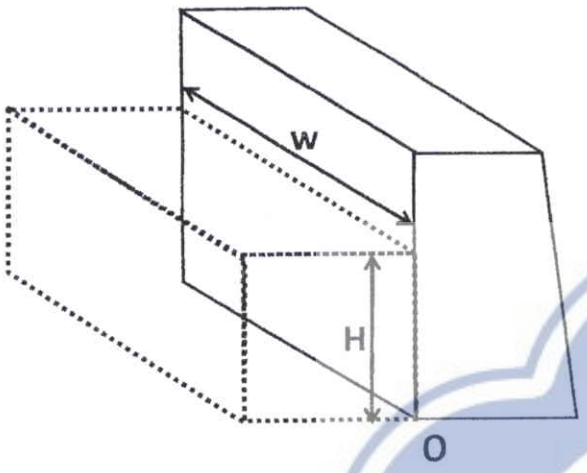
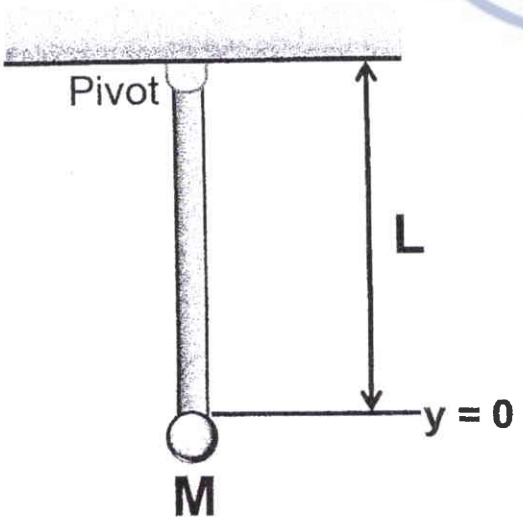
考試科目	普通物理	系所別	應用物理研究所	考試時間	2 月 8 日(六) 第 2 節

1. **(16%)** Water is filled to a height H behind a dam of width w. (a) Determine the resultant force exerted by the water on the dam. (b) Determine the total torque exerted by the water behind the dam about a horizontal axis through O.



2. **(16%)** A small ball of mass $2M$ is attached to the end of a uniform rod of mass M and length L that is pivoted at the top. When the ball and rod starts to oscillate for small displacements from equilibrium about the pivot, (a) determine the moment of inertia of the ball and rod system about the pivot. (b) Calculate the distance between pivot and center of mass for the ball and rod system. (c) Show that oscillation of the ball and rod system is simple harmonic motion. (d) Calculate the frequency of oscillation. (Note, the moment of inertia of rod at center is $I_{CM} = ML^2/12$. You can use $\tau = I\alpha$ to deduce the equation of simple harmonic motion in physical pendulum $d^2x/dt^2 = -w^2 x$)



