

university physics 1 formula sheet

Mastering University Physics 1: Your Ultimate Formula Sheet Guide

university physics 1 formula sheet: a phrase that often conjures images of intense study sessions and the daunting task of memorizing critical equations. For many students embarking on their first university-level physics course, a comprehensive formula sheet is not just a study aid; it's a lifeline. This article aims to demystify the process of creating and utilizing such a sheet, offering detailed explanations of the fundamental concepts and equations you'll encounter in University Physics 1. We'll delve into the core areas of mechanics, including kinematics, dynamics, work, energy, momentum, rotational motion, and oscillations, providing a structured approach to understanding and applying these essential physics formulas. By the end of this guide, you'll have a clearer vision of what a robust physics 1 formula sheet should encompass and how to leverage it effectively for academic success.

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The Importance of a University Physics 1 Formula Sheet

A well-crafted university physics 1 formula sheet is more than just a collection of equations; it's a testament to your understanding of fundamental physical principles. In a course that lays the groundwork for all future physics studies, mastering these foundational equations is paramount. This sheet serves as a condensed reference, allowing you to quickly access the tools needed to solve a wide range of problems. It helps in organizing your thoughts during exams and problem-solving sessions, preventing the panic that can arise from searching for a forgotten formula. Moreover, the process of building the sheet itself is a powerful learning exercise, forcing you to review, understand, and categorize the core concepts of mechanics. A good formula sheet should encompass kinematics, Newton's laws, energy conservation, momentum, rotational motion, and simple harmonic motion – the pillars of introductory university physics.

Foundational Concepts in Kinematics

Kinematics is the branch of physics that describes motion without considering its causes. It's all about understanding how things move. This forms the bedrock of your university physics 1 journey.

Definitions and Units

Before diving into equations, it's crucial to be clear on the basic definitions and their standard SI units. These are the building blocks upon which all other concepts rest.

- **Position ($\vec{r}$ or x):** Location of an object. Unit: meters (m).
- **Displacement ($\Delta \vec{r}$ or Δx):** Change in position. $\Delta x = x_f - x_i$. Unit: meters (m).
- **Velocity ($\vec{v}$ or v):** Rate of change of position. Average velocity: $\vec{v}_{avg} = \Delta \vec{r} / \Delta t$. Instantaneous velocity: $\vec{v} = d\vec{r}/dt$. Unit: meters per second (m/s).
- **Speed:** Magnitude of velocity.
- **Acceleration ($\vec{a}$ or a):** Rate of change of velocity. Average acceleration: $\vec{a}_{avg} = \Delta \vec{v} / \Delta t$. Instantaneous acceleration: $\vec{a} = d\vec{v}/dt$. Unit: meters per second squared (m/s²).

One-Dimensional Motion

When motion occurs along a straight line, we simplify our analysis significantly. These equations are fundamental for solving problems involving objects moving forward, backward, up, or down.

For constant acceleration (a), the following kinematic equations are indispensable:

- $v_f = v_i + at$ (final velocity equals initial velocity plus acceleration times time)
- $\Delta x = v_i t + \frac{1}{2}at^2$ (displacement equals initial velocity times time plus one-half acceleration times time squared)
- $v_f^2 = v_i^2 + 2a\Delta x$ (final velocity squared equals initial velocity squared plus two times acceleration times displacement)
- $\Delta x = \frac{v_i + v_f}{2} t$ (displacement equals the average velocity times time)

Remember that v_i , v_f , a , and Δx are all vector quantities, meaning their direction matters. In one dimension, we often use signs (+ or -) to indicate direction.

Two-Dimensional Motion

Extending kinematics to two dimensions allows us to describe projectile motion and the movement of objects in planes. The key is to treat the horizontal and vertical components of motion independently, as they are not influenced by each other (neglecting air resistance).

For an object with initial velocity $\vec{v}_0$ at an angle θ with the horizontal, and constant acceleration $\vec{a}$:

- Initial velocity components: $v_{0x} = v_0 \cos \theta$, $v_{0y} = v_0 \sin \theta$.
- Equations for horizontal motion (assuming $a_x = 0$, no air resistance):
- $x = x_0 + v_{0x} t$
- Equations for vertical motion (under gravity, $a_y = -g$):
- $v_y = v_{0y} - gt$
- $y = y_0 + v_{0y} t - \frac{1}{2}gt^2$
- $v_y^2 = v_{0y}^2 - 2g(y - y_0)$

These equations are what allow us to calculate things like the range of a projectile or how long it takes to hit the ground.

