Maynooth University
National University of Ireland Maynooth

OLLSCOIL NA hÉIREANN MÁ NUAD
THE NATIONAL UNIVERSITY OF IRELAND MAYNOOTH

BE in Electronic Engineering with Communications
BE in Electronic Engineering with Computers
BE in Electronic Engineering
BSc in Robotics & Intelligent Devices

Year 1

SEMESTER 1
2017 -2018

Physics for Engineers 1
EE 104

(*Prof. J. A. Murphy, Dr. C. O'Sullivan, Dr. N. Trappe*)

Time allowed: 2 hours

Answer ***any four*** questions

All questions carry equal marks

<u>All workings</u> must be clearly shown

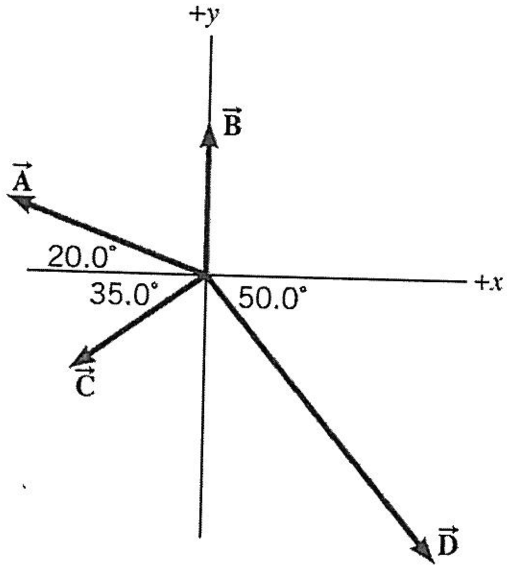
Relevant physical constants and data can be found at the end of the paper

MECHANICS

1. (a) Use dimensional analysis to check that the equation below is dimensionally correct and state if the equation is valid, where the symbols have their usual meaning. *(7 marks)*

$$x = \frac{v^2}{2a}$$

(b) The magnitudes of the four displacement vectors shown in the drawing are $|\vec{A}| = 14\,\text{km}$, $|\vec{B}| = 9\,\text{km}$, $|\vec{C}| = 10\,\text{km}$, and $|\vec{D}| = 23\,\text{km}$. Calculate the magnitude and directional angle for the resultant displacement that occurs when these vectors are added together. *(9 marks)*



(c) An object is dropped from rest from a height of 115 m and is measured to strike the ground with a speed of 96 miles per hour including air resistance (drag). Calculate, in units of miles per hour, how fast the object would have been travelling on impact had air resistance been absent, and calculate the time the object was falling. (1 mile = 1.61 km). *(9 marks)*

2. (a) Write a brief description of simple harmonic motion and give a physical example of this type of motion. State Hooke's Law for an ideal spring. A hand exerciser utilizes a coiled spring. A force of 110 N is required to compress the spring by 20 mm. Determine the force needed to compress the spring by 10 mm. *(9 marks)*

(b) Young's Modulus of elasticity Y for a material can be written as

$$Y = \frac{stress}{strain}$$

Explain the terms stress and strain and give their units. Explain how Young's Modulus can be used to compare the strength of two cables made from different materials? *(8 marks)*

(c) A cable initially 3 m long with a diameter of 4 mm is stretched to a length of 3.05 m by a force of 450 N. What is Young's Modulus for this cable? *(8 marks)*

3. (a) A ball has an initial speed of 15 m/s. Only one external force then acts on the ball. After this force acts, the speed of the ball is reduced to 7 m/s. Has the force applied positive or negative work to the ball? Explain with the relevant equation. *(8 marks)*

