UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2009/10

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

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) A body with an initial velocity of 4 m/s is accelerated at 3 m/s^2 for 4 s. It then moves at constant velocity for 3 s after which it is accelerated at -4 m/s^2 for 5 s. Sketch

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

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

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

(b) A negligent camper parks his vehicle with faulty parking brakes in neutral on a steep incline a certain distance from the edge of a cliff 30 m high. The incline makes an angle of 37° with the horizontal. (See Figure 1). The vehicle starts moving on its own from rest and reaches a velocity of 20 m/s, when it reaches the edge of the cliff.

(i) What are the *x*- and *y*-components of the velocity of the vehicle when it hits the bottom of the cliff? **(4 marks)**

(iii) How much time does the vehicle take to move from the edge of the cliff to the point where it lands at the bottom of the cliff? **(3 marks)**

(iv) How far from the edge of the cliff does the vehicle land? **(3 marks)**

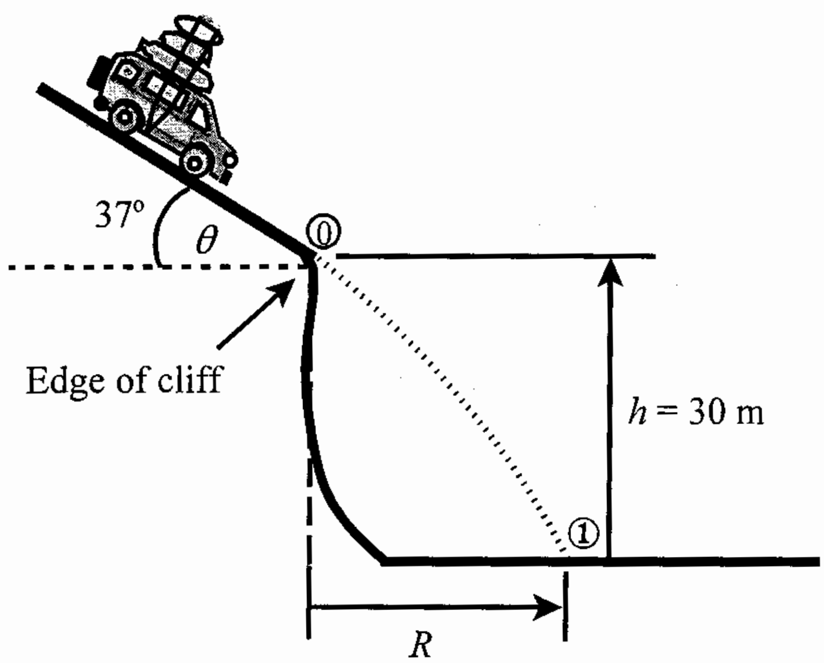

Figure 1.

QUESTION 2

(a) The system shown in Figure 2 is in equilibrium. The beam is uniform, 12 m long, and weighs 2000 N. The cable is attached to the beam at a distance of 10 m from the wall, and the mass m on the beam is centred at 4 m from the wall.

(i) Find the tension in the cable. **(7 marks)**

(ii) Find the x- and y-components of the reaction force by the wall. **(3 marks)**

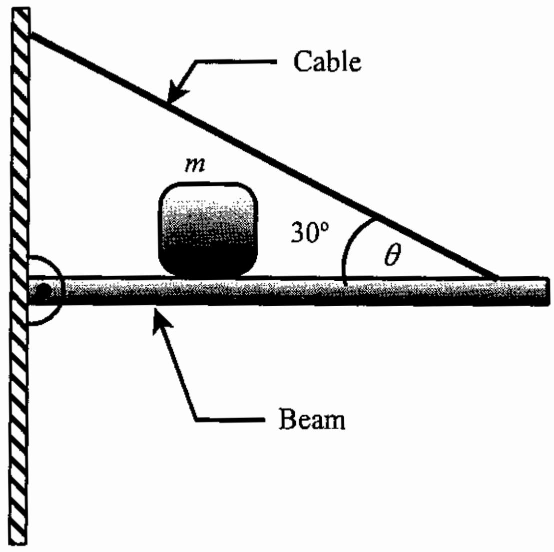

Figure 2.

