University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER I EXAMINATION – 2010/2011

PHYC 10150

Physics for Engineers I

Professor J. Lunney
Professor L.O. Hanlon
Dr. V. Lobaskin*

Time Allowed: 2 Hours

Instructions for Candidates

Candidates should attempt 4 questions, two questions in Section A and two questions in Section B. Use a *separate* answer book for each section. All questions carry equal marks. The marks allocated to each part of a question are indicated in brackets.

Instructions for Invigilators

Non-programmable calculators are permitted.

55576

55576

Section A

1.
a) A stone with mass 0.80 kg is attached to one end of a string 0.90 m long. The string will break if its tension exceeds 600 N. The stone is whirled in a horizontal circle on a frictionless tabletop; the other end of the string remains fixed. Find the maximum speed the stone can attain without breaking the string. Find the period of revolution of the stone at the maximum speed.

(10 marks)

b) It takes a horizontal force of 160 N to slide a box along a surface of a level floor at constant speed. The coefficient of static friction is 0.52 and the coefficient of kinetic friction is 0.47. If the box is placed on a dolly of mass 5.3 kg and with coefficient of rolling friction 0.018, what horizontal acceleration would that 160-N force provide?

(15 marks)

2.
a) A 1.20-kg piece of cheese is placed on a vertical spring of negligible mass and force constant k =1800 N/m that is compressed 15.0 cm. When the spring is released, how high does the cheese rise from this initial position? (The cheese and spring are not attached).

(10 marks)

b) A particle is moving along the x-axis in a potential field $U(x) = \alpha x^4$, where $\alpha = 1.20\ \mathrm{J/m^4}$. What is the force (magnitude and direction) produced by this potential at $x = -0.800\mathrm{m}$?

(15 marks)

3.
a) An object is undergoing a simple harmonic motion with period 1.200 s and amplitude 0.600 m. At t=0 the object is at x=0. How far is the object from the equilibrium position when t=0.480 s? What is its acceleration at that point?

(10 marks)

b) A 150-g ball is undergoing simple harmonic motion on the end of a horizontal spring with force constant k =300 N/m. When the ball is 0.0120 m from its equilibrium position, it has a speed of 0.300 m/s. What is the total energy of the ball at any point of its motion? What is the maximum speed attained by the ball during its motion?

(15 marks)

Section B

4.
a) Three moles of ideal gas are in a rigid cubical box with side of length 0.200 m. What is the force that the gas exerts on each side of the box when the gas temperature is 20°C? What is the force when the temperature is increased to 100°C?

(12 marks)

b) An underground tank with a capacity of 1700 L (1.70 m^3) is filled with ethanol that has an initial temperature of 19°C. After the ethanol has cooled off to the temperature of the tank and ground, which is 10.0°C, how much empty space will there be above the ethanol in the tank? Assume that the volume of the tank does not change. Take the coefficient of thermal expansion of ethanol 75.0×10^{-5}1/°C.

(13 marks)

5.

a) A car alarm is emitting sound waves of frequency 520 Hz. You are on a motorcycle, traveling directly away from the car. How fast must you be traveling if you detect a frequency of 490 Hz?

(12 marks)

b) The D-note (588 Hz) of a trumpet causes a guitar string to vibrate in its second overtone with large amplitude. The vibrating portion of the guitar string has length 63.5 cm. What is the speed of transverse waves on the guitar string?

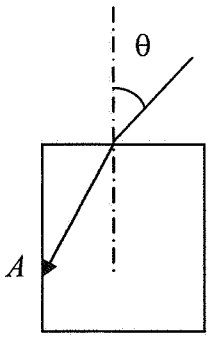
(13 marks)

6.

a) Monochromatic X-rays are incident on a crystal for which the spacing of the atomic planes is 0.440 nm. The first-order maximum in the Bragg reflection occurs when the incident and reflected X-rays make an angle of 39.5° with the crystal planes. What is the wavelength of the X-rays?

(10 marks)

b) A ray of light is incident in air on a block of a transparent solid whose index of refraction is n=1.38. What is the *largest* angle of incidence θ for which the total internal reflection will occur at the vertical face? (Point A shown on the figure)



(15 marks)

Auxiliary formulae

$$a=\frac{v^2}{r};\quad F_{fr}=\mu F_N;\quad F=-\frac{dU}{dx};\quad PV=nRT;\quad U=\frac{kx^2}{2};\quad K=\frac{mv^2}{2};\quad U=mgh;$$

$$V=V_0(1+\beta\Delta T);\quad f'=f\frac{v\pm v_D}{v\pm v_S};\quad 2d\sin\theta=\lambda;\quad n_1\sin\theta_1=n_2\sin\theta_2;\quad v=f\lambda$$

Recommended Values of Physical Constants and Conversion Factors

(*Sources*: 2006 CODATA recommended values; http://physics.nist.gov/constants)

speed of light in vacuum, $c = 299\ 792\ 458$ (exact) m s^{-1}

electric (permittivity) constant, $\varepsilon_0 = 8.854\ 187\ 817\ldots \times 10^{-12}$ (exact) F m^{-1}

magnetic (permeability) constant, $\mu_0 = 12.566\ 370\ 614\ldots \times 10^{-7}$ (exact) N A^{-1}

(unified) atomic mass unit, u = $1.660\ 538\ 782(83) \times 10^{-27}$ kg

alpha particle mass (in u) = 4.001 506 179 127(62) u

atomic mass unit energy equivalent = $1.492\ 417\ 830(74) \times 10^{-10}$ J

atomic mass unit energy equivalent (in MeV) = 931.494 028(23) MeV

Avogadro constant, $N_A = 6.022\ 141\ 79(30) \times 10^{23}$ mol^{-1}

Bohr radius, $a_0 = 0.529\ 177\ 208\ 59(36) \times 10^{-10}$ m

Bohr magneton, $\mu_B = 927.400\ 915(23) \times 10^{-26}$ J T^{-1}

Boltzmann constant, $k = 1.380\ 6504(24) \times 10^{-23}$ J K^{-1}

classical electron radius, $r_e = 2.817\ 940\ 2894(58) \times 10^{-15}$ m

Compton wavelength of the electron, $\lambda_C = 2.426\ 310\ 2175(33) \times 10^{-12}$ m

deuteron mass (in u) = 2.013 553 212 724(78) u

electron mass, $m_e = 9.109\ 382\ 15(45) \times 10^{-31}$ kg

elementary charge, $e = 1.602\ 176\ 487(40) \times 10^{-19}$ C

molar mass of carbon-12 = 12×10^{-3} (exact) kg mol^{-1}

neutron mass, $m_n = 1.674\ 927\ 211(84) \times 10^{-27}$ kg

Newtonian constant of gravitation, $G = 6.674\ 28(67) \times 10^{-11}$ m^3 kg^{-1}

nuclear magneton, $\mu_N = 5.050\ 783\ 24(13) \times 10^{-27}$ J T^{-1}

Planck constant, $h = 6.626\ 068\ 96(33) \times 10^{-34}$ J s

proton mass, $m_p = 1.672\ 6216\ 37(83) \times 10^{-27}$ kg

Rydberg constant, R = 10 973 731.568 527(73) m^{-1}

Stefan-Boltzmann constant, $\sigma = 5.670\ 400(40) \times 10^{-8}$ W m^{-2} K

gas constant, $R = 8.314472(15)$ J mol^{-1} K^{-1}

triton mass (in u) = 3.015 500 7134(25) u

oOo