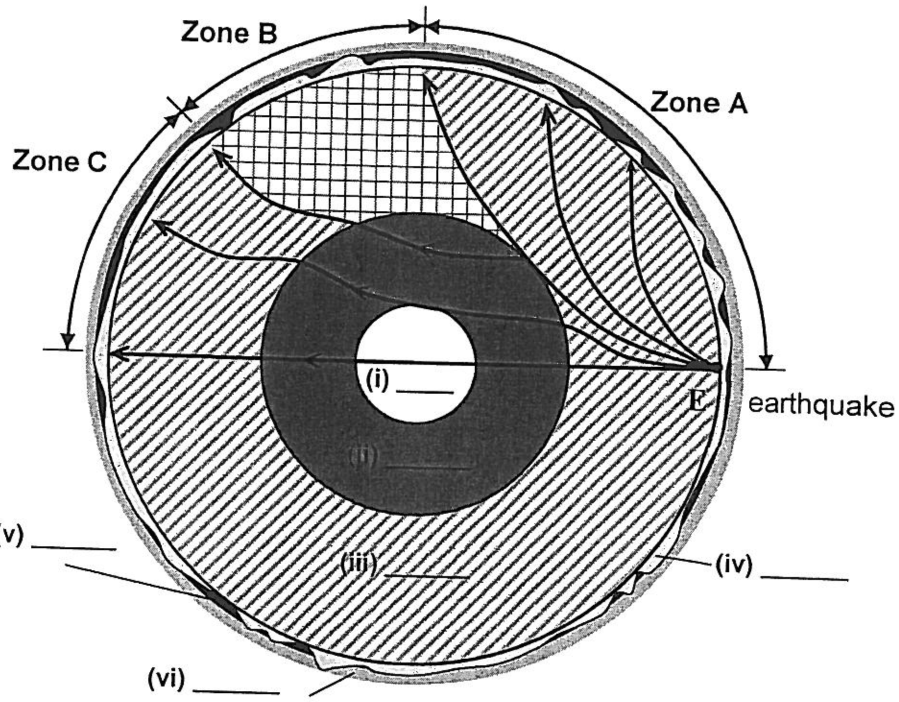
(b) A 45-gram golf ball is struck and its initial speed is 41 m/s.
(i) How much work is done on the ball by the club?
(ii) Assume that the force of the golf club acts parallel to the motion of the ball, and that the club is in contact with the ball for a distance of 10 mm. Ignore the weight of the ball and determine the average force applied to the ball by the club. *(8 marks)*

(c) Outline the *impulse – momentum* theorem briefly. A space probe is traveling in outer space with an initial momentum of 7.5×10^7 kg.m/s. To slow down the probe a retrorocket applies a force of 2.0×10^6 N for a period of 12 s. Calculate the final momentum of the probe. *(9 marks)*

HEAT/PROPERTIES OF MATTER

4. (a) Briefly describe what is meant by the terms (i) *P-wave* and (ii) *S-wave* in seismology. *(6 marks)*

(b) In the diagram of the Earth below, label the layers (i) to (vi).
Indicate which type(s) of seismic wave would be detected in each of the 3 zones, from an earthquake near the surface at the point marked 'E'.
Why do the seismic waves follow curved paths? *(12 marks)*



(c) A seismic station is located 2,000 km from the epicentre of an earthquake. If the station records the arrival of P-waves at 09:00am, at what time will it record the arrival of S-waves?
[You may use that P- and S-waves travel at speeds of about 5 $km.s^{-1}$ and 3 $km.s^{-1}$, respectively.] *(7 marks)*

5. (a) Briefly explain the differences between convective and conductive heat transfer. Explain why heavy curtains drawn across a window may reduce the heat loss from a room on a cold night. *(8 marks)*

(b) What is absolute zero on the Celsius scale and explain how it arises from absolute pressure of a gas changing with changing temperature. *(8 marks)*

(c) Apply the Stefan-Bolzmann law of radiation to the following example:
Two objects have the same size and shape. Object A has an emissivity of 0.3, and object B has an emissivity of 0.6. Each radiates the same power. What is the ratio of the temperatures of object A to object B? Outline your reasoning. *(9 marks)*

6. (a) Outline the main required properties of a thermometer to measure temperature accurately. Outline the principle of operation of a thermocouple thermometer and how it can be used to measure temperature. *(8 marks)*

(b) A simple pendulum consists of a ball connected to one end of a thin brass wire. The period of the pendulum is two seconds. The temperature rises by 140 °C, and the length of the wire increases. Calculate the new period of the heated pendulum taking the coefficient of linear expansion of brass to be 19×10^{-6} / °C. *(8 marks)*