(b) The system shown in Figure 3 moves such that m_1 moves down the inclined plane and m_2 moves to the right and m_3 moves up the inclined plane. Neglect the masses of the cords and assume the pulleys are frictionless. The coefficient of friction between all surfaces is 0.1.

(i) Make a resolved force diagram for each body from which useful equations of motion can be obtained. **(4 marks)**

(ii) Write down the equations of motion for each body. **(6 marks)**

(iii) Determine the expression for the acceleration of the system. **(5 marks)**

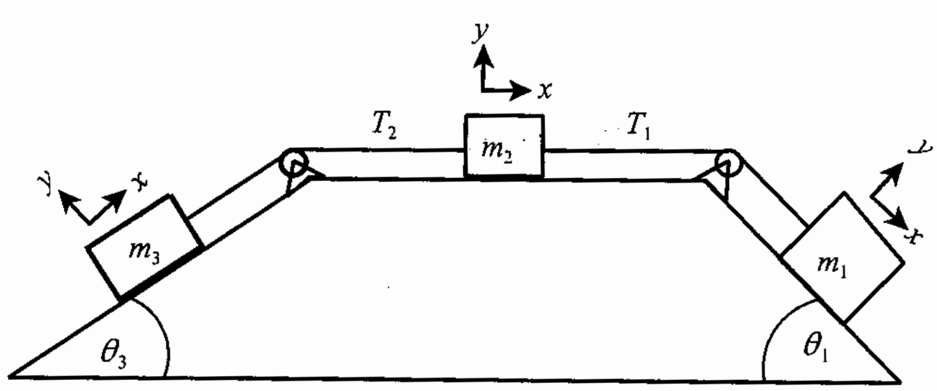

Figure 3.

QUESTION 3

(a) A body is acted upon by a force $\vec{F} = (6\hat{i} - 2\hat{j})$ N and is displaced by the vector $\vec{r} = (3\hat{i} + 1\hat{j})$ m. What is the work done by the force $\vec{F}$ to displace the body by the vector $\vec{r}$? **(3 marks)**

(b) A body is attached to a horizontal spring of spring constant k. A force of 200 N is required to compress the spring a distance of 5 cm.

(i) What is the spring constant for the spring? **(2 marks)**

(ii) What is the potential energy of the system when the spring is compressed 5 cm? **(2 marks)**

(iii) After the body is let go, what is the velocity of the mass when the spring returns to its original length? **(4 marks)**

(c) A billiard ball B rests on a frictionless table and is struck by another billiard ball A of the same mass m, which is originally traveling at velocity $\upsilon_A = 20$ m/s and is deflected at an angle $\theta_A = 30°$ from its original direction with a speed υ_A' as shown in Figure 4. Billiard ball B acquires a velocity υ_B' at an angle θ_B with the original direction of billiard ball A.

(i) Find the angle θ_B, the velocity of billiard ball B makes with the original direction of billiard ball A. **(10 marks)**

(ii) Find the speed υ_B' of billiard ball B after the collision. **(2 marks)**

(iii) Determine by calculation whether or not the collision is perfectly elastic. **(2 marks)**

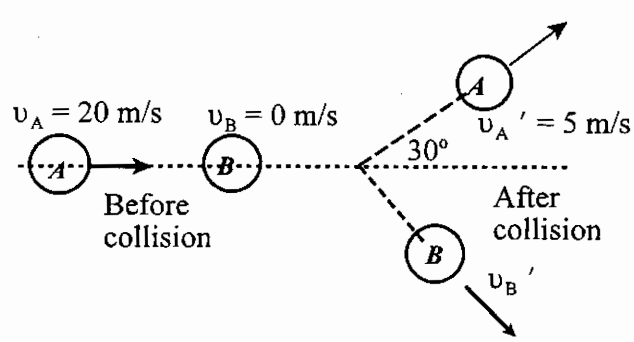

Figure 4.

