.

1. Identify the variables.

$m = 1\, kg$

$r = 0.2\, m$

$v = 3\, m/s$

$I_{sphere} = ?$

$\omega = ?$

$K_{total} = ?$

2. Use these equations: $I_{sphere} = \frac{2}{5}mr^2$ and $\omega = \frac{v}{r}$ and $K_{total} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$.

3. Find the moment of inertia of a sphere.

$I_{sphere} = \frac{2}{5}mr^2$

$I_{sphere} = \frac{2}{5}(1)(0.2)^2$

$I_{sphere} = 0.016\, kg * m^2$

4. Find the angular velocity.

$\omega = \frac{v}{r}$

$\omega = \frac{3}{0.2}$

$\omega = 15\, rad/s$

5. Find the total kinetic energy.

$K_{total} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$K_{total} = \frac{1}{2}(1)(3)^2 + \frac{1}{2}(0.016)(15)^2$

$K_{total} = 6.3\ J$

Note: Practice using both rotational and linear analogs.

6.6 MOTION OF ORBITING SATELLITES.

The Motion of Orbiting Satellites involves gravitational forces and rotational dynamics. The conservation of angular momentum and energy principles apply.

Example question 6.5: A satellite in a circular orbit around Earth has a speed of 7.8 km/s at a distance of 7000 km from the Earth's center. Calculate its angular momentum given that its mass is 500 kg.

1. Identify the variables.

$v = 7.8\, km/s$

$r = 7000\, km$

$m = 500\, kg$

$L = ?$

2. Use the equation for angular momentum: $L = mvr$

3. Find the angular momentum.

4. $L = mvr$

$L = (500)(7.8 * 10^3)(7000)$

$L = 2.73 * 10^{10}\ kg * m^2/s$

Key Takeaways:

- Grasp the principles of the conservation of angular momentum.
- Understand the different forms of energy in rotating systems.
- Apply the concepts of torque and work to rotational motion.
- Analyze rolling motion and the motion of orbiting satellites.

Unit 7: Oscillations.

Exam Weighting: 5-8%.

Note: Just like Unit 6, the AP Physics 1 exam comprises very little content from this unit. This handbook will very briefly go through this unit.

7.1 DEFINING SIMPLE HARMONIC MOTION (SHM).

Simple Harmonic Motion (SHM): a type of periodic motion where the restoring force is directly proportional to the displacement and acts in the direction opposite to that of displacement.

The motion is sinsuodial in time.

The restoring force follows Hooke's Law: $F = - k\Delta x$

Example question 7.1: A mass m is attached to a spring with a spring constant k and set into SHM. If the amplitude of the motion is A, determine the maximum acceleration of the mass.

1. Identify variables.

$\Delta x = A$

2. Relate Newton's second law with Hooke's law.

$F = ma$

$F = - k\Delta x$

$ma = - k\Delta x$

3. Simplify

$ma = - kA$

$a_{max} = \frac{kA}{m}$

7.2 FREQUENCY AND PERIOD OF SHM.

Frequency and period are inversely proportional to each other.

Frequency (f): the number of cycles per unit time.

$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Period (T): the time it takes for one complete cycle of motion.

$$T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{L}{g}}$$

Example question 7.2: A pendulum has a length L and is displaced by a small angle θ. Derive the expression for its period T and explain the conditions under which this approximation holds. For small angles, the restoring force is approximately proportional to the displacement.

1. Identify the equation of motion.

$T = 2\pi\sqrt{\frac{L}{g}}$

2. Identify the conditions.

The period is independent of the mass and amplitude of the oscillation, depending only on the length of the pendulum and the acceleration due to gravity.

Note: Pay special attention to the conditions under which approximations like the small-angle approximation are valid.

7.3 REPRESENTING AND ANALYZING SHM.

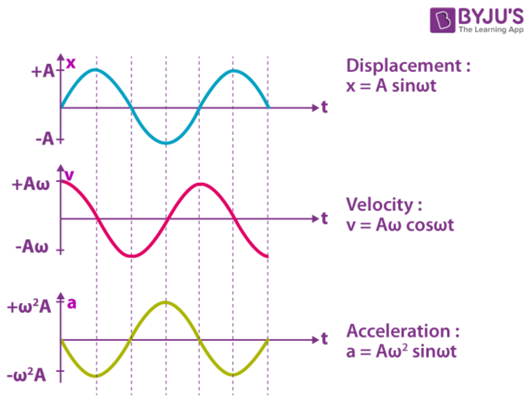


Figure 6.1: Position, velocity, and acceleration graphs.

