University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER II EXAMINATION (RESIT) – 2012/2013

PHYC 10150

Physics for Engineers I

Dr. P.J.M. van der Burgt
Professor P.A. Dunne
Dr. V. Lobaskin*

Time Allowed: 2 Hours

Instructions for Candidates

Candidates should attempt 4 questions, 2 questions in Section A and 2 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. i) A 20.0 kg curling stone is initially stationary on an ice surface with negligible friction. At time t = 0, a horizontal force begins to move the stone. The force is given by $\vec{F} = (10.0 - 30.00t^2)\hat{\mathbf{i}}$, with $\vec{F}$ in newtons and t in seconds, and it acts until its magnitude is zero. Plot schematically the x-component of the velocity and the x-position of the stone as a function of time. What is the change in momentum of the stone between t = 0 and the instant at which F = 0? (25 marks)

2. i) A 700 g block is released from rest at height h_0 above a vertical spring with spring constant k = 400 N/m and negligible mass. The block sticks to the spring and momentarily stops after compressing the spring 19.0 cm. How much work is done by the block on the spring, and how much work is done by the spring on the block? What is the value of h_0? (10 marks)

   ii) An astronaut is being tested in a centrifuge. The centrifuge has a radius of 10 m and, in starting, rotates according to $\theta = 0.30t^2$, where t is in seconds and θ is in radians. When t = 5.0 s, what are the magnitudes of the astronaut's angular velocity, linear velocity, tangential acceleration, and radial acceleration? (15 marks)

3. i) A particle executes simple harmonic motion with an amplitude of 4.00 cm. At what position does its speed equal half its maximum speed? (15 marks)

   ii) A machine part is undergoing a simple harmonic motion with a frequency of 5.00 Hz and an amplitude of 1.80 cm. How long does it take the part to go from x = 0 to x = −1.80 cm? (10 marks)

Section B

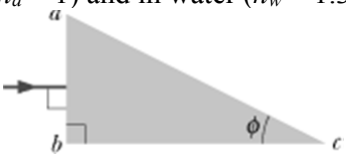
4. i) A 20.0 l tank contains 0.225 kg of helium at 18.0°C. The molar mass of helium is 4.00 g/mol. How many moles of helium are in the tank? What is the pressure in the tank in Pascals and in atmospheres? Consider helium as an ideal gas and take one atmosphere to be equal to 101.325 kPa. (10 marks)

   ii) Initially, the rms speed of an atom of a monatomic ideal gas is 250 m/s. The pressure and the volume of the gas are each doubled while the number of moles of the gas is kept constant. What is the final rms speed of the atoms? (15 marks)

5. i) A detector initially moves at constant velocity directly toward a stationary sound source and then (after passing it) directly from it. The emitted frequency is f. During the approach the detected frequency is f'_{app} and during the recession it is f'_{rec}. If the frequencies are related by $(f'_{\text{app}} - f'_{\text{rec}})/f = 0.500$, what is the ratio of the speed of the detector to the speed of sound? (15 marks)

   ii) With what tension must a rope of length 2.50 m and mass 0.125 kg be held for transverse waves of frequency 40.0 Hz to have a wavelength of 0.750 m? (10 marks)

6. i) In the figure below, a ray of light is perpendicular to the face *ab* of a glass prism (n_g = 1.52). Find the largest value for the angle ϕ so that the ray is totally reflected at face *ac* if the prism is immersed in air (n_a = 1) and in water (n_w = 1.33).



(15 marks)

ii) Monochromatic light is directed at a normal incidence onto a planar transmission grating. The first order maximum is observed at an angle of 8.94°. What is the angular position of the fourth-order maximum? (10 marks)

Auxiliary formulae

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

$$PV = nRT$$

$$v = f\lambda$$

$$U = mgh$$

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

$$I = MR^2$$

$$v = \sqrt{\frac{3RT}{M}}$$

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

$$f' = f\frac{v \pm v_D}{v \pm v_S}$$

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^{-2}

(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 (in u), $m_e = 5.485\ 799\ 0943(23) \times 10^{-4}$ u

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 (in u), $m_n = 1.008\ 664\ 915\ 97(43)$ u

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 (in u), $m_p = 1.007\ 276\ 466\ 77(10)$ u

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

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

oOo