QUESTION 4

(a) The four particles illustrated in Figure 5 are connected by rigid rods of negligible mass. The origin is at the centre of the rectangle the masses form. The system is rotated from zero angular velocity to an angular velocity of 62.8 rpm in 5 s.

(i) What is the angular acceleration of the system? **(3 marks)**
(ii) What is the moment of inertia of the system about the *z*-axis? **(4 marks)**
(iii) What torque is applied to the system? **(2 marks)**
(iv) What is the final rotational kinetic energy of the system? **(2 marks)**
(v) What is the final centripetal force on the particle of mass 4 kg? **(2 marks)**
(vi) What is the final angular momentum of the system? **(2 marks)**

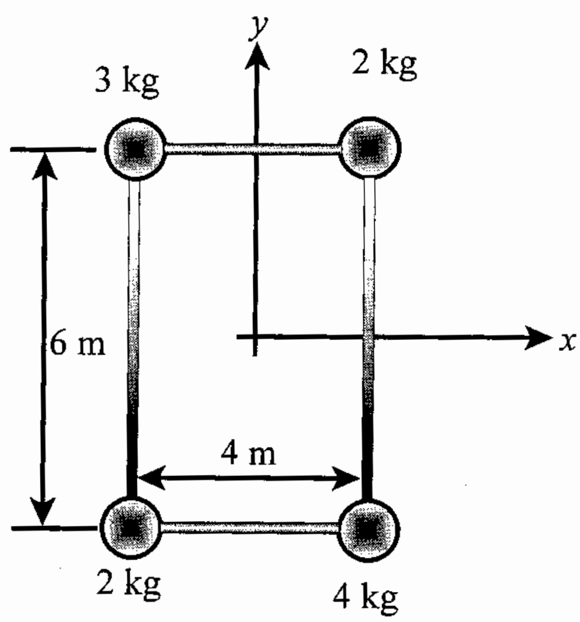

Figure 5.

(b) Discuss with the aid of a diagram the stress versus strain graph for ductile metal and label all its points. Give the characteristics of each region. **(7 marks)**

(c) What is Young's modulus? **(3 marks)**

QUESTION 5

(a) With the aid of a diagram, show how hydraulics can be used to achieve a higher force than the applied force. **(5 marks)**

(b) A first year student of mass $m = 55$ kg, who cannot swim, wants to also have fun in a fresh water swimming pool. She finds a flat plastic slab of thickness $t_p = 5$ cm thick and density $\rho_s = 300$ kg/m^3, and wants to use it to float on the water without getting wet. Determine the minimum area A_p of the plastic slab she will need to float on the water. **(5 marks)**

(c) Steam from an overheating engine at a temperature of 130°C is bubbled into a perfectly insulated copper container of mass 20 kg, with water of mass 50 kg at an initial temperature of 20°C. The specific heat capacity of copper is 387 J/(kg.°C). Determine the final temperature of the system after 5 kg of steam has been bubbled into the water.

(15 marks)

GENERAL DATA SHEET

Speed of light in vacuum, $c = 2.9978 \times 10^8$ m/s
Speed of sound in air = 334 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 = 1.36×10^4 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)
Avogadro's number, $N_A = 6.022 \times 10^{23}$ mol^{-1}
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
Specific heat capacity for water, $c_w = 4186$ J/(kg K)
Specific heat capacity for ice, $c_i = 2090$ J/(kg K)
Specific heat capacity for steam, $c_s = 2079$ J/(kg K)
Latent heat of fusion for ice, $L_f = 3.33 \times 10^5$ J/kg
Latent heat of vapourisation for water $L_v = 2.260 \times 10^6$ J/kg
Coulomb's constant, $k_e = \dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9$ Nm^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