Newton's Laws of Motion and Dynamics

Dynamics is the study of motion and its causes, primarily forces. Sir Isaac Newton's three laws of motion are the cornerstone of this field.

Newton's First Law: Inertia

Also known as the law of inertia, this law states that an object at rest stays at rest and an

object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force. This simply means objects tend to resist changes in their state of motion.

Newton's Second Law: Force and Acceleration

This is arguably the most important law for quantitative problem-solving. It states that the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

- The fundamental equation is $\sum \vec{F} = m\vec{a}$, where $\sum \vec{F}$ is the vector sum of all forces acting on the object, m is the mass of the object, and $\vec{a}$ is its acceleration.

This equation is a vector equation, meaning it applies independently to the x and y components of motion. Understanding how to identify all forces acting on an object (drawing free-body diagrams!) is critical for applying this law.

Newton's Third Law: Action-Reaction

This law states that for every action, there is an equal and opposite reaction. If object A exerts a force on object B, then object B exerts a force of equal magnitude and opposite direction on object A.

Crucially, these action-reaction forces act on different objects. For instance, when you push on a wall, the wall pushes back on you with the same force. This law is vital for understanding interactions between objects.

Friction

Friction is a force that opposes motion between surfaces in contact. There are two main types: static friction and kinetic friction.

- **Static friction (f_s):** Acts when surfaces are at rest relative to each other. It can vary in magnitude from zero up to a maximum value. $0 \leq f_s \leq \mu_s N$, where μ_s is the coefficient of static friction and N is the normal force.
- **Kinetic friction (f_k):** Acts when surfaces are sliding relative to each other. It is generally constant in magnitude. $f_k = \mu_k N$, where μ_k is the coefficient of kinetic friction.

Typically, $\mu_k < \mu_s$, meaning it's harder to get something moving than to keep it moving.

Work, Energy, and Power

This section delves into concepts that provide alternative ways to analyze motion, often

simplifying problems that would be complex using only Newton's laws.

Defining Work

Work is done when a force causes a displacement. In physics, it's a scalar quantity.

- For a constant force $\vec{F}$ acting over a displacement $\vec{d}$, the work done is $W = \vec{F} \cdot \vec{d} = Fd \cos \theta$, where θ is the angle between the force and displacement vectors.
- If the force is not constant or the path is curved, work is calculated using integration: $W = \int \vec{F} \cdot d\vec{r}$.

Work can be positive (force and displacement in the same general direction), negative (force and displacement in opposite directions), or zero (force perpendicular to displacement).

Kinetic Energy

Kinetic energy (K) is the energy an object possesses due to its motion.

- $K = \frac{1}{2}mv^2$, where m is mass and v is speed.

The **Work-Energy Theorem** is a crucial link: the net work done on an object equals the change in its kinetic energy. $W_{\text{net}} = \Delta K = K_f - K_i$.

Potential Energy

Potential energy (U) is stored energy that an object possesses due to its position or configuration.

- **Gravitational Potential Energy:** $U_g = mgh$, where m is mass, g is acceleration due to gravity, and h is height above a reference point.
- **Elastic Potential Energy (for a spring):** $U_s = \frac{1}{2}kx^2$, where k is the spring constant and x is the displacement from the spring's equilibrium position.

Forces that do work that can be recovered by reversing the process are called conservative forces. Gravity and the spring force are conservative. Friction is a non-conservative force.

Conservation of Energy

One of the most powerful principles in physics, the conservation of mechanical energy

states that in the absence of non-conservative forces, the total mechanical energy of a system remains constant.

- Total Mechanical Energy (E) = Kinetic Energy (K) + Potential Energy (U).
- $E_{\text{initial}} = E_{\text{final}}$, which translates to $K_i + U_i = K_f + U_f$.

When non-conservative forces (like friction) are present, the work done by these forces changes the total mechanical energy: $W_{\text{nc}} = \Delta E = E_f - E_i$.

Power

Power (P) is the rate at which work is done or energy is transferred.

- Average Power: $P_{\text{avg}} = W / \Delta t$.
- Instantaneous Power: $P = dW/dt$.
- Another useful form for constant force: $P = \vec{F} \cdot \vec{v}$.

The SI unit for power is the watt (W), which is one joule per second (J/s).

Momentum and Collisions

Momentum is a concept related to an object's mass and velocity, and its conservation is vital for analyzing interactions, especially collisions.

Linear Momentum

Linear momentum ($\vec{p}$) is a vector quantity defined as the product of an object's mass and its velocity.

