

General Physics I–Honors: PHYS 101H (Fall 2023)
Quiz 1

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Instructions

In this quiz you will apply your understanding of dimensional analysis and problem solving techniques in physics. Read the following instructions carefully.

DO NOT TURN OVER THIS SHEET UNTIL INSTRUCTED.

Please write your name on the quiz.

You have ten minutes to attempt all three multiple-choice questions in this quiz. Indicate your answer clearly by **circling** the correct option.

You may use electronic calculators.

You may **not** use:

- any formula sheets or notes;
- electronic devices, including phones, tablets and laptops (unless previously arranged);
- textbooks or other reference resources;
- course notes or slides.

You may (or may not) find the following table of Taylor series helpful:

$$\begin{aligned}\frac{1}{1+x} &= \sum_{n=0}^{\infty} x^n &&= 1 - x + x^2 - x^3 + \dots \\ \ln(1+x) &= \sum_{n=1}^{\infty} (-1)^{n-1} \frac{x^n}{n} &&= x - \frac{x^2}{2} + \frac{x^3}{3} + \dots \\ e^x &= \sum_{n=0}^{\infty} \frac{x^n}{n!} &&= 1 + x + \frac{x^2}{2} + \frac{x^3}{6} + \dots \\ \sin x &= \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{(2n+1)!} &&= x - \frac{x^3}{6} + \frac{x^5}{120} + \dots \\ \cos x &= \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n}}{(2n)!} &&= 1 - \frac{x^2}{2} + \frac{x^4}{24} + \dots \\ \arctan x &= \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{2n+1} &&= x - \frac{x^3}{3} + \frac{x^5}{5} + \dots \\ (1+x)^m &= \sum_{n=0}^{\infty} \binom{m}{n} x^n &&= 1 + mx + \frac{m(m+1)}{2} x^2 + \dots\end{aligned}$$

Question 1**4pts**

The Planck length is a quantity that characterizes the distance at which both quantum effects and gravitational effects must be considered. In other words, the Planck length tells us the distance at which we must have a quantum theory of gravity to be able to correctly describe the physics that happens at those distances (we have several candidate theories, but none that have been experimentally verified, yet). The Planck length depends on three fundamental physical constants. Each of these constants is associated with one of the three theories that form the pillars of modern physics. These are: Planck's constant, $\hbar = 1.05 \times 10^{-34}$ kg m²/s, which characterizes quantum mechanics; the gravitational constant, $G = 6.67 \times 10^{-11}$ m³/(kg s²), which characterizes general relativity, the theory of gravity; and the speed of light, $c = 3.0 \times 10^8$ m/s, which is associated with special relativity. Which combination of these fundamental constants gives the correct expression for the Planck length?

- (a) $\sqrt{\hbar G/c^2}$; (b) $\sqrt{\hbar G/c^3}$; (c) $\sqrt{\hbar G/c^4}$.

Question 2**3pts**

The equation for the period of a simple pendulum undergoing oscillations is usually given as

$$T_0 = 2\pi\sqrt{\frac{\ell}{g}},$$

where ℓ is the length of the pendulum and g is the acceleration due to gravity. In fact, this equation is only valid when the pendulum is swinging with a small angle, $\theta \lesssim 6^\circ$. For larger angles, a different expression is valid. Which of the following expressions could be the correct equation for the period, T , of a simple pendulum for angles of oscillation up to $\theta \approx 90^\circ$?

- (a) $T = 2\pi\sqrt{\frac{\ell}{g}} \cdot \frac{2}{1+\cos(\theta/2)}$; (b) $T = 2\pi\sqrt{\frac{\ell}{g}} \cdot \frac{2}{1+\sin(\theta/2)}$; (c) $T = 2\pi\sqrt{\frac{\ell}{g}} \cdot \frac{2}{1+\tan(\theta/2)}$.

Question 3**3pts**

Which of the following options is a good estimate for the number of heartbeats in an adult human's lifetime?

- (a) 2×10^6 ; (b) 2×10^9 ; (c) 2×10^{12} .