UNIVERSITY OF ESWATINI

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2018/2019

TITLE OF PAPER:	INTRODUCTORY PHYSICS I
COURSE NUMBER:	PHY101
TIME ALLOWED:	THREE HOURS
INSTRUCTIONS:	ANSWER ANY FOUR OUT OF FIVE QUESTIONS
	EACH QUESTION CARRIES 25 MARKS
	MARKS FOR EACH SECTION ARE IN THE RIGHT HAND MARGIN
	GIVE CLEAR EXPLANATIONS AND USE CLEAR DIAGRAMS IN YOUR SOLUTIONS. MARKS WILL BE LOST WHERE IT IS NOT CLEAR HOW THE EQUATIONS USED WERE OBTAINED

THIS PAPER HAS SEVEN PAGES INCLUDING THE COVER PAGE

THE LAST PAGE CONTAINS DATA THAT MAY BE USEFUL IN SOME QUESTIONS

DO NOT OPEN THE PAPER UNTIL PERMISSION HAS BEEN GIVEN BY THE CHIEF INVIGILATOR

QUESTION 1

(a) Find the angle between vectors $\vec{A} = 3\hat{\imath} - 4\hat{\jmath} + 2\hat{k}$ and $\vec{A} = 2\hat{\imath} + 4\hat{\jmath} - 3\hat{k}$ using the cross product. **(7 marks)**

(b) A particle starts from rest at the origin and accelerates as shown in Figure 1. Determine

i. the particle's velocity at $t = 10.0$ s and $t = 20.0$ s, and **(2 marks)**

ii. the distance travelled in the first 10.0 s, 15.0 s, and 20.0 s. **(3 marks)**

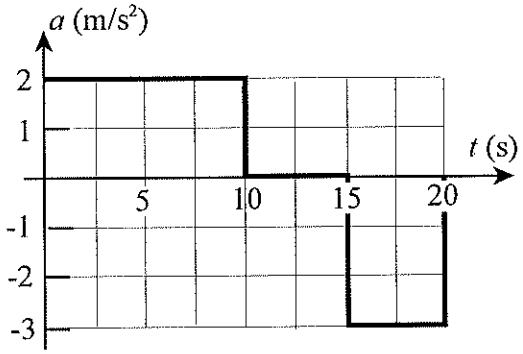

Figure 1. Acceleration-time graph for a particle starting at the origin with zero initial velocity

(c) A person on top of a multi-story building 60.0 m high on a flat field and fires a projectile with a velocity $v_0 = 24.9$ m/s at an angle $\theta = 53.0°$ with the horizontal.

i. How high above ground does it rise? **(3 marks)**

ii. Find the x- and y-components of the velocity when it hits the ground, **(3 marks)**

iii. Find the time for the entire flight of the projectile and **(3 marks)**

iv. its range. **(2 marks)**

v. Find the angle the final velocity makes on impact with the ground. **(2 marks)**

QUESTION 2

(a) When a bus initially at rest suddenly moves a passenger standing in the aisle falls. Explain what causes the passenger to fall? **(3 marks)**

(b) A heavy crate is placed on a flat-bed truck and not tied down. When the truck accelerates forward, the crate stays on the truck. What force causes the crate to move with the truck? Also make a force diagram for the crate. **(3 marks)**

(c) The Figure 2 below shows a traction system used to provide support and traction for an injured leg with a broken tibia and fibula.

i. Make a force diagram for the forces applied by the traction. **(3 marks)**

ii. Find the horizontal component of the force applied to the leg by the traction, **(2 marks)**

iii. Find the vector force exerted on the leg by the traction, and **(2 marks)**

iv. the angle the traction force make with the horizontal. **(2 marks)**

(d) Figure 3 below illustrates an arm holding a ball at an angle with the horizontal. The forces acting on the arm are as follows:

F_h – downward force exerted by the upper arm bone, the humerus, acting at the elbow

T_b – upward force exerted by the biceps acting a distance $b = 5.00$ cm from the elbow

