Name ______________________________

Student No. ________________________

ARTS & SCIENCE 2D06 DR. A.A. Chen

DAY CLASS
DURATION OF EXAMINATION: 3 hours
MCMASTER UNIVERSITY FINAL EXAMINATION April 2014

THIS EXAMINATION PAPER INCLUDES **14** PAGES AND **15** QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

Special Instructions:

— Use of any electronic calculator is allowed.
— Write all answers on the exam paper itself.
— At the back there is a scratch page and a memory sheet of formulae. Hand this page in with the rest of your exam paper.
— Mark values are given beside each question.
— Complete steps must be explicitly written down to earn full marks on any question.

Question	Mark	Max	Question	Mark	Max
A1		3	B1		5
A2		3	B2		5
A3		3	B3		5
A4		3	B4		5
A5		3	B5		5
A6		3	B6		5
A7		3	B7		5
A8		3			
			TOTAL		44

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PART A: Do all of the following questions in part A.

[3] A1. A brick of unknown material weighs 5 N in air and 4.55 N when submerged in water. What is the density of the material?

[3] A2. Consider a 0.25-kg harmonic oscillator that has a total energy of 8.7 J. If the maximum oscillation amplitude is 20.0 cm, what is the oscillation frequency?

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[3] A3. A 0.492-m string is clamped at both ends. If the lowest standing-wave frequency in the string is 326 Hz, calculate the speed of the wave.

[3] A4. Laser light of wavelength 633 nm passes through a circular hole, and is detected on a screen located 4.0 m behind the hole. The width of the central maximum is measured to be 4.4 cm. What is the diameter of the hole?

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[3] A5. What should the wavelength of a proton be, if it has the same kinetic energy as the energy of a photon of wavelength 700 nm?

[3] A6. Suppose an imaginary atom had only three energy levels. If these levels are evenly spaced, then how many spectral lines would one expect to measure? How would their wavelengths compare to one another?

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[3] A7. One method of roughly determining the size of a molecule is to measure the wavelengths of the emitted photons, and to treat the molecule as an infinite square well with an electron trapped inside. If the photons emitted in the $n = 2$ to $n = 1$ transition have wavelengths of 4240.0 nm, what is the width of the molecule?

[3] A8. For a planet that has shrunken to its Schwarzschild radius, how fast (based on Newtonian physics) would you have to throw a ball upward such that it escapes from the planet's gravitational pull? Is this physically possible?

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PART B: Do ANY 4 of the following 7 questions. Each has the same mark value.

[5] B1. Consider a rectangular dam that is 40-m wide, and that supports a body of water to a height of 35 m.

(a) Neglecting atmospheric pressure, determine the total force due to the water pressure acting on a thin horizontal strip of the dam of thickness dy, located at depth y.

(b) From your result in part (a), calculate the total horizontal force exerted by the water on the dam.

(c) Why is it reasonable to neglect atmospheric pressure in the calculations above?

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[5] B2. Consider a simple pendulum, comprising a ball of mass M hanging from a string (whose mass can be neglected). The angle of this pendulum with respect to the horizontal is given by $\theta = \theta_\circ \cos[(5.44\ rad/s)t + \phi]$.

If when the pendulum is first released, the angle was 0.05 radians and $d\theta/dt =$ - 0.30 radians/s, calculate (a) the phase constant ϕ; and (b) the maximum angle that the pendulum will reach as it oscillates. (Neglect air resistance.)

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[5] B3. (a) Suppose that a neutron has a momentum of magnitude p, but of unknown direction. With only this information, provide an estimate for the uncertainty in the neutron's momentum. (Explain/derive your answer.)

(b) Calculate this neutron's de Broglie wavelength and compare it with the smallest allowable uncertainty in the neutron's position. Why might these two quantities be related to each other?

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[5] B4. The figure below shows a horizontal pipe with two thicknesses. Water flows through the pipe from the left and then out into the atmosphere at a speed $v_2 = 16$ m/s. The diameters of the two sections of the pipe are 6.0 cm and 4.0 cm.

(a) Find the volume of water that flows into the atmosphere during a 5-minute time interval.

(b) In the wider section of the pipe, what are the speed v_1 and the gauge pressure?

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[5] B5. Consider the spring-block system shown in the figure. The floor is frictionless, the two springs are identical (*i.e.*, they have the same k), and the block has mass m.