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

Newton's second law can be rephrased in terms of momentum: the net force acting on an object is equal to the rate of change of its momentum. $\sum \vec{F} = d\vec{p}/dt$. This is a more general form that applies even when mass is changing.

Impulse

Impulse ($\vec{J}$) is the change in momentum of an object. It is also defined as the average force applied to an object multiplied by the time interval over which it is applied.

- $\vec{J} = \Delta \vec{p} = \vec{p}_f - \vec{p}_i$.

- $\vec{J} = \vec{F}_{\text{avg}} \Delta t$.

Therefore, $\vec{F}_{\text{avg}} \Delta t = m\vec{v}_f - m\vec{v}_i$. Impulse is a useful concept for analyzing the effect of brief, large forces, such as those in collisions.

Conservation of Momentum

If the net external force on a system is zero, then the total linear momentum of the system is conserved. This is a fundamental principle in physics.

- For a system of particles, $\sum \vec{p}_{\text{initial}} = \sum \vec{p}_{\text{final}}$.

This means that even if objects within the system interact strongly (like during a collision), their total momentum before the interaction is equal to their total momentum after the interaction, provided no external forces are doing significant work.

Types of Collisions

Collisions are a primary application of momentum conservation. They are categorized based on whether kinetic energy is conserved.

- **Elastic Collisions:** Both momentum and kinetic energy are conserved. This is an idealized scenario.
- **Inelastic Collisions:** Momentum is conserved, but kinetic energy is not. Some kinetic energy is converted into other forms, like heat or sound.
- **Perfectly Inelastic Collisions:** A special case of inelastic collisions where the colliding objects stick together after the collision. Momentum is conserved, but kinetic energy is lost.

Rotational Motion

This area extends the concepts of linear motion to objects that rotate around an axis.

Angular Kinematics

Just as we have linear displacement, velocity, and acceleration, we have their angular counterparts.

- **Angular Position (θ):** Angle of rotation, measured in radians (rad).
- **Angular Velocity (ω):** Rate of change of angular position. $\omega = d\theta/dt$. Unit: rad/s.

- **Angular Acceleration (α):** Rate of change of angular velocity. $\alpha = d\omega/dt$. Unit: rad/s^2 .

For constant angular acceleration, analogous kinematic equations exist:

- $\omega_f = \omega_i + \alpha t$
- $\Delta \theta = \omega_i t + \frac{1}{2} \alpha t^2$
- $\omega_f^2 = \omega_i^2 + 2\alpha \Delta \theta$

The linear (tangential) quantities are related to angular quantities by the radius (r): $v_t = r\omega$, $a_t = r\alpha$. Note that tangential acceleration (a_t) is the component of linear acceleration tangent to the circular path. Centripetal acceleration ($a_c = v^2/r = r\omega^2$) is directed towards the center and is responsible for changing the direction of the velocity.

Torque and Rotational Dynamics

Torque ($\vec{\tau}$) is the rotational equivalent of force. It is what causes an object to rotate or change its rotational motion.

- For a force $\vec{F}$ applied at a distance $\vec{r}$ from the pivot point, the torque is $\vec{\tau} = \vec{r} \times \vec{F}$. The magnitude is $\tau = rF \sin \theta$, where θ is the angle between $\vec{r}$ and $\vec{F}$.
- Newton's second law for rotation: $\sum \vec{\tau} = I\vec{\alpha}$, where I is the moment of inertia and α is the angular acceleration.

Torque is the "twist" that makes things spin or stop spinning. Just like net force causes linear acceleration, net torque causes angular acceleration.

Rotational Inertia

Moment of inertia (I) is the rotational equivalent of mass. It is a measure of an object's resistance to changes in its rotational motion. It depends on the mass of the object and how that mass is distributed relative to the axis of rotation.

- For a point mass m at a distance r from the axis of rotation, $I = mr^2$.
- For a collection of point masses, $I = \sum m_i r_i^2$.
- For continuous objects, I is found by integration: $I = \int r^2 dm$.

Different shapes have different formulas for moment of inertia (e.g., solid cylinder, hollow

sphere, rod). These are typically provided in textbooks or on formula sheets.

Angular Momentum

Angular momentum ($\vec{L}$) is the rotational equivalent of linear momentum.

- For a point mass, $\vec{L} = \vec{r} \times \vec{p} = \vec{r} \times (m\vec{v})$.
- For a rigid body rotating about a fixed axis, $L = I\omega$.

The conservation of angular momentum states that if the net external torque on a system is zero, its total angular momentum remains constant ($\Delta \vec{L} = 0$). This is why a figure skater spins faster when they pull their arms in.

