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UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2010/11

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) Given the vectors $\vec{A} = 2\hat{i} + 3\hat{j} + 4\hat{k}$ and $\vec{B} = -\hat{i} - 2\hat{j} - 3\hat{k}$, find the cross product of the two vectors $(\vec{A} \times \vec{B})$. **(4 marks)**

(b) A particle starts moving from the origin with velocity of 6 m/s, and is accelerated at 3 m/s^2 for 4 s. It then moves at constant velocity for 4 s after which it is accelerated at -5 m/s^2 for 6 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)**

(c) An aircraft carrying relief supplies flies over an area devastated by a natural disaster. The pilot sights the refugee camp and lowers the aircraft to an altitude of 100 m with a horizontal speed of 50 m/s. The pilot releases the supplies simply by opening the cargo doors.

(i) How much time do the supplies spend in air? **(3 marks)**

(ii) At what distance from the refugee camp must the supplies be dropped so that they land right at the camp? **(3 marks)**

QUESTION 2

(a) The system shown in Figure 1 is in equilibrium. Static friction between m_2 and the surface keeps m_2 stationery.

(i) Find the tension in each cord. **(7 marks)**

(ii) Find the coefficient of static friction between m_2 and the surface, assuming the friction is at the maximum value. **(3 marks)**

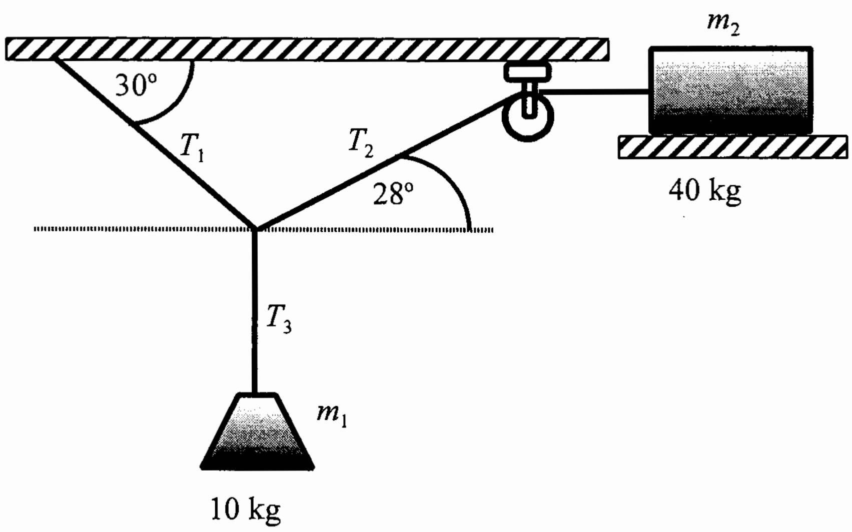

Figure 1.

(b) A force F is applied to the system shown in Figure 2. The system moves such that m_1 and m_3 move towards the right while m_2 moves up the inclined plane. All bodies move at constant velocity. The the coefficient of kinetic friction between all surfaces in contact is 0.5. The pulleys have negligible mass and are frictionless. The masses of the cords can be neglected.

(i) Study the system carefully and make correct force diagrams for each mass. **(6 marks)**

(ii) Write down the force equations for each mass. **(4 marks)**

(iii) Find the applied force F. **(5 marks**

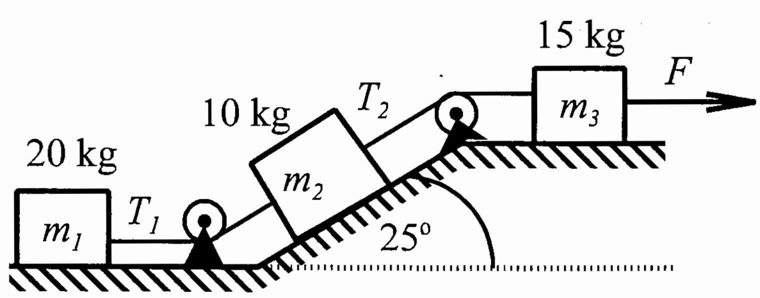

Figure 2.

QUESTION 3

(a) A household uses 5 indoor incandescent lamps rated at 65 W, and each operates for 4 hours a day. In addition they use 4 outdoor security incandescent lamps each rated at 100 W which are kept on for 8 hours a day. Electricity costs 75 cents per kilowatt-hour.

(i) Determine the annual cost of lighting for the household. **(3 marks)**

(ii) If the household changes to compact flourescent lamps (CFLs) rated at 15 W for indoor lighting and 28 W for the security lights, how much money would they save per year in electricity cost? **(3 marks)**

(b) A block of mass $M = 1$ kg resting on a frictionless surface is connected to a coil spring of spring constant $k = 900$ N/m placed against a stop. A bullet of mass $m = 5$ g is fired into the block with a velocity $\upsilon_0 = 400$ m/s. The bullet passes through the block leaving the block with velocity V, and the impact compresses the block by a distance $A = 5$ cm. See Figure 3. Assume the collision between the block and the bullet is very fast.

