UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2011/2012

TITLE O F PAPER: INTRODUCTORY PHYSICS I

COURSE NUMBER: P101

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

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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. **(4 marks)**

b. A body with an initial velocity of 3 m/s is accelerated at 4 m/s^2 for 5 s. It then moves at constant velocity for 3 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 netball player throws a ball from a height $y_0 = 1.8$ m above ground, with a velocity of 10 m/s at an angle of 30^0 with the horizontal.

   i. How high above ground does the ball rise? **(4 marks)**

   ii. How much time does the ball spend in flight? **(2 marks)**

QUESTION 2

a. Consider Figure 1 below. Let the coefficient of static friction between mass m_2 and the incline be $\mu = 0.4$. The system remains in equilibrium. The problem is to find the maximum value of m_1 for the system to remain in equilibrium. For the maximum value of m_1, the system is such that m_1 is just about to move down and m_2 is just about to move up the inclined plane.

   i. Make a resolved force diagram for each mass. **(5 marks)**
   ii. Write down the equations of motion for each mass. **(3 marks)**
   iii. Find the maximum value of the mass m_1 to keep the system in static equilibrium? **(4 marks)**

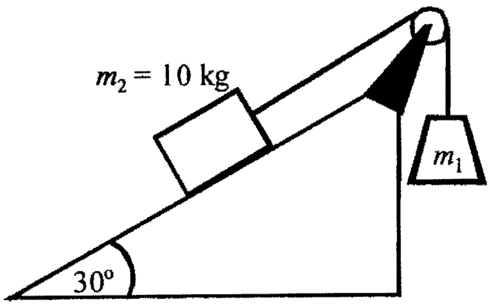

Figure 1.

b. A person holds a mass $m = 2.5$ kg in his hand 48 cm from the elbow. The forearm is horizontal as shown in Figure 2(a). The biceps muscles are attached at a distance of 3 cm from the elbow and make an angle $\theta = 70°$ with the horizontal. The effective weight of the forearm is 1.52 kg and acts 18 cm from the elbow. A mechanical equivalent of the situation is shown in Figure 2(b). Find

   i. the tension in the biceps, **(8 marks)**
   ii. the x and y components of the reaction force by the elbow, and **(3 marks)**
   iii. the angle the reaction force by the elbow makes with the horizontal. **(2 marks)**

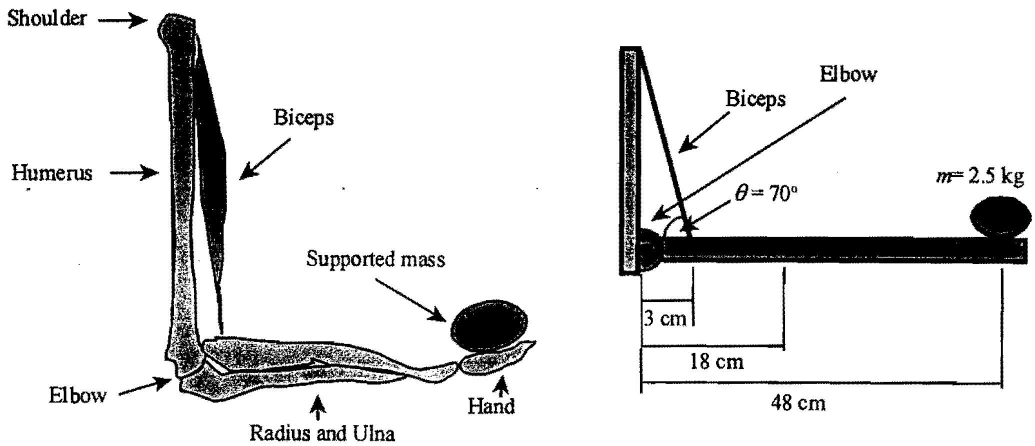

Figure 2. **(a)** **(b)**

QUESTION 3

a. A student of mass 55 kg eats a breakfast rated at 1000 food calories. How far can he climb up a mountain before getting hungry again? Neglect energy required to move horizontally. **(4 marks)**

b. A mass $m = 20$ kg moves with a velocity $v_0 = 10$ m/s towards a spring resting on a frictionless surface. The spring is held against a stop (See Figure 3). Calibration of the spring shows that a force of 50 N is required to compress the spring 2.5 cm.

   i. Find the spring constant of the spring. **(2 marks)**
   ii. What is the initial kinetic energy of the block? **(2 marks)**
   iii. Find the maximum compression of the spring? **(4 marks)**

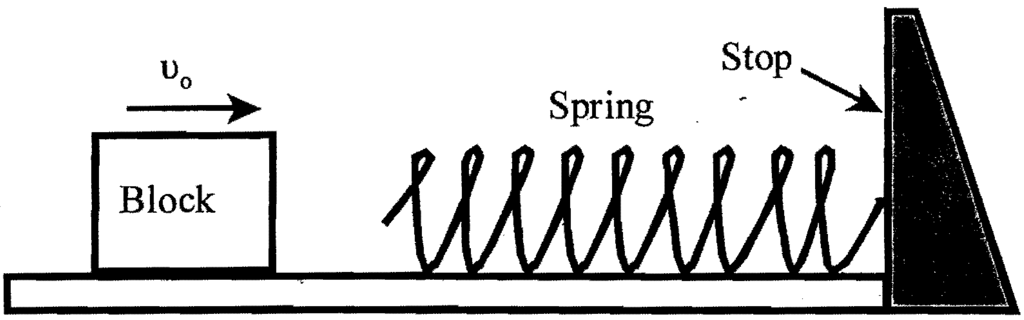

Figure 3.

