UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2017/2018

TITLE O F 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. Given the vectors $\vec{A}$ and $\vec{B}$, $\vec{A} = 3\hat{\imath} + 2\hat{\jmath} - 5\hat{k}$ and $\vec{B} = 4\hat{\imath} + 3\hat{\jmath} - 2\hat{k}$, find the cross product of the two vectors. **(3 marks)**

b. A body with an initial velocity of 2 m/s is accelerated at 4 m/s^2 for 5 s. It then moves at constant velocity for 2 s after which it is accelerated at -5 m/s^2 for 4 s. Sketch

   i. the acceleration-time, **(4 marks)**

   ii. the velocity-time, and **(5 marks)**

   iii. the distance-time graphs for this motion. **(6 marks)**

c. A ball is kicked with a velocity of 18.4 m/s at an angle of 35° with the ground and hits a target 30.0 m away at some height.

   i. Determine the time the ball spends in flight. **(2 marks)**

   ii. At what height is the target? **(3 marks)**

   iii. Determine whether the ball is on its way up or down when it hits the target. **(2 marks)**

QUESTION 2

a. Consider Figure 1 below. Let the coefficient of kinetic friction between all the masses and the surfaces be $\mu = 0.400$. The system accelerates to the right at 0.425 m/s^2. Find the value of the force F accelerating the system. **(10 marks)**

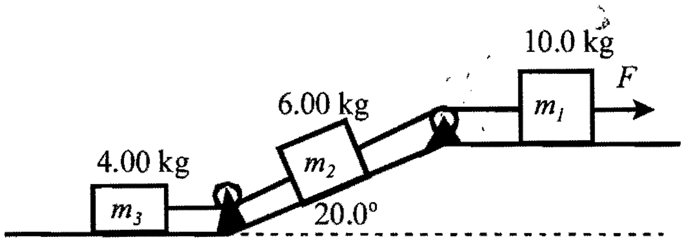


Figure 1.

b. A person holds a mass $m = 2.50$ kg in his hand 48.0 cm from the elbow. The forearm is horizontal as shown in Figure 2(a). The biceps muscles are attached at a distance of 3.00 cm from the elbow and make an angle $\theta = 80.0°$ with the horizontal. The humerus bone is attached to the elbow and makes an angle ϕ with the forearm. The effective mass of the forearm is 1.52 kg and acts 18.0 cm from the elbow. A mechanical equivalent of the situation is shown in Figure 2(b). Find

i. the tension in the biceps, and **(9 marks)**

ii. the x and y components of the reaction force R by the elbow. **(3 marks)**

iii. Determine and illustrate the angle the reaction force R by the elbow makes with the horizontal. **(3 marks)**

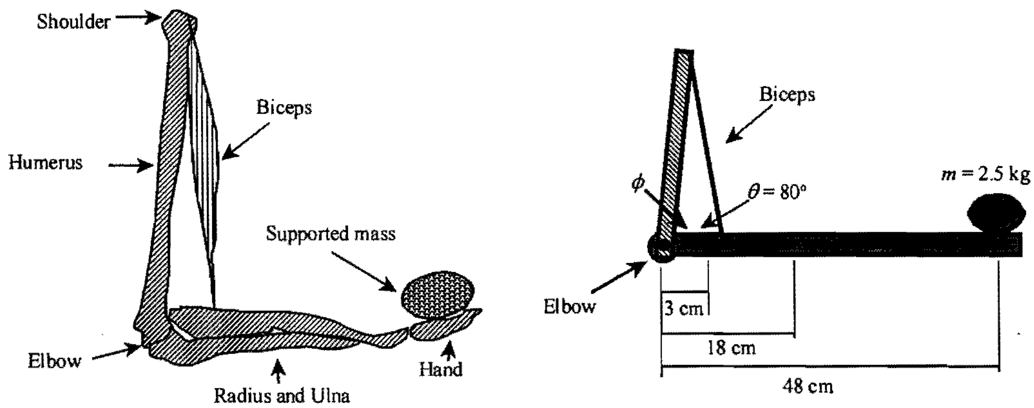
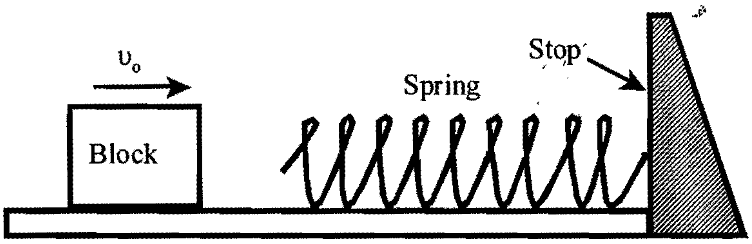


Figure 2. **(a)** **(b)**

QUESTION 3

a. A mass $m = 1.50$ kg moves with a velocity $v_0 = 10.0$ m/s towards a spring resting on a frictionless surface. The spring constant is 840 N/m. Find the amount by which the spring compresses when the mass momentarily comes to rest. **(5 marks)**



b. A car of mass $m_1 = 1875$ kg travelling east towards an intersection crashes into the side of a stalled car of mass $m_2 = 1051$ kg facing north in the middle of the intersection. Skid marks show that the vehicles slide together a distance of $d = 25.0$ m before coming to a stop. The coefficient of friction between the road surface and the tyres is 07.00. The speed limit where the accident occurred is 120 km/hr.
   i. Find the initial velocity of the wreckage just after collision. **(5 marks)**
   ii. Determine whether the driver in the moving vehicle had violated the speed limit. **(5 marks)**

c. A sharp shooter fires a rifle while standing with the butt of the gun against his shoulder. Your physics tells you that the forward momentum of the bullet is equal but opposite the backward momentum of the gun. Why is it less dangerous to be hit by the gun as compared to the bullet? **(3 marks)**

d. A construction worker of mass 80.0 kg falls off a building from a height of 12.5 m. Determine the force of impact with the ground if the collision time is 0.100 s. Also determine by comparing the force to the weight of a 50 kg bag of cement if injury is likely. **(5 marks)**

e. If the speed of a particle is doubled, by what factor is its momentum and kinetic energy changed? You can use calculations if helpful. **(2 marks)**

QUESTION 4

(a) The thickest and strongest tendon in the human body is the Achilles tendon that connects the heel to the calf muscle. Its average cross-sectional area, length and Young's modulus are 78.1 mm^2, 25.0 cm and 474 MPa, respectively. During a sprint a 75 kg sprinter exerts 13.0 times his body weight on the tendon.

i. Find the stress on the muscle. **(2 marks)**

ii. What is the strain on the muscle? **(2 marks)**

iii. By how much does the tendon stretch as a length, fraction and percent? **(3 marks)**

(b) A flat bottomed river barge is 6.00 m deep. It supports a mass 1.80 million kg of cargo in fresh water. The top of the barge is 1.00 m above the water level. The barge has an average density of 168 kg/m^3. Determine the cross-sectional area of the barge. First state the principle used to solve this problem. **(6 marks)**

(c) A medicine is administered intravenously to a patient with systolic/diastolic pressures of 140/90 mmHg, using a hypodermic syringe with a medicine that has the same density as water. The barrel of the syringe has a cross-sectional area $A = 2.5 \times 10^{-5}$ m^2, and the needle has a cross-sectional area $a = 1.00 \times 10^{-8}$ m^2. (See Figure 4.) A force of 2.00 N is used on the plunger to push the medicine.

i. What is the pressure applied to the medicine in the syringe? **(1 mark)**

ii. Find the ratio of the square of the velocity of the medicine inside the barrel to the square of the velocity of the medicine inside needle? **(3 marks)**

iii. What is the systolic pressure of the blood in the vein in Pascal? **(1 mark)**

iv. With what velocity does the medicine enter the blood vein under systolic pressure? State assumptions made. **(7 marks)**

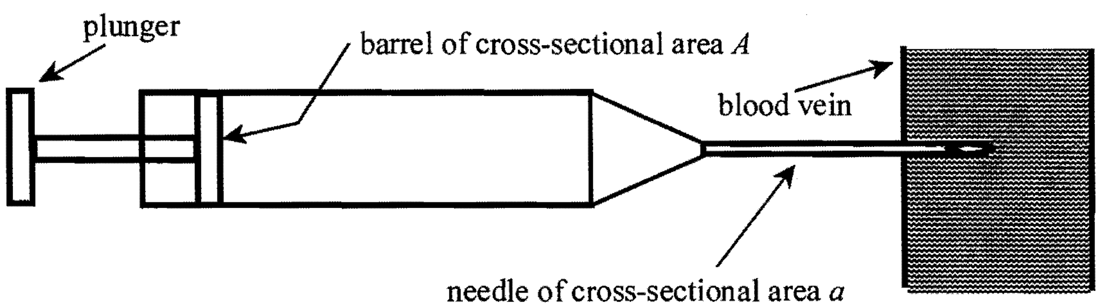


Figure 4

QUESTION 5

a. The same quantity of the same food is placed in two different pots. Water is poured in one pot to a level that covers the food, while in the other pot an equal amount of cooking oil is added. The two pots are placed in on hot plate set to provide equal amounts of heat per unit time. Which food will cook faster and why? **(3 marks)**

b. A PHY101 student adds steam at 100°C to ice at 0.00°C in a perfectly insulating container.
   i. If the amount of steam is 10.0 g and that of ice is 50.0 g show that all the ice melts and find the final temperature of the system. **(10 marks)**
   ii. If now the amount of steam is reduced to 1.00 g and the amount of ice remains at 50.0 g, show that not all the ice melts and find the amount that is left when the system comes to equilibrium. **(7 marks)**

c. A diver in the sea is 25.0 m below the water surface and the temperature of the water in this depth is found to be 5.00°. He exhales and bubbles that rise to the top. One of the bubbles has a volume of 1.00 cm^3. What is the volume of this bubble when it reaches the top surface which is at a temperature of 20.0°C? Take the density of seawater to be 1025 kg/m^3. **(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
Coulomb constant $k_e = 8.9875 \times 10^9$ $N{\cdot}m^2/C^2$
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
Speed of light in vacuum $c = 2.997\,8 \times 10^8$ m/s
Speed of sound in air $v_s = 343$ m/s
Standard atmospheric pressure = 1.013×10^5 Pa
Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ $W/(m^2{\cdot}K^4)$
Threshold of hearing $I_0 = 10^{-12}$ W/m^2
Universal gravitational constant $G = 6.67 \times 10^{-11}$ $N{\cdot}m^2/kg^2$
1 calorie = 1c = 4.186 J
1 food calorie = 1Calorie = 1C = 10^3 calories = 4.186×10^3 J.

Fresh 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
1 Ci = 3.7×10^{10} decays/s
1Bq = 1 decay/s