7.4 ENERGY OF SIMPLE HARMONIC OSCILLATORS.

$E = \frac{1}{2}k\Delta x^2$ = constant

Energy oscillates between kinetic and potential forms.

Example question 7.3: A mass-spring system has a mass of 0.5 kg and a spring constant of 100 N/m. If the mass is displaced by 0.2 m from equilibrium, calculate the maximum velocity of the mass.

1. Identify the variables.

$m = 0.5\ kg$

$k = 100\ N/m$

$\Delta x = 0.2\ m$

$v_{max} = ?$

2. Relate these equations: $E = \frac{1}{2}k\Delta x^2$ and $K_{max} = \frac{1}{2}mv_{max}^2$.

$\frac{1}{2}k\Delta x^2 = \frac{1}{2}mv_{max}^2$

3. $\frac{1}{2}(100)(0.2)^2 = \frac{1}{2}(0.5)v_{max}^2$

$v_{max} = 2\ m/s$

Key Takeaways:

- Know how to find frequency and time period, and their relation to each other.
  - $f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$
  - $T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{L}{g}}$
- Master defining characteristics and equations of SHM.
- Be able to draw out position, velocity, and acceleration graphs in your head and on paper.

Unit 8: Fluids.

Exam Weighting: 10-15%.

Note: This unit is new for the 2024-2025 AP Physics 1 exam.

8.1 INTERNAL STRUCTURE AND DENSITY.

Density (ρ): fundamental property of fluids.

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

$Density = mass / Volume$

Most common units: mass per unit volume.

Example question 8.1: A metal block has a mass of 2 kg and a volume of 0.5 m³. Calculate its density and determine if it will float or sink in water.

1. Identify the variables.

$m = 2\, kg$

$V = 0.5\, m^3$

$\rho_{block} = ?$

2. Use this equation: $\rho = \frac{m}{V}$

$\rho_{block} = \frac{2}{0.5}$

$\rho_{block} = 4\, kg/m^3$

3. Compare with the density of water: $\rho_{water} = 1000\, kg/m^3$

$\rho_{block} < \rho_{water}$

The metal block will float in water.

8.2 PRESSURE.

Pressure (P): the force exerted per unit area.

Pascal's principle:

$P = \frac{F}{A}$

$Pressure = Force / Area$

$P_{small} = P_{large}$

Example question 8.2: A hydraulic press has a small piston with an area of 0.01 m² and a large piston with an area of 1 m². If a force of 100 N is applied to the small piston, calculate the force exerted by the large piston.

1. Identify the variables.

$A_{small} = 0.01\, m^2$

$A_{large} = 1\, m^2$

$F_{small} = 100\, N$

$F_{large} = ?$

2. Use Pascal's principle: $P_{small} = P_{large}$

$P_{small} = \frac{F_{small}}{A_{Small}} = \frac{100}{0.01} = 10000\, Pa$

3. Use Pascal's principle again: $P = \frac{F}{A}$

$F_{large} = P_{large} * A_{large}$

$10000 * 1 = 10000\, N$

8.3 FLUIDS AND NEWTON'S LAWS.

Archimedes' principle states that the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially, is equal to the weight of the fluid that the body displaces.

Buoyant Force: the upward force exerted by a fluid on a submerged object, described by Archimedes' principle.

$F_b = \rho_{fluid} * V_{displaced} * g$

$Buoyant\ Force\ =\ Density\ of\ the\ fluid\ *\ Volume\ of\ the\ fluid\ displaced\ *\ Acceleration\ due\ to\ gravity$

Example question 8.3: A cube of side length 0.1 m and density 500 kg/m³ is fully submerged in water. Calculate the buoyant force acting on the cube and determine if it will float or sink when released.

