UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE
FAKULTEIT NATUURWETENSKAPPE

DEPARTMENT OF PHYSICS /DEPARTEMENT FISIKA

MODULE: **PHY1A3E/PHY3EA1**

CAMPUS **APK**

EXAM **12 JUNE 2019**
VENUE **CLES 101**
TIME SLOT **08:30**

LECTURER **DOOMNULL UNWUCHOLA**

MODERATOR **PROF G.R. HEARNE**

DURATION 180 min **MARKS 142**

THIS PAPER CONSIST OF 8 PAGES INCLUDING THE COVER PAGE

INSTRUCTIONS: Answer ALL questions and include detailed diagrams respectively.

QUESTION 1 follows /…

Question 1 [25]

1.1 A hydrometer has a circular stem of diameter 2 mm. it floats in alcohol of density 800 kg.m^{-3} and surface tension 25 x 10^{-3} N.m^{-1}. How much deeper does it float than if the alcohol had zero surface tension? The angle of contact between alcohol and the hydrometer stem is 0^{o}. (6)

1.2 How high will water rise, due to capillary action between two places of glass 0.1 mm apart when placed in vertically in water? Assume that the angle of contact between water and glass is 0^{o}, and that the surface tension of the water is 0.072 N.m^{-1}. (6)

1.3 What mass of mercury must be put into a glass bottle of capacity 100 cm^{3} so that the remaining volume is invariant with temperature?
[Density of mercury: 13.6 x 10^{3} kg. m^{-3}].
[Coefficient of volume of expansion: glass: 2.4 x 10^{-5} ^{o}C^{-1}].
[Coefficient of volume of expansion: mercury: 18.2 x10^{-5} ^{o}C^{-1}]. (8)

1.4 Shown in Figure1.4 is a man standing with his lower body against the wall, and bending forward from waist. Assume that 1/3 of his body weight acts vertically through his ankles, and that the remaining 2/3 acts through a point 0.7 m above his waist. If the tips of his toe are 0.2 m from the ankles, through what angle θ from the vertical can he lean before he topples forward?

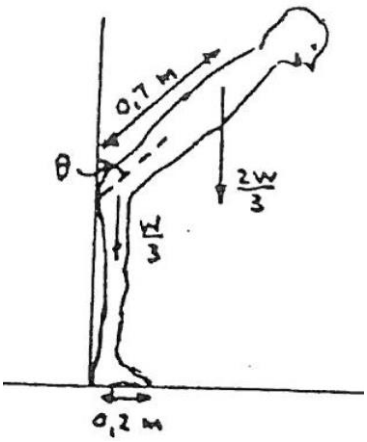


Figure 1.4 (5)

Question 2 [18]

2.1 A uniform ladder of the length 10 m and mass 40 kg stands against a smooth vertical wall with its foot 6 m from the wall. The limiting coefficient of friction between the foot of the ladder and the floor is 0.4. A man of mass 80 kg climbs up the ladder. Calculate:

(a) the force due to friction between the foot of the ladder and the floor when the man is half-way up the ladder, (3)

(b) the maximum value of the force due to friction (i.e. when the ladder starts to slip), and (3)

(c) how far up the ladder he is when this happens. (4)

2.2 Shown in Figure 2.2 is a man pulling on a string, the end of which is located 500 mm from the shoulder joint (**A**). The muscle (**BC**) pulling the arm down acts at a point 50 mm from the shoulder joint. Calculate:

2.2.1 the force that the muscle must exert to extend the spring, of spring constant 10^4 Nm^{-1}, by 10 mm, and (4)

2.2.2 the force exerted on the arm at the shoulder joint (**A**). (4)

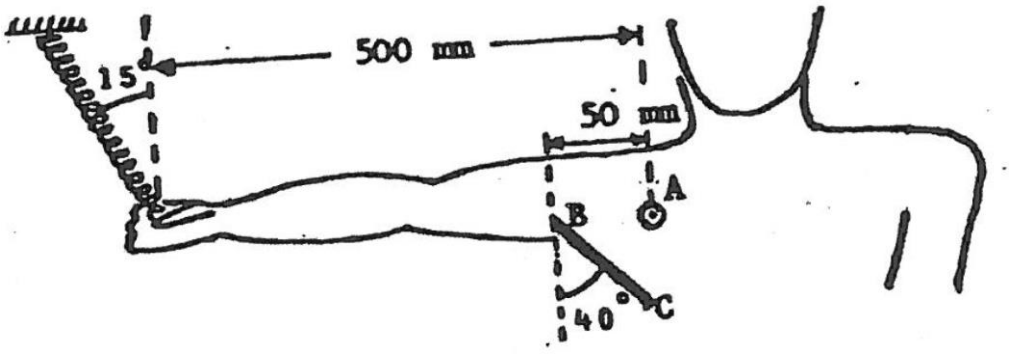


Figure 2.2

Question 3 [21]

3.1 At the request of the Physiotherapist at the Student Centre, a UJ rugby player is raising and lowering a weight of 50 N attached to his foot. His leg (together with the foot) has a weight of 40 N. When his leg is at 30^0 to the horizontal, the patellar ligament is at 50^0 to the horizontal and the distances to the points of application of the forces from the knee joint Fig 3.1. Calculate:

3.1.1 the tension in the ligament, (4)

3.1.2 the magnitude and direction of the reaction force at the knee joint? (6)

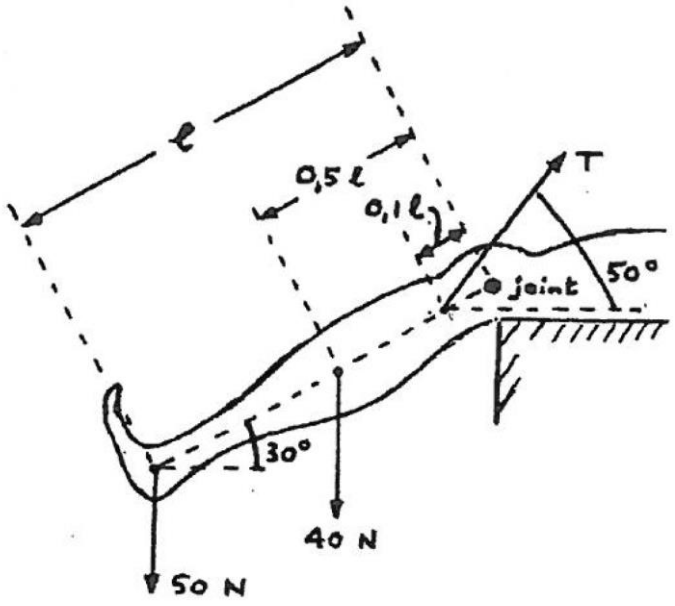
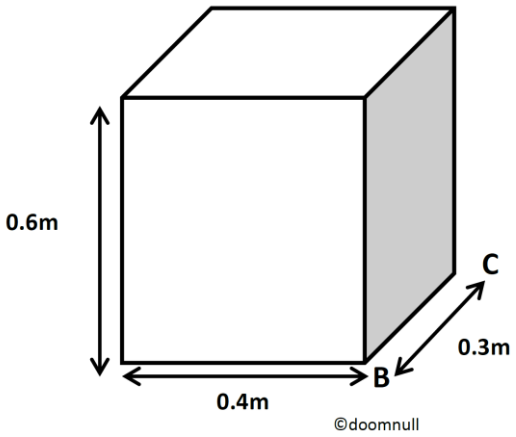


Fig. 3.1

3.2 A cube rests on a rough plane, the coefficient of friction between the cube and the plane is 0.82. Using detailed diagrams and proofs, show If the cube will topple first or slide first, if the angle the plane makes with the horizontal is increased? (5)

3.3



A uniform rectangular block of density 850 kg.m^{-3} rests on a horizontal table. Calculate:

3.3.1 the least force necessary to start it tilting about the edge **BC**; (3)

3.3.2 through what angle can it be tilted before toppling over. (3)

Question 4 [25]

4.1 A glass pane 200 mm wide and 5 mm thick just fits a vertical steel window-frame when both glass and steel are at 30 ^{o}C. Calculate the force the window-frame will exert on the glass in a vertical direction when both glass and steel are cooled to 5 ^{o}C . Assume that glass does not affect the contraction of the steel.
Coefficient of linear expansion for steel = 11 x 10^{-6} ^{o}C^{-1}.
Coefficient of linear expansion for glass = 8 x 10^{-6} ^{o}C^{-1}.
Young's modulus for glass = 7 x 10^{10} N.m^{-2}. (9)

4.2 Two copper spheres of equal mass are attached to strings of length 1m and suspended from the same point on the ceiling. Both spheres are drawn apart until each string is at 45^o to the vertical, and then simultaneously released. After the collision, the maximum angle each string makes with the vertical is 30^o. Assuming that 90 % of the energy lost is converted into heat; calculate the temperature rise of each sphere.
(Given: Specific heat of copper = 390 Jkg^{-1}^{o}C^{-1}; g = 10 ms^{-2}) (8)

4.3 A lead bullet travelling at 350 m/s strikes a target and is brought to rest. The bullet is initially at 27^{o}C and 20% of its energy was lost by heat. What fraction of the bullet melts?
Given: Specific heat of lead = 130 Jkg^{-1}^{o}C^{-1}.
Latent heat of fusion of lead = 2.5 x 10^4 Jkg^{-1} . (8)
Melting point of lead = 327^{o}C.

Question 5 [33]

5.1 Given the moment of inertia I of a continuous rigid object with the sum of the elemental masses dm expressed as an integral over the volume of the object:

$$I = \int r^2 \, dm$$

5.1.1 Show that the moment of inertia of a thin spherical shell (hollow sphere) of radius R and mass M is $I_{CM} = \frac{2}{3} MR^2$.
[Hint: $dm = \frac{M}{A} \, dA$]
[Hint: *dm* = (total mass*)* x (total surface area) / (surface area of strip)]
[Also use: $\int \cos^3\theta \, d\theta = \sin\theta - (\sin^3\theta) / 3$]. (6)

5.1.2 Show that the moment of inertia of a solid sphere of radius R and mass M is $I_{CM} = \frac{2}{5} MR^