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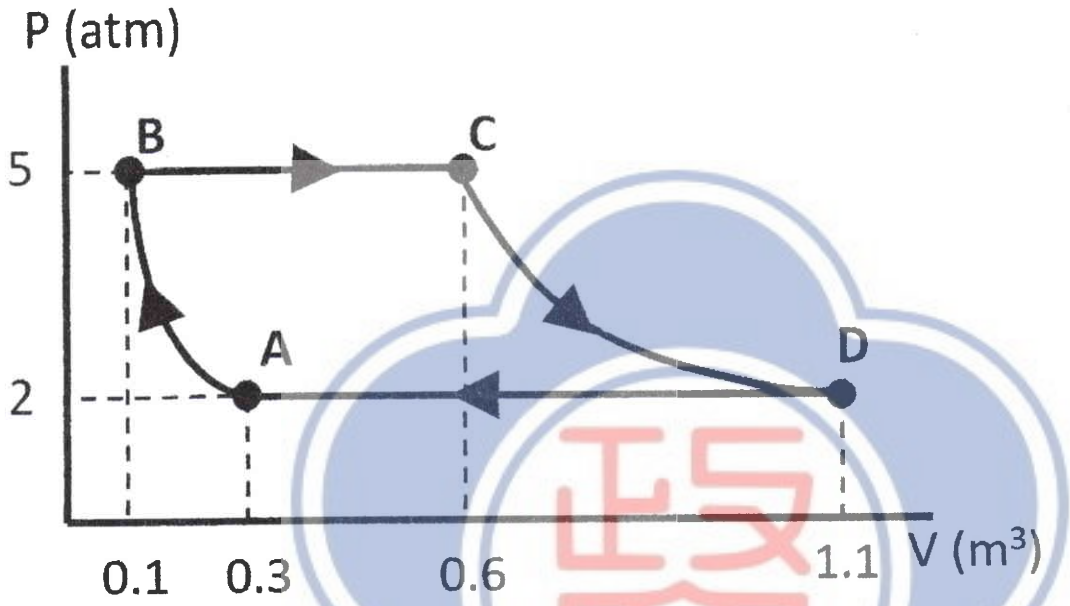
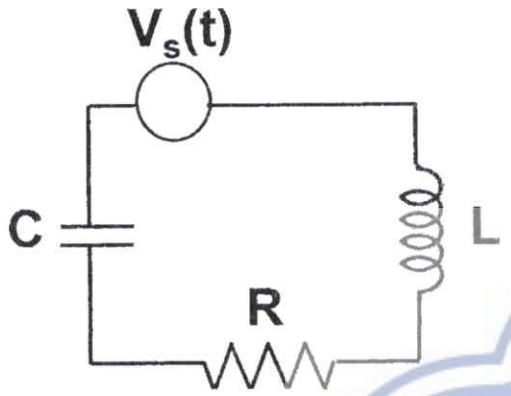
3. **(16%)** A sample of an ideal gas goes through the process shown in the figure. From *A* to *B*, the process is adiabatic; from *B* to *C*, it is isobaric with 82 kJ of energy entering the system by heat; from *C* to *D*, the process is isothermal; and from *D* to *A*, it is isobaric with 91 kJ of energy leaving the system by heat. Determine the difference in internal energy from A to B. (Note: $1\text{atm} = 1.013 \times 10^5\ Pa$ and $E_{int,ab} = Q_{ab} + W_{ab} = Q_{ab} - PV_{ab}$)



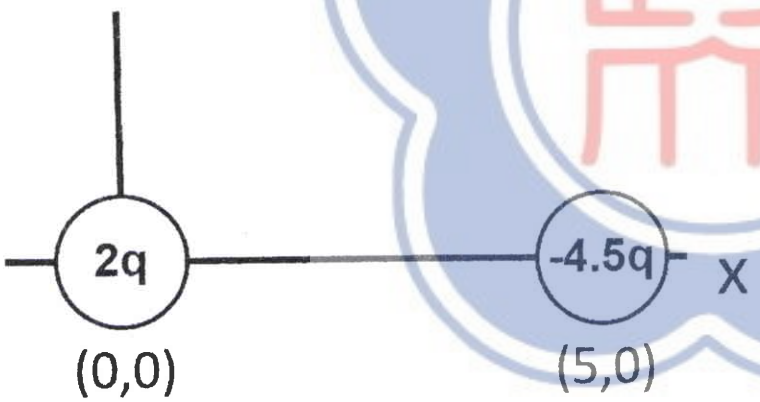
4. **(16%)** A plane electromagnetic sinusoidal wave propagating in the z direction. Suppose the frequency is 3×10^{14} Hz and the intensity is 1370 W/m^2. Calculate (a) the wavelength of the wave (b) the max amplitude of electrical field in the EM wave, (c) the max amplitude of magnetic field in the EM wave. (d) Write an expression for magnetic field *B(x,t)* with numerical values (Note the intensity of EM wave is the average of poyting vector;$\vec{S} = \vec{E} \times \vec{B}/u_0$; $u_0 = 4\pi \times 10^{-7}\ N/A^2$; $c = 3 \times 10^8\ m/s$)

考 試 科 目	普通物理	系 所 別	應用物理研究所	考 試 時 間	2 月 8 日（六）第 2 節

5. **(18%)** A sinusoidal voltage $v_s(t) = 15\sin 100t$, where Δv is in volts and t is in seconds, is applied to a series RLC circuit with $L = 100$ mH, $C = 100.0\ \mu$F, and $R = 120.0\ \Omega$. What is the impedance of (a) inductance, (b) capacitance, (c) resistance, (d) the circuit? (e) What is the maximum current? (f) What is the phase angle for current.



6. **(18%)** A particle with charge $+2q$ is at the origin. A particle with charge $-4.5q$ is at $x = 5.00$ m on the x axis. (a) For what finite value(s) of x is the electric field zero? (b) For what finite value(s) of x is the electric potential zero?



