1. [40 points] **Short answer questions**

4
    (a) True or False? *Justify your answers.*

      (i) **(T/F)** No experiment inside an isolated sealed lab in space can determine its acceleration.

      (ii) **(T/F)** No experiment inside an isolated sealed lab in space can determine its orientation.

      (iii) **(T/F)** No experiment inside an isolated sealed lab in space can determine its velocity.

5
    (b) If the photoelectric effect is observed for one metal, can you conclude that the effect will also be observed for another metal under the same conditions? Explain.

7
    (c) What is a scanning tunneling microscope (STM)? Explain how it works.

6
    (d) Write down (a) the time-independent Schrödinger equation and (b) the time-dependent Schrödinger equation for a free particle of mass m moving in one dimension.

8
    (e) A particle is described by the following wavefunction:

$$\psi = 0.9\varphi_1 + 0.4\varphi_2 + c_3\varphi_3,$$

    where φ_1, φ_2 and φ_3 are orthonormal wavefunctions. Use the normalization condition for ψ to calculate the constant c_3.

10
    (f) The figures below (Fig. 1) show normalized real wavefunctions at a certain time, plotted as $\psi(x)$ versus x, for a quantum particle confined to the one-dimensional region $-1 \leq x \leq 1$:

      (i) Which wavefunction (A, B, or C) will yield the largest expectation value of the position $\langle x \rangle$? Briefly give your reason.

      (ii) Which wavefunction (A, B, or C) will yield the largest value for $\langle x^2 \rangle$? Briefly give your reason.
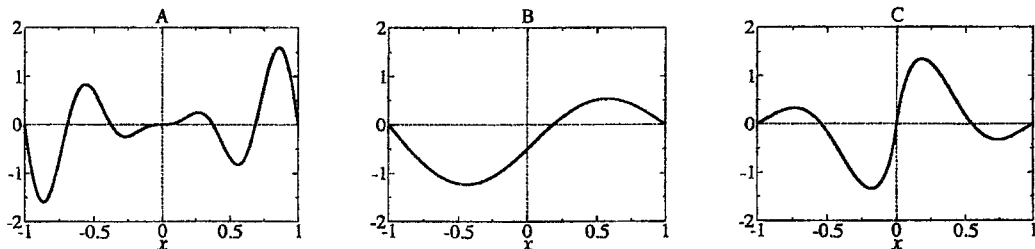

Fig. 2

考 試 科 目	近代物理	所　別	應用物理所	考試時間	3 月 1 日(日) 第二節

2. [20 points] **Relativity**

   (a) Two spaceships approach each other, each moving with the same speed as measured by an observer on the Earth. If their relative speed is 0.70c, what is the speed of each spaceship?

   (b) How fast and in what direction must galaxy A be moving if an absorption line found at 550 nm (green) for a stationary galaxy is shifted to 450 nm (blue) for A?

3. [40 points] **Quantum particle in a box**

   Consider a particle in a one-dimensional infinite square well of length L.

   (a) At time t the particle is known to be in the ground state. Calculate the probability that this particle will be found in the middle half of the well, that is, between $x = L/4$ and $x = 3L/4$.

   (b) Assume that the particle is described at time $t = 0$ by a wavefunction that is a superposition of the ground state ($\varphi_1(x)$) and the first excited state ($\varphi_2(x)$) of the well:

   $$\Psi(x, t = 0) = \frac{1}{\sqrt{2}}\left[\varphi_1(x) + \varphi_2(x)\right],$$

   where $\varphi_1(x)$ and $\varphi_2(x)$ are normalized.

   i. Find $\Psi(x,t)$ at any later time $t > 0$.

   ii. Calculate the expectation value of the energy for the particle at any time.

   iii. Show that the average particle position $\langle x \rangle$ oscillates with time as

   $$\langle x \rangle = x_0 + A\cos(\omega t)$$

   where x_0 is the mean position and A is the amplitude of oscillation. Determine the angular frequency ω.

備　　註	一、作答於試題上者，不予計分。 二、試題請隨卷繳交。