(c) In filling the water for a bath, how many kilograms of hot water at 49.0 °C must you mix with cold water 13.0 °C so that the temperature of the bath water is to be 36.0 °C? Take the total mass of water (hot plus cold) as 191 kg and ignore any heat loss. *(9 marks)*

FUNDAMENTAL CONSTANTS AND UNITS

Acceleration due to Earth's gravity	g	=	9.80		m s^{-2}
Alpha particle mass		=	6.69	$\times 10^{-27}$	kg
Atomic mass unit	1 u	=	1.661	$\times 10^{-27}$	kg
		=	931.5		MeV c^{-2}
Avogadro's number	N_A	=	6.022	$\times 10^{23}$	(mol)$^{-1}$
Bohr magneton	μ_B	=	9.274	$\times 10^{-24}$	J T^{-1}
Bohr radius	a_o	=	5.292	$\times 10^{-11}$	m
Boltzmann Constant	k_B	=	1.381	$\times 10^{-23}$	J K^{-1}
Density of water (4 ^{0}C)		=	1.000	$\times 10^{3}$	kg m^{-3}
Electron mass	m_e	=	9.109	$\times 10^{-31}$	kg
		=	5.486	$\times 10^{-4}$	u
Electron volt	1 eV	=	1.602	$\times 10^{-19}$	J
Elementary charge	e	=	1.602	$\times 10^{-19}$	C
Gas constant	R	=	8.315		J K^{-1} (mol)$^{-1}$
Gravitational constant	G	=	6.673	$\times 10^{-11}$	N m^2 kg^{-2}
Latent heat of fusion of water		=	3.35	$\times 10^{5}$	J kg^{-1}
Latent heat of fusion of ice		=	33.5	$\times 10^{4}$	Jkg^{-1}
Neutron mass	m_n	=	1.675	$\times 10^{-27}$	kg
		=	1.008 665		u
Permeability of free space	μ_o	=	4π	$\times 10^{-7}$	T m A^{-1}
Permittivity of free space	ε_o	=	8.854	$\times 10^{-12}$	C^2 N^{-1} m^{-2}
	$1/(4\pi\varepsilon_o)$	=	8.99	$\times 10^{9}$	N m^2 C^{-2}
Planck's constant	h	=	6.626	$\times 10^{-34}$	J s
	$\hbar = h/2\pi$	=	1.055	$\times 10^{-34}$	J s
Proton mass	m_p	=	1.672	$\times 10^{-27}$	kg
		=	1.007 276		u
Rydberg constant	R_∞	=	1.097	$\times 10^{7}$	m^{-1}
Rydberg energy	E_R	=	13.59		eV
Specific heat capacity of ice		=	2000		Jkg^{-1}K^{-1}
Specific heat capacity of water		=	4186		Jkg^{-1}K^{-1}
Speed of light in vacuum	c	=	2.998	$\times 10^{8}$	m s^{-1}
Stefan-Boltzmann constant	σ	=	5.670	$\times 10^{-8}$	J s^{-1} m^{-2} K^{-4}
Thermal conductivity of glass		=	0.84		Wm^{-1}K^{-1}
Thermal conductivity of ice		=	2.2		J s^{-1} m^{-1} K^{-1}
Thermal conductivity of insulated wall		=	0.041		Wm^{-1}K^{-1}
Wien's constant		=	2.898	$\times 10^{-3}$	m K

ASTRONOMICAL UNITS AND DATA

Astronomical unit	1 A.U.	=	1.496	$\times 10^{11}$	m
Earth's mass	M_E	=	5.974	$\times 10^{24}$	kg
Earth's radius (equatorial)	R_E	=	6.378	$\times 10^{6}$	m
Light year	1 ly	=	9.461	$\times 10^{15}$	m
Parsec	1 pc	=	3.086	$\times 10^{16}$	m
Solar mass	$M_\odot$	=	1.989	$\times 10^{30}$	kg
Solar radius	$R_\odot$	=	6.960	$\times 10^{8}$	m