UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2013/2014

TITLE OF 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) Given two vectors $\vec{A}$ and $\vec{B}$, state what is the meaning of the dot product $(\vec{A} \cdot \vec{B})$ of the two vectors. Also include an equation and illustrative diagram(s). **(4 marks)**

(b) For vectors $\vec{A} = 4\hat{\imath} - 3\hat{\jmath} + 5\hat{k}$ and $\vec{B} = -2\hat{\imath} + 4\hat{\jmath} - 3\hat{k}$, find

(i) the angle between the two vectors, and **(7 marks)**

(ii) the cross-product $\vec{A} \times \vec{B}$. **(4 marks)**

(c) A basketball player standing on the floor 10 m from the basket hoop shoots a basketball from a height of 2 m, (see Figure 1). The initial velocity of the ball is v_0 = 10.7 m/s and leaves the hands of the player at an angle $\vartheta = 40^{\circ}$ with the horizontal. The ball hits the basket after reaching maximum velocity.

(i) Find the time the basketball spends in flight to the basket hoop? **(3 marks)**

(ii) What is the height *h* of the hoop above ground? **(4 marks)**

(iii) Determine the x and *y*-component of the velocity of the ball when it enters the basket hoop. **(3 marks)**

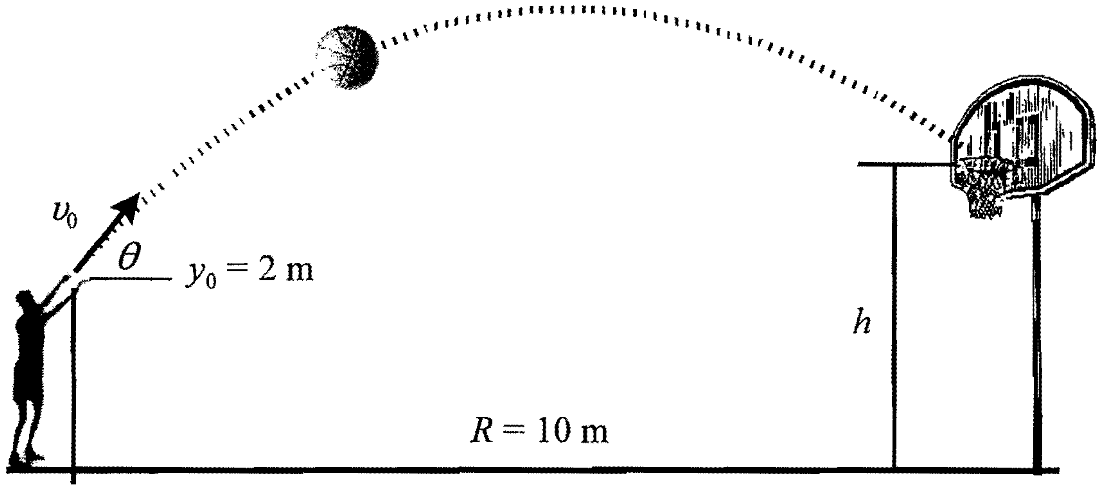

Figure 1.

QUESTION 2

(a) The three blocks in Figure 2 are connected by strings of negligible mass that pass over frictionless pulleys. The acceleration of the system is such that m_1 moves down the inclined plane, m_2 moves to the right and m_3 moves up the inclined plane. The acceleration of each mass is a = 2 m/s^2. The coefficient of friction is the same between all surfaces.

(i) Make force diagrams for each body. The forces must be resolved along appropriate coordinates so that useful equations of motion can be obtained. **(6 marks)**

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

(iii) Find the coefficient of kinetic friction. **(4 marks)**

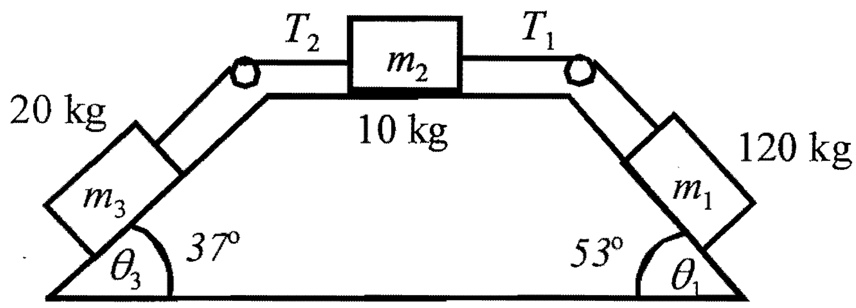

Figure 2.

(b) The system shown in Figure 3 is in equilibrium. The beam is uniform, 10 m long, and weighs 2000 N. The masses m_1 = 200 kg and m_2 = 300 kg are positioned at distances of 2 m and 6 m from the wall, respectively.