W – weight of the lower arm of mass 2.00 kg acting a distance $d = 15.0$ cm from the elbow

mg – weight of the ball of mas 5.00 kg acting a distance of $l = 35.0$ cm from the elbow.

i. Find the force exerted by the biceps to hold the lower arm and the ball in the position shown, **(8 marks)**

ii. Find the reaction force by the humerus F_h. **(2 marks)**

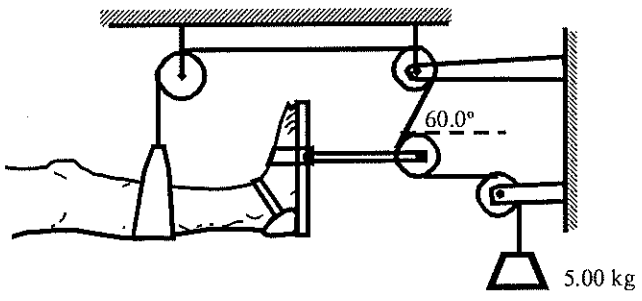

Figure 2. Hospital traction system for a leg.

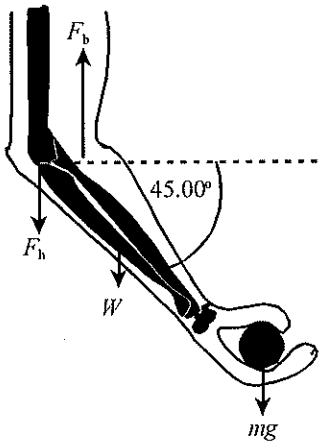

Figure 3. Arm at an angle holding a ball.

QUESTION 3

(a) When a stone is whirled around at the end of a rope it undergoes centripetal motion. Explain whether the centripetal force does work in this case. **(2 marks)**

(b) A 5.00 kg steel ball is dropped onto a copper plate from a height of 10.0 m. If it makes a dent of depth 3.20 mm on the plate, what is the average force exerted on the ball during impact? **(6 marks)**

(c) It takes 4.00 J of work to stretch a spring obeying Hooke's law by 10.0 cm from its natural length. A block of mass 0.525 kg is attached to the free end of the stretched spring. Determine the velocity of the mass when the stretched spring contracts by 5.00 cm from the stretched length. **(5 marks)**

(d) A heavy truck of mass $m_t = 20\,000$ kg moving east collides head-on with a car of mass $m_c = 1000$ kg moving west, where the masses include those of the drivers. Coincidentally both vehicles were moving at a speed of 108 km/h in opposite directions. The collision time is 0.150 s.

i. Assuming a perfectly inelastic collision, find the velocity of the wreckage after the collision. **(4 marks)**

ii. Find the force of impact on each vehicle and comment on the results. **(4 marks)**

iii. Find the force of impact on each driver and comment, assuming that both drivers have the same mass of 85.0 kg. **(4 marks)**

QUESTION 4

(a) Use physics to explain why cutting instruments have to be sharpened from time-to-time. You can use equations to aid your explanation. **(3 marks)**

(b) The Young's modulus for a human bone is about 1.50×10^{10} N/m^2. The bone breaks if a stress greater than 1.50×10^{8} N/m^2 is imposed on it.

i. What is the maximum force that can be exerted on the femur bone in the leg if it has a minimum effective diameter of 2.50 cm? **(2 marks)**

ii. If such a force is applied compressively to a femur that is 25.0 cm long, by how much will it be shortened? **(3 marks)**

(c) An open box made of steel plate of thickness $t = 2.00$ cm thick and density 7800 kg/m^2 has a width $w = 2.35$ m, length $l = 5.89$ m and height $h = 2.69$ m. The box is to be used to carry goods across a river. For safety reasons, the bottom of the box must never float be below 4 m.

i. Determine the distance d from the bottom of the box to the water level if the box is floating on freshwater with the open end upward. **(5 marks)**

ii. How much mass can the box carry safely? **(4 marks)**

(d) A horizontal blood vessel of cross-sectional area A_1 carries blood of density 1060 kg/m^3 at a pressure of 125 mm of mercury with a velocity of $v_1 = 0.500$ m/s towards constriction of cross-sectional area $A_2 = 0.200A_1$.