1. Identify the variables.

$V = (0.1)^3 = 0.001\, m$

$\rho_{cube} = 500\, kg/m^3$

$\rho_{water} = 1000\, kg/m^3$

$F_b = ?$

2. Use this equation to calculate the buoyant force: $F_b = \rho_{water} * V_{cube} * g$

$F_b = (1000)(0.001)(9.8)$

$F_b = 9.8\, N$

3. Calculate the weight of the cube by relating buoyant force and the force of gravity on the cube.

$W_{cube} = m_{cube} * g = \rho_{cube} * V_{cube} * g$

$W_{cube} = 500(0.001) * 9.8$

$W_{cube} = 4.9\, N$

4. Compare the buoyant force and weight of cube.

$W_{cube} < F_b$

The cube will float when released.

8.4 FLUIDS AND CONSERVATION LAWS.

Continuity Equation:

$A_1 v_1 = A_2 v_2$

A: Cross-sectional area

v: Fluid velocity

Bernoulli's Equation:

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

P: Pressure

ρ: Density

v: Velocity

g: Acceleration due to gravity

h: Height

Example question 8.4: Water flows through a pipe with a varying cross-sectional area. At point A, the cross-sectional area is 0.05 m² and the velocity is 2 m/s. At point B, the cross-sectional area is 0.02 m². Calculate the velocity of water at point B and the difference in pressure between points A and B if they are at the same height.

1. Identify the variables.

$A_A = 0.05\,m^2$

$v_A = 2\,m/s$

$A_B = 0.02\,m^2$

$\rho_{water} = 1000\,kg/m^3$

$v_B = ?$

$\Delta P_{A-B} = ?$

2. Use the continuity equation: $A_1 v_1 = A_2 v_2$:

$A_A v_A = A_B v_B$

$(0.05)(2) = (0.02)v_2$

$v_2 = 5\,m/s$

3. Apply Bernoulli's equation at the same height ($h_1 = h_2$).

$P_1 + \frac{1}{2}\rho {v_1}^2 = P_2 + \frac{1}{2}\rho {v_2}^2$

$P_A + \frac{1}{2}(1000)(2)^2 = P_B + \frac{1}{2}(1000)(v_B)^2$

$P_A - P_B = 10500\,Pa$

Note: Pay attention to the assumptions made in fluid problems, such as incompressible flow and negligible viscosity.

Key Takeaways:

- Know Pascal's principle: $P = \frac{F}{A}$
- Understand the fundamental properties of fluids, including density and pressure.
- Apply Newton's laws to fluid systems, including buoyant forces and hydraulic systems.
- Use continuity and Bernoulli's equations to analyze fluid flow and pressure changes.

0.4: Appendix.

Mechanics Symbols		
Symbol	Quantity	Units
a, a_t, a_c	acceleration, tangential acceleration, centripetal acceleration	m/s^2
$d, \Delta x, \Delta y$	displacement, displacement in the x direction, displacement in the y direction	m
$F_c, F_g, F_k, F_N, F_{ne}$	centripetal force, gravitational force, force of kinetic friction, normal force, net force	N
f, f_n	frequency, *n*th harmonic frequency	Hz
g	acceleration of gravity on a planet	m/s^2
k	spring constant	$\frac{N}{m}$
KE, ME, PE	kinetic energy, mechanical energy, potential energy	J
T	period of a pendulum	s
τ	torque	Nm
μ_k, μ_s	coefficient of kinetic friction, coefficient of static friction	
P	power	W
p	momentum	$kg * m/$
v, v_t	velocity, tangential speed	m/s
ω	angular speed	rad/s
λ	wavelength	m
W	work	J

SI Units	
ISQ Base Quantity	SI Base Unit
Time	second (s)
Length	meter (m)
Mass	kilogram (kg)
Force	newton (N)
Energy	joule (J)
Work	joule (J)
Power	watt (W)

Common SI Prefixes		
n	nano	10^{-9}
μ	micro	10^{-6}
m	milli	10^{-3}
c	centi	10^{-2}
d	deci	10^{-1}
k	kilo	10^{3}
M	mega	10^{6}
G	giga	10^{9}
T	tera	10^{12}

0.5: References.

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