備 註	一、作答於試題上者，不予計分。 二、試題請隨卷繳交。

考試科目	近代物理	系所別	應用物理研究所	考試時間	2月8日(六) 第三節

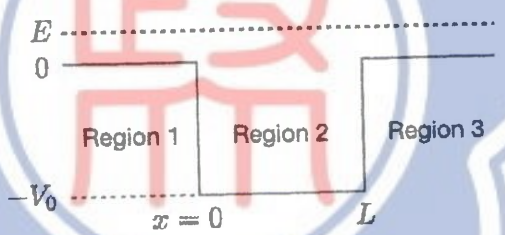
1. [*50 points*] **Short answer questions**

[6] (a) If a container has volume V' in its own rest frame, S', what is its volume as measured by an observer in S, with respect to which it is moving at high speed v?

[6] (b) Particle X_1 of mass m_1 is moving with speed $v_1 > 0.5c$ and kinetic energy K_1. It collides with particle X_2 of mass m_2 that is initially at rest. The collision produces only a new particle X_3 of mass m_3 and kinetic energy K_3 (that is, $X_1 + X_2 \rightarrow X_3$). Is m_3 greater than, less than, or equal to the sum of $m_1 + m_2$? *Explain your answer.*

[6] (c) Let E represent the average energy of spin-1/2 electrons in a certain block of metal at a temperature of 0 K. Now suppose the electrons have spin 1 instead of spin 1/2. Would you expect the average energy of the spin = 1 electrons in an otherwise identical block of metal at 0 K to be greater than, the same as, or less than the energy E? *Explain your answer.*

[6] (d) A matter wave of energy $E > 0$ and wave number k is incident from the left on a potential well of width L and depth V_0. The top of the well is at zero energy and the bottom of the well is at $-V_0$, as shown in the figure below. Write down the spatial part of the wave function in Region 3.



[6] (e) Please give an approximate value for each of the items below (2 points each).

(i) Energy (in units of eV) of a photon of visible light.

(ii) Diameter of an atom.

(iii) Diameter of a nucleus.

[10] (f) Is $\psi(x,t) = A\sin(kx - \omega t)$ an acceptable solution to the time-dependent Schrödinger wave equation? *Explain.*

[10] (g) The resistivity of most metals increases with increasing temperature, whereas the resistivity of a semiconductor decreases with increasing temperature. What explains this difference in behavior?

備註	一、作答於試題上者，不予計分。 二、試題請隨卷繳交。

考試科目	近代物理	系所別	應用物理研究所	考試時間	2月 8日(六) 第三節

2. [*15 points*] **Molecular Energy Levels**
The vibrational energy levels of a certain diatomic molecule are given by $E_n = \hbar\omega(n + 1/2)$, where n is an integer and $\hbar\omega = 0.124\,\text{eV}$. (Note that $hc = 1240\,\text{eV·nm}$.)

[5] (a) What is the energy (in units of eV) of the longest-wavelength photon that can be emitted by transitions between vibrational states of this molecule?

[5] (b) What would the wavelength of this photon be?

[5] (c) Considering whatever value you found for part (b), is this wavelength represent photons in the visible, infrared, or ultraviolet?

3. [*15 points*] **Stern-Gerlach experiment**
In a Stern-Gerlach type of experiment, the magnetic field varies with distance in the z direction according to $dB_z/dz = 1.4\,\text{T/mm}$. The silver atoms travel a distance $x = 3.5\,\text{cm}$ through the magnet. The most probable speed of the atoms emerging from the oven is $v = 750\,\text{m/s}$. Find the separation of the two beams as they leave the magnet. The mass of a silver atom is $1.8 \times 10^{-25}\,\text{kg}$, and its magnetic moment is about 1 Bohr magneton ($\simeq 9.27 \times 10^{-24}\,\text{J·T}^{-1}$).

4. [*20 points*] **Particle on a ring**
We consider a particle with mass m.

[5] (a) Write down the time-independent Schrödinger equation for this particle confined to move on a circle of radius R.

[15] (b) The wave functions must be single-valued functions on the circle, i.e. the solutions to the Schrödinger equation must satisfy the condition: $\psi(x) = \psi(x + 2\pi R)$. Find the energy eigenvalues.

備註	一、作答於試題上者，不予計分。 二、試題請隨卷繳交。