Simple Harmonic Motion (SHM)

Simple harmonic motion is 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. It's ubiquitous in nature.

Characteristics of SHM

The defining characteristic of SHM is that the acceleration is proportional to the negative of the displacement from equilibrium.

- The restoring force is often of the form $F = -kx$ (Hooke's Law).
- This leads to acceleration $a = -kx/m = -\omega^2 x$, where $\omega = \sqrt{k/m}$ is the angular frequency.
- The angular frequency ω is related to the period (T) and frequency (f) by: $\omega = 2\pi f = 2\pi/T$.

The motion is sinusoidal, often described by $x(t) = A \cos(\omega t + \phi)$ or $x(t) = A \sin(\omega t + \phi)$, where A is the amplitude and ϕ is the phase constant.

Mass-Spring System

A classic example of SHM is a mass attached to a spring.

- Angular frequency: $\omega = \sqrt{k/m}$.
- Period: $T = 2\pi \sqrt{m/k}$.
- Frequency: $f = \frac{1}{2\pi} \sqrt{k/m}$.

The kinetic and potential energies oscillate between maximum values, and the total mechanical energy is conserved (if no damping).

Pendulums

A simple pendulum (a mass suspended by a string) also exhibits SHM for small angles of oscillation.

- For small angles (θ small), the period is: $T = 2\pi \sqrt{L/g}$, where L is the length of the pendulum and g is the acceleration due to gravity.
- Note that the period of a simple pendulum does not depend on the mass or the amplitude (for small angles).

Tips for Creating and Using Your Formula Sheet

Crafting an effective university physics 1 formula sheet is an art form. It's about more than just copying equations; it's about understanding their context and relationships.

- **Organize by Topic:** Group formulas logically under headings like Kinematics, Newton's Laws, Energy, etc. This makes it easier to find what you need quickly.
- **Define Symbols:** Briefly state what each symbol represents and its units. This prevents confusion, especially when dealing with multiple variables.
- **Include Key Concepts/Diagrams:** Don't just list formulas. Add small notes about when to use them or quick sketches of free-body diagrams or energy level diagrams.
- **Write it by Hand:** The act of writing out the formulas helps with memorization and deeper understanding. It forces you to actively recall and process the information.
- **Test Your Sheet:** Before an exam, practice solving problems only using your formula sheet. This will reveal any gaps or areas where you struggle to find the right equation.
- **Focus on Understanding, Not Just Memorization:** The formula sheet is a tool. True mastery comes from understanding the underlying physics principles and how to apply them, not just memorizing symbols.
- **Keep it Concise:** Avoid unnecessary clutter. Stick to the essential formulas you'll need. A massive, unorganized sheet can be counterproductive.

Your formula sheet should be a living document, evolving as you progress through the course. Add new insights, refine existing entries, and tailor it to your specific learning style and the emphasis of your course.

Q: What are the most critical topics to include on a University Physics 1 formula sheet?

A: The most critical topics generally include kinematics (1D and 2D), Newton's Laws of Motion, Work, Energy, and Power, Linear Momentum and Collisions, Rotational Motion (kinematics, dynamics, angular momentum), and Simple Harmonic Motion. These form the core of most introductory physics courses.

Q: Should I include derivations on my formula sheet?

A: It's generally not recommended to include full derivations on your formula sheet, as this would make it too long and defeat its purpose as a quick reference. Focus on the final formulas and perhaps a brief note on the conditions under which they apply.

Q: How can I ensure I'm using my formula sheet correctly during an exam?

A: Practice is key! Work through numerous practice problems using only your formula sheet to simulate exam conditions. This will help you quickly locate the relevant equations and understand their applications.

Q: What is the difference between vector and scalar formulas on a physics sheet?

A: Scalar formulas deal with quantities that have only magnitude (like speed, mass, energy), while vector formulas deal with quantities that have both magnitude and direction (like velocity, force, momentum). It's important to note which ones are vectors and use appropriate notation (like arrows over symbols).

Q: Is it better to have one large formula sheet or several smaller ones for different topics?

A: This depends on your professor's rules and your personal preference. Many students find a single, well-organized sheet more efficient during exams. However, if your professor allows multiple sheets, breaking them down by topic can sometimes help with organization and speed.

Q: How do I determine the correct formula for a complex problem on my exam?

A: First, identify what the problem is asking for and what information is given. Then, think

about the fundamental physics principles involved (e.g., motion, forces, energy). Scan your formula sheet for equations that relate the knowns to the unknowns within that principle. Often, drawing a diagram (like a free-body diagram) can help clarify which forces or quantities are relevant.

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