i. What is the velocity of the blood at the constriction? **(2 marks)**

ii. Determine the pressure at the constriction and obtain the pressure difference $\Delta P = P_1 - P_2$. **(6 marks)**

QUESTION 5

(a) In your aunts kitchen you find a mayonnaise glass jar with a metal lid and you have difficulty opening it. With your knowledge of physics you run hot water over lid for a minute and try to open the jar again and it opens easily. Explain how this works. **(2 marks)**

(b) Generally as you go to higher altitudes it gets colder as manifested by snow caps in some mountain peaks some of which are permanent. Physics tells you that hot air rises. Explain this contradiction. **(4 marks)**

(c) What mass of steam at 130 °C must be condensed onto a 0.100 kg glass cup to warm the cup and the 0.200 kg of water it contains from 20.0 °C to 50.0 °C? The specific heat for glass is 837 J/kg·K **(7 marks)**

(d) A cube 30.0 cm on each side is made of a rubberised plastic that can be filled with air to pressures above atmospheric pressure. If the cube has a hole you would expect it to completely collapse when you stand on it. Consider the case when the cube is sealed containing dry air with an average molecular mass of 28.97 g/mol at a temperature of 25.0°C at atmospheric pressure.

i. What is the weight of the air it contains? **(5 marks)**

ii. Determine the force due to the air inside each side of the cube. **(2 marks)**

iii. Explain with the aid of equations, including the calculation of the root mean square velocity of each air molecule, and explain how such a small amount of gas can exert such a great force that is many times your weight. **(5 marks)**

DATA SHEET

General Data

Air refractive index = 1.00
Avogadro's number $N_A = 6.022 \times 10^{23}$ mol^{-1}
Boltzmann's constant $k_B = 1.38 \times 10^{-23}$ J/K
Density of mercury = 1.36×10^4 kg/m^3
Gas constant $R = 8.314$ J/(mol·K)
Gravitational acceleration $g = 9.80$ m/s^2
Refractive index of air $n_{air} = 1.000$
Standard atmospheric pressure = 1.013×10^5 Pa
Speed of light in vacuum $c = 2.997\ 8 \times 10^8$ m/s
Speed of sound in air $\upsilon_s = 343$ m/s
Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W/(m^2·K^4)
Threshold of hearing $I_0 = 10^{-12}$ W/m^2
Universal gravitational constant $G = 6.67 \times 10^{-11}$ N. m^2/kg^2
1 calorie = 1 c = 4.186 J
1 food calorie = 1 Calorie = 1C = 10^3 calories = 4.186×10^3 J

Water data

$c(water) = 4186$ J/(kg·K) $c(ice) = 2090$ J/(kg·K) $c(steam) = 2079$ J/(kg·K)
$L_f(ice) = 3.33 \times 10^5$ J/kg $L_v(water) = 2.260 \times 10^6$ J/kg
ρ (water) = 1000 kg/m^3 refractive index $n_w = 1.333$

Electricity and nuclear data

Alpha particle mass = $6.644\ 657 \times 10^{-27}$ kg
Charge of an electron = -1.6×10^{-19} C
Charge of a proton = $+1.6 \times 10^{-19}$ C
Coulomb's constant $k_e = 8.987\ 5 \times 10^9$ Nm^2/C^2
Deuteron mass = $3.343\ 583 \times 10^{-27}$ kg
Electron mass, $m_e = 9.109 \times 10^{-31}$ kg
Neutron mass $m_n = 1.675 \times 10^{-27}$ kg
Proton mass, $m_p = 1.673 \times 10^{-27}$ kg
1 atomic mass unit = 1 amu = 1 u = 1.66×10^{-27} kg
$\epsilon_0 = 8.85 \times 10^{-12}$ C^2(N·m^2)
1 Ci = 3.7×10^{10} decays/s
1Bq = 1 decay/s