

考 試 科 目	普通物理 (一)	所 別	應用物理	816> 8163	考 試 時 間	3 月 6 日 (星期六) 第 3 節
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1. According to the sound level shown in Table 1, calculate the sound intensity produced by rock concert. (10 points)

Table 1

Source of Sound	β (dB)
Nearby jet airplane	150
Jackhammer, machine gun	130
Siren, rock concert	120
Subway, power mower	100
Busy traffic	80
Vacuum cleaner	70
Normal conversation	50
Mosquito buzzing	40
Whisper	30
Rustling leaves	10
Threshold of hearing	0

2. Briefly describe the operation principle of Atomizer shown in Figure 1. (10 points)

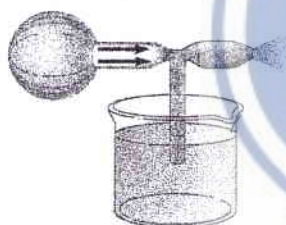


Figure 1 _____

3. Using Figure 2 to briefly describe the Merry-Go-Round experiment. (10 points)

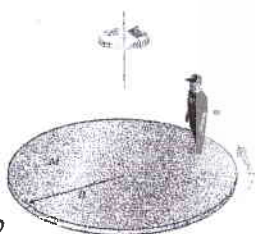


Figure 2 _____

4. The potential energy associated with the force between two neutral atoms in a molecule can be modeled by the Lennard-Jones potential energy function $U(x)$ (shown in Figure 3), where x is the separation of the atoms. Write down the criterion for the existence of stable equilibrium. (10 points)

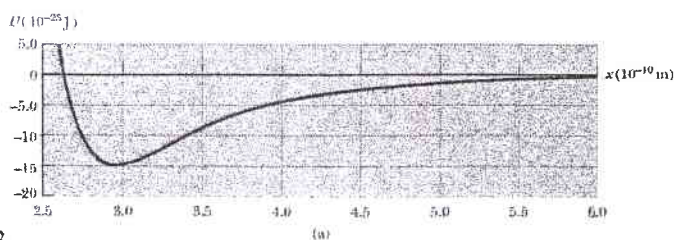


Figure 3

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5. A small sphere of mass m is attached to the end of a cord of length R and sent into motion in a vertical circle about a fixed point O as illustrated in Figure 4. What speed would the ball have as it passes over the top of the circle if the tension in the cord goes to zero instantaneously at this point? (10 points)

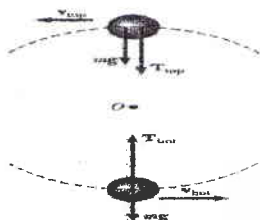


Figure 4

6. If an engine operates between 320°C and 32°C , what is its maximum thermodynamic efficiency? (10 points)
7. Find the entropy change of a system that undergoes a reversible, adiabatic process. (10 points)
8. Figure 5 illustrates amplitude versus frequency for a damped oscillator when a periodic driving force is present. Explain the physical meaning of the "quality factor" using these resonance curves. (10 points)

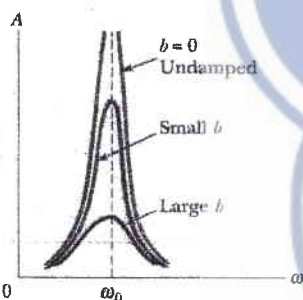


Figure 5

9. Briefly describe the first experiment (shown in Figure 6) to measure the universal gravitational constant G by Henry Cavendish in 1798. (10 points)

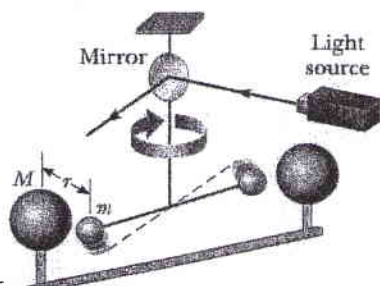


Figure 6

10. A middle C on a piano has a fundamental frequency of 262 Hz . What are the next two harmonics of this string? (10 points)

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1. [20 points] Short Answer Questions

- (a) What emit electromagnetic radiation?
- (A) steady electric currents
(B) rotating electric charges
(C) oscillating electric dipoles
- (b) Which has more energy, a photon of ultraviolet radiation or a photon of infrared radiation?
- (c) An x-ray photon is scattered by an electron. What happens to the frequency of the scattered photon relative to that of the incident photon?
- (d) What is a scanning tunneling microscope (STM)? Explain how it works.