(a) Derive an expression for the frequency of oscillation of this system in terms of k and m.

(b) Now suppose that the springs are different, such that with only the right spring in place, the block oscillates with a frequency of 30 Hz; while if only the left spring is attached, the frequency is 45 Hz. What is the oscillation frequency of the block with both springs attached?

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[5] B6. The advent of "revolutions" in science follow discernable trends. For example, the discovery of the quantum theory, with the hydrogen atom as its subject, took us from Balmer's fortuitous guess, through Bohr's transitional model, to the "mature" picture in the synthesis of de Broglie, Schrödinger, Heisenberg, and others. Which stage do you think is the most challenging? Which is the easiest? Justify, and elaborate on, your answers.

Marks awarded will depend on content, organization, grammar, clarity, and the quality of your writing.

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[5] B7. Is light a particle or a wave? Explain your answer. From yet another perspective, we also learned in lectures this term that although light has no mass, it feels the influence of the gravitational force. How is this possible, since according to Newton, only objects with mass should interact gravitationally?

Marks awarded will depend on content, organization, grammar, clarity, and the quality of your writing.

END OF EXAM QUESTIONS

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Extra Page (turn it in with your exam copy)

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Memory Sheet (turn it in with your exam copy)

Solution for quadratic equation: $x = (-b \pm \sqrt{b^2 - 4ac})/2a$
Area of sphere: $A = 4\pi r^2$
Volume of sphere: $V = \frac{4}{3}\pi r^3$
First two terms of Taylor series: $(1 + x)^a \simeq 1 + ax$
Chain Rule: $dy/dt = (dy/dx)\ (dx/dt)$
Schwarzschild radius: $R_s = 2GM/c^2$
Gravitation potential energy: $U = -GMm/r$
Hydrostatic law of pressure with depth: $\Delta P = \rho g \Delta y$
Archimedes' principle of buoyancy: $F_B = \rho_f V g$
Fluid flow speed: $A \cdot v = const$ where A is cross-section area of tube
Bernoulli's equation: $P + \frac{1}{2}\rho v^2 + \rho g y = const$
Hooke's law: $F = -kx$
Oscillation period for SHM: $T = 2\pi\sqrt{m/k} = 2\pi/\omega$
Simple harmonic motion: $x(t) = A\ \cos(\omega t + \phi)$
Simple Pendulum: $T = 2\pi\sqrt{L/g}$
Wave speed: $v = f\lambda = \omega/k$
Travelling wave: $y(x,t) = A\ \sin(kx - \omega t + \phi)$ where $k = 2\pi/\lambda$, $\omega = 2\pi/T$
2-slit interference pattern: $I = I_0 \cdot \cos^2(\pi d sin\theta/\lambda)$
Diffraction minima: $a\ \sin\theta = m\ \lambda$
Photon energy: $E = hc/\lambda$
Energy levels of H atom: $E_n = -13.6eV/n^2$
Wavelengths emitted by H atom: $\frac{1}{\lambda_n} = R(\frac{1}{n^2} - \frac{1}{m^2})$
de Broglie relation: $\lambda = h/p$
Schrodinger equation: $\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}(E - U)\psi = 0$
Particle in a box: energy levels $E_n = n^2 h^2/8mL^2$
Uncertainty principle: $\Delta p \cdot \Delta x > \hbar \qquad \Delta E \cdot \Delta t > \hbar$

Physical constants:

Gravitation constant $G = 6.67 \times 10^{-11} Nm^2/kg^2$
Speed of light $c = 3.00 \times 10^8$ m/sec
Planck's constant $h = 6.626 \times 10^{-34}$ J-sec and $\hbar = h/(2\pi)$
Rydberg constant $R = 1.097 \times 10^7\ \text{m}^{-1}$
Standard atmospheric pressure at sea level $P_0 = 1.013 \times 10^5$ Pa
Density of water $\rho = 1000\ \text{kg/m}^3$
Density of air at sea level $\rho_0 = 1.3\ \text{kg/m}^3$
mass of electron $= 9.1 \times 10^{-31}$ kg
mass of proton or neutron $= 1.67 \times 10^{-27}$ kg
1 eV (electron volt) $= 1.6 \times 10^{-19}$ Joules
charge on electron $e = 1.6 \times 10^{-19}$ coulomb
1 nm $= 1 \times 10^{-9}$ m

THE END