(i) Find the speed υ_f with which the bullet emerges from the block. **(6 marks)**

(ii) What percentage of the energy is converted into heat during the impact.**(4 marks)**

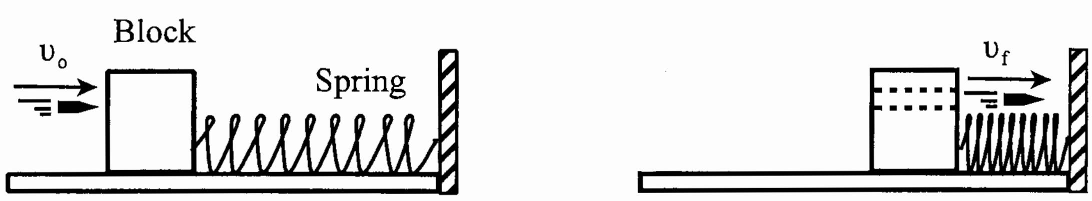

Figure 3. (a) Before impact (b) After impact

(c) A woman of mass $m = 60$ kg stands at the rim of a horizontal turntable having a moment of inertia of $I_T = 500$ kg m^2 and a radius $R = 2$ m. The turntable is initially at rest and is free to rotate about a frictionless vertical axle through its centre. The woman starts to walk clockwise around the rim at constant speed v = 1.5 m/s relative to the ground.

(i) In what direction does the turntable rotate? **(2 marks)**

(ii) At what angular velocity does the turntable rotate? **(5 marks)**

(iii) How much work does the woman do to set herself and the turntable into motion? **(2 marks)**

QUESTION 4

(a) Assume that Young's modulus is 1.5×10^{10} N/m^2 for a human bone and that the bone will fracture if stress greater than 1.5×10^{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 2.5 cm. **(3 marks)**

(ii) If the bone is 25 cm long, by how much will it shortened if subjected to the maximum force? **(3 marks)**

(b) A U-tube of uniform cross-sectional area, open to atmosphere, is partially filled with mercury. Water is then added into both arms. If the equilibrium configuration of the tube is as shown in Figure 4, with h_2 = 1 cm, determine the value of h_3. **(6 marks)**

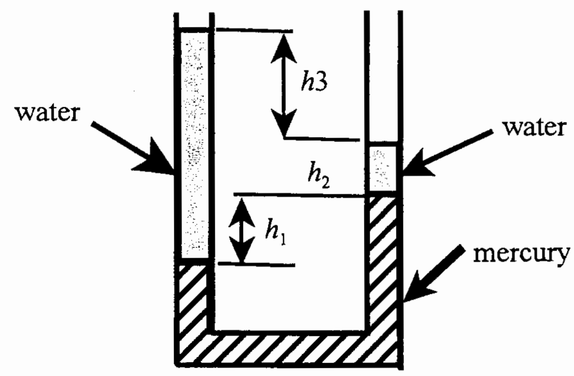

Figure 4.

(c) A Styrofoam slab has density ρ_s = 550 kg/m^3 and thickness h = 10 cm. A student of mass m = 55 kg who cannot swim rests on the slab on fresh water, and the slab sinks so that its top surface is at the level of the water. Find the area of the slab. **(6 marks)**

(d) A hypodermic needle contains medicine with the density of 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. A force of magnitude F = 2 N acts on the plunger, making the medicine to squirt horizontally with velocity υ from the needle (see Figure 5). Determine the speed of the medicine as it leaves the needle. **(7 marks)**

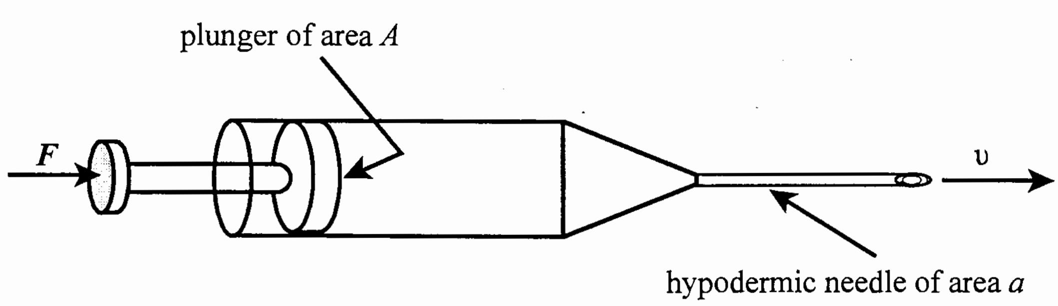

Figure 5.

QUESTION 5

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(a) On a day when the temperature is 98.6°F, determine the temperature in the Celsius and Kelvin scales. **(2 marks)**

(b) A copper telephone wire has essentially no sag between poles 35 m apart on a winter day when the temperature is -15°C. How much longer is the wire on a summer day when the temperature is 40°C? For copper $\alpha = 1.7 \times 10^{-5} (°C)^{-1}$. **(3 marks)**

(c) An ice bath is made by adding 250 g of ice at 0°C to 600 g of water at 18°C in an insulated vessel.

(i) Show that the heat energy from the water is not enough to melt all the ice, and therefore an ice bath is formed. **(4 marks)**

(ii) How much ice remains when the system reaches equilibrium? **(4 marks)**

(d) Why is it that on a cold day, a tile floor in a bathroom may feel uncomfortably cold to your bare feet, while a carpet floor in an adjoining room at the same temperature may feel comfortable? **(4 marks)**

(e) A hollow cube 10 cm on each edge contains air with an equivalent molar mass of 28.9 g/mol at atmospheric pressure and a temperature of 27°C.

(i) Find the weight of the gas. **(4 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. **(2 marks)**

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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, $k_e = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9$ 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