2. [12 points] Electrostatics

A spherically symmetric charge distribution with total charge Q has charge density $\rho \propto 1/r$ for $r < R$ and $\rho = 0$ otherwise. Find the electric field and the electric potential everywhere in space (for $r \leq R$ and $r > R$). Take the potential to be zero at $r = \infty$.

3. [12 points] Maxwell's equations

- (a) A physicist claims to have found magnetic field lines as shown in Fig. 1. Is this finding consistent with Maxwell's equations? Justify your answer.

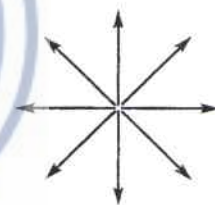


Fig. 1

- (b) Write the continuity equation expressing (local) charge conservation. Explain why the original form of Ampère's law, which does not include the displacement current term, contradicts the continuity equation.

4. [9 points] Polarization of Light

Consider two beams of light, (A) and (B), described as follows:

(A) a beam of fully linearly polarized light with the polarization direction making an angle of 45° with the vertical axis (the y axis); (B) an equal mixture of vertically polarized light (polarized in y) and horizontally polarized light (polarized in x).

How would you design an experiment to distinguish these two beams?

5. [10 points] Interference

Two waves of the same frequency ω are described by

$$\mathbf{E}_1(\mathbf{r}, t) = \mathbf{E}_0 e^{i(\mathbf{k}_1 \cdot \mathbf{r} - \omega t + \phi_1)}$$

$$\mathbf{E}_2(\mathbf{r}, t) = \mathbf{E}_0 e^{i(\mathbf{k}_2 \cdot \mathbf{r} - \omega t + \phi_2)},$$

where the amplitude $\mathbf{E}_0$ and the wave vectors $\mathbf{k}_1, \mathbf{k}_2$ are constant real vectors. Determine the condition for constructive interference when the two waves are superposed.

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6. [15 points] Relativity

- (a) State the postulates upon which Einstein based his special theory of relativity.
- (b) Maxwell's wave equation for the z -component of an electric field, E_z , propagating in the x -direction is

$$\frac{\partial^2 E_z(x, t)}{\partial x^2} - \frac{1}{c^2} \frac{\partial^2 E_z(x, t)}{\partial t^2} = 0,$$

where c is the speed of light. Is this equation invariant under a Galilean transformation to a reference frame moving with relative speed v in the x direction? Clearly show how you derive your answer.

7. [12 points] Quantum Physics

The figures below (Fig. 2) show normalized real wave functions at a certain time, plotted as $\psi(x)$ versus x , for a quantum particle confined to the one-dimensional region $-1 \leq x \leq 1$:

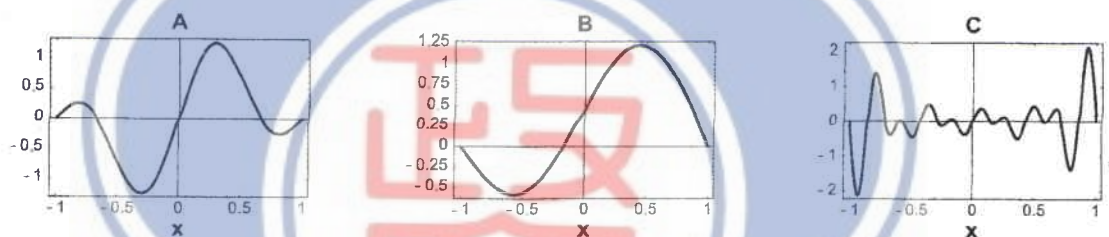


Fig. 2

- (a) Which wave function (A, B, or C) will yield the largest expectation value of the position $\langle x \rangle$? Briefly give your reason.
- (b) Which wave function (A, B, or C) will yield the largest value for $\langle x^2 \rangle$? Briefly give your reason.

8. [10 points] Prerequisite Mathematics

- (a) Diagonalize the following matrix:

$$\begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}.$$

- (b) Consider the differential equation

$$\frac{d^2 f(x)}{dx^2} + k^2 f(x) = 0, \quad \text{with } k > 0,$$

which satisfies the boundary conditions:

$$f(0) = f(\pi) = 0.$$

Find the condition for k such that this boundary value problem has a non-zero solution.