(i) Determine the tension in the cord. **(6 marks)**

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

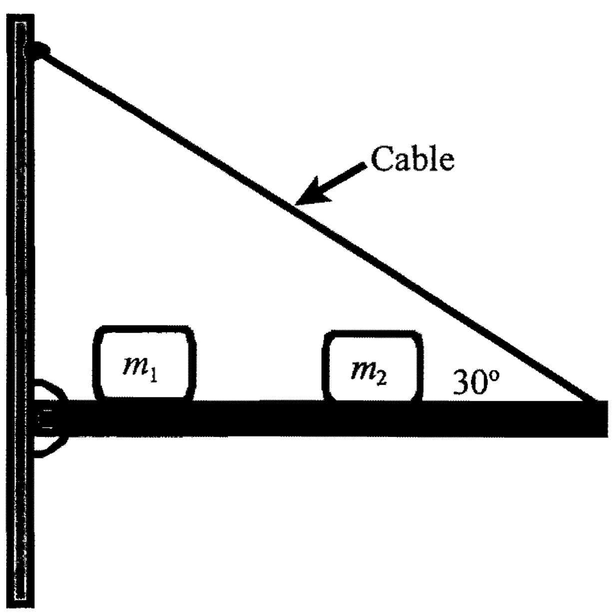

Figure 2.

QUESTION 3

4

(a) A body is projected vertically upward with a velocity of 50 m/s. Use energy methods to determine

(i) its maximum height h, and **(4 marks)**

(ii) its velocity v_{20} at a height $h_{20} = 20\text{ m}$.

(iii) and comment on the answer obtained **(4 marks)**

(b) A construction worker of mass 80 kg falls over a height of 20 m. The collision with the ground takes 0.05 s.

(i) Determine the force of impact with the ground. **(6 marks)**

(ii) Compare the force of impact to the weight of a 50 kg bag of cement, and use your own judgment to conclude as to whether the worker is likely to be injured in this collision. **(3 marks)**

(c) A car of mass $m_c = 1500$ kg traveling east (along positive x axis) with speed $v_c = 25\text{ m/s}$ collides at an intersection with a small truck of mass $m_t = 2500$ kg van travelling north (along the y axis) at a speed of $v_t = 20$ m/s. Find the direction of motion of the wreckage if the two stick to each other after the collision. **(8 marks)**

QUESTION 4

(a) A certain person has bones having a Young's modulus $Y = 1.5 \times 10^{10}$ N/m^2, and maximum strength of 1.5×10^8 N/m^2.

(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? **(5 marks)**

(ii) If the femur has length $l_0 = 25$ cm and is subjected to a force of 62500 by how much does the bone shorten under this force? The force is acting within the proportional region) **(4 marks)**

(b) First state the principle used to solve this problem. .A solid platform of area $A = 4$ m^2 and density $\rho_p = 650$ kg/m^3 is to be used to support a load of mass m_l = 850 kg on fresh water. Determine the thickness t of the platform to just support the load above the water. **(8 marks)**

(c) A hypodermic syringe contains medicine with the density of water. The barrel of the syringe has a cross-sectional area A = 2.50 x 10^{-5} m^2 and the needle has a cross-sectional area of a = 1.00 x 10^{-8} m^2. In injecting a patient, a force of 2 N is applied to the barrel to make the medicine squirt horizontally through the needle. Use Bernoulli's equation to determine the speed with which the medicine comes out of the needle. The blood pressure in the vain is 120 mm Hg. **(8 marks)**

QUESTION 5

(a) On a day when the temperature reaches 98 °F, what is the temperature in degrees Celsius and in Kelvin? **(4 marks)**

(b) A segment of steel railroad track has a length of 30 m at a temperature of 0 °C. The coefficient of thermal expansion for steel is 11×10^{-6} °C^{-1}. What is the length when the temperature rises to 40 °C. **(5 marks)**

(c) A 1.50 kg piece of steel at a temperature of 600°C is dropped into a well insulated container with 20 kg of water at 25 °C. The specific heat capacity of steel is 448 J/kg °C .What is the final temperature of the system? **(8 marks)**

(d) A hollow cube 25 cm on each edge contains nitrogen with an equivalent molar mass of 28.02 g/mol at atmospheric pressure and a temperature of 20 °C.

(i) Find the weight of the gas. State any assumptions made. **(3 marks)**

(ii) What is the force the gas exerts on each face of the cube? **(2 marks)**

(iii) Explain why such a small amount of gas can exert such a great force. **(3 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*) = 3.33×10^5 J/kg	L_v(*water*) = 2.260×10^6 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