c. A head-on collision occurs between a truck of mass $M = 5000$ kg moving towards the right at $v_t = 10$ m/s and a car of mass $m = 1000$ kg moving towards the left with a velocity $v_c = 10$ m/s. Both vehicle masses include the masses of the drivers, each of mass 80 kg. The collision time is 0.12 s. After the collision, the two vehicles stick together making one wreckage that moves in the original direction of the truck.

   i. Find the velocity of the wreckage just after impact. **(5 marks)**
   ii. Determine the force of collision on each vehicle using the rate of change of momentum for the car and then using the rate of change of momentum for the truck. **(4 marks)**
   iii. Comment on the results from ii., and state how they relate to Newton's Third law. **(4 marks)**

QUESTION 4

(a) A steel piano wire of length $l_0 = 1.12$ m, cross-sectional area $A = 6 \times 10^{-3}$ cm^2 long and Young's modulus $Y = 20 \times 10^{10}$ N / m^2 is under a tension of 115 N.

- (i) What is the stress on the wire? **(2 marks)**
- (ii) By how much does it stretch under the tension? **(3 marks)**

(b) State Pascal's law and give one example with explanations on how it is used in every day life. **(6 marks)**

(c) A medicine is administered intravenously to a patient with systolic/diastolic pressures of 140/90, 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 $a = 1 \times 10^{-8}$ m^2. (See Figure 4.) A force of 2 N is used on the plunger to push the medicine.

- (i) What is the pressure applied to the medicine in the syringe? **(2 marks)**
- (ii) How is the square of the velocity of the medicine inside the barrel related 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? **(2 marks)**
- (iv) With what velocity does the medicine enter the blood vein under systolic pressure? **(7 marks)**

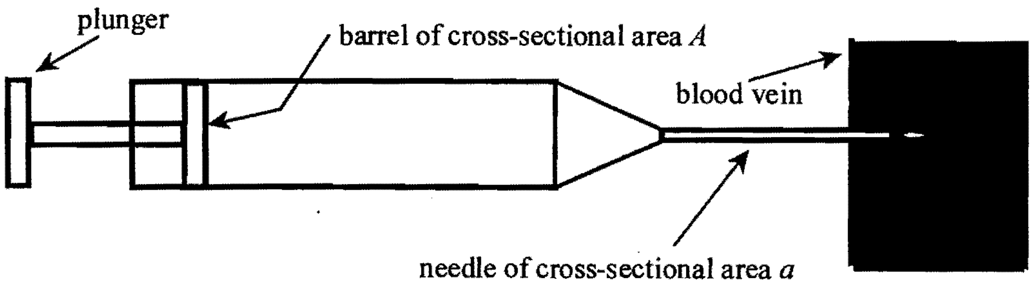

Figure 4

QUESTION 5

a. How does a thermo-flask prevent heat transfer between its contents and the surroundings? **(7 marks)**

b. An insulated vessel contains ice of mass $m_i = 250$ g at a temperature $T_i = 0^oC$. Water of mass $m_w = 600$ g at a temperature of $T_w = 18^oC$ is added to the ice.

  i. Show that the energy required to melt the ice is greater than the energy available in the water when cooled to 0°C which means that some ice is left over at equilibrium. **(4 marks)**

  ii. How much ice is left over when the system reaches equilibrium? **(3 marks)**

c. A clinic cylinder of radius 10 cm and height 1.2 m contains three atmospheres of oxygen of molar mass 32.0 g/mol at a temperature of 25°C.

  i. What is the weight of the gas in the cylinder? **(4 marks)**

  ii. What is the force the gas exerts on each face of the cube? **(4 marks)**

  iii. Why can such a small amount of gas exert such a great force? **(3 marks)**

GENERAL DATA SHEET

Avogadro's number $N_A = 6.022 \times 10^{23}\ mol^{-1}$
Speed of light in vacuum $c = 2.9978 \times 10^8$ m/s
Speed of sound in air = 343 m/s
Gravitational acceleration = 9.80 m/s^2
Universal gravitational constant $G = 6.67 \times 10^{-11}\ N\ m^2/kg^2$
Density of mercury (Hg) = $1.36 \times 10^4\ kg/m^3$
Density of water = 1000 kg/m^3
Standard atmospheric pressure = 1.013×10^5 Pa
Gas constant R = 8.314 J/(K mol)
Threshold of hearing $I_0 = 10^{-12}\ W/m^2$
1 calorie = 1 c = 4.186 J
1 food calorie = 1 Calorie = 1C = 10^3 calories = 4.186×10^3 J

c_{water} = 4186 J/(kg K) c_{ice} = 2090 J/(kg K) c_{steam} = 2079 J/(kg K)
$L_{f\text{-}ice} = 3.33 \times 10^5$ J/kg $L_{v\text{-}water} = 2.260 \times 10^6$ J/kg

Refractive index of water $n_{water} = 1.333$
k_e = 8.9875 x 109 $N{\cdot}m^2/C^2$
Charge of an electron = -1.6×10^{-19} C
Charge of a proton = $+1.6 \times 10^{-19}$ C
1 atomic mass unit = 1 amu = 1 u = 1.66×10^{-27} kg
Electron mass, $m_e = 9.109 \times 10^{-31}$ kg
Proton mass, $m_p = 1.673 \times 10^{-27}$ kg
Neutron mass $m_n = 1.675 \times 10^{-27}$ kg