University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER I EXAMINATION – 2011/2012

PHYC 10150

Physics for Engineers I

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Time Allowed: 2 Hours

Instructions for Candidates

Candidates should attempt 4 questions, two questions in Section A and two questions in Section B. 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.

Section A

1. a) A 70.0 kg skater moving initially at 2.40 m/s on rough horizontal ice comes to rest gradually in 3.52 s due to friction from the ice. What force does the friction exert on the skater? (10 marks)

   b) A bowling ball weighing 70 N is attached to the ceiling by a 3.80 m rope. The ball is pulled to one side and then released; it then swings back and forth as a pendulum. As the rope swings through the vertical, the speed of the bowling ball is 4.20 m/s. What is the acceleration of the bowling ball, in magnitude and direction, at this instant? What is the tension in the rope at this instant? (15 marks)

2. a) A certain spring is found not to obey the Hooke's law; it exerts a restoring force $F_x(x) = -\alpha x - \beta x^2$ if it is stretched or compressed. The mass of the spring is negligible. Derive an expression for the potential energy function $U(x)$ for this spring. (10 marks)

   b) Consider the same spring. Let U=0 when x=0, α =60.0 N/m and β =18.0 N/m^2. An object with mass 0.900 kg on a frictionless, horizontal surface is attached to this spring, pulled a distance 1.00 m to the right (+x direction) to stretch the spring, and released. What is the speed of the object when it is 0.50 m to the right of the x=0 equilibrium position? (15 marks)

3. a) A uniform sphere with mass 28.0 kg and radius 3.80 m is rotating at constant angular velocity about a stationary axis that lies along a diameter of the sphere. If the kinetic energy of the sphere is 176 J, what is the tangential velocity of a point at the rim of the sphere? (15 marks)

   b) A pump is required to lift 800 kg of water per minute from a well 14.0 m deep and eject it horizontally with a speed of 18.0 m/s. How much work is done per minute in lifting the water? How much work is done giving the water its final kinetic energy? What must be the power output of the pump? (10 marks)

Section B

4. a) A 2.50-kg aluminium block is heated to 80.0°C and then dropped into 8.00 kg of water at 10.00°C. Assuming that the block–water system is thermally isolated, what is the system's equilibrium temperature? Assume the specific heat of aluminium equals 0.900 J/(g °C) and specific heat of water equals 4.19 J/(g °C). (10 marks)

   b) A beam of hydrogen molecules (H_2) is directed toward a wall, at an angle of 55° with the normal to the wall. Each molecule in the beam has a speed of 1.0 km/s and a mass of 3.3 × 10^{-24} g. The beam strikes the wall over an area of 2.0 cm^2, at the rate of 10^{23} molecules per second. What is the beam's pressure on the wall? (15 marks)

5. a) A rope, under a tension of 200 N and fixed at both ends, oscillates in a second-harmonic standing wave pattern. The displacement of the rope is given by $y = (0.10\text{m})\sin(\pi x/2)\sin(12\pi t)$, where x = 0 at one end of the rope, x is in metres, and t is in seconds. What is the (i) length of the rope, (ii) the speed of the waves on the rope, and (iii) the mass of the rope? (iv) If the rope oscillates in a third-harmonic standing wave pattern, what will be the period of oscillation?
(15 marks)

b) Assume that a detector is located at a distance *D* from an isotropic point source of sound. After it is moved 20.0 m toward the source it registers that the intensity of the sound has doubled. Calculate the distance *D*. (10 marks)

6. a) Assume that the limits of the visible spectrum are arbitrarily chosen as 400 and 700 nm. Calculate the number of rulings per millimetre of a grating that will spread the first-order spectrum through an angle of 25.0°. (15 marks)

b) A beam of initially unpolarised light is sent through two polarising sheets placed one on top of the other. What must be the angle between the polarising directions of the sheets if the intensity of the transmitted light is to be one-quarter the incident intensity? (10 marks)

Auxiliary formulae

$$d\sin\theta = n\lambda$$

$$E = E_0 \cos^2\theta$$

$$\omega = \sqrt{\frac{k}{m}}$$

$$v = \sqrt{\frac{\tau}{\mu}}$$

$$PV = nRT$$

$$v = f\lambda$$

$$K = \frac{I\omega^2}{2}$$

$$I_{ball} = \frac{2MR^2}{5}$$

$$U = mgh$$

$$\sin(\alpha+\beta) = \sin\alpha\cos\beta + \cos\alpha\sin\beta$$

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, ε_0 = 8.854 187 817… × 10^{-12} (exact) F m^{-1}

magnetic (permeability) constant, μ_0 = 12.566 370 614… × 10^{-7} (exact) N A^{-1}

(unified) atomic mass unit, u = 1.660 538 782(83) × 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) × 10^{-10} J

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

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

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

Bohr magneton, μ_B = 927.400 915(23) × 10^{-26} J T^{-1}

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

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

Compton wavelength of the electron, λ_C = 2.426 310 2175(33) × 10^{-12} m

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

electron mass (in u), m_e = 5.485 799 0943(23) × 10^{-4} u

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

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

neutron mass (in u), m_n = 1.008 664 915 97(43) u

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

nuclear magneton, μ_N = 5.050 783 24(13) × 10^{-27} J T^{-1}

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

proton mass (in u), m_p = 1.007 276 466 77(10) u

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

Stefan-Boltzmann constant, σ = 5.670 400(40) × 10^{-8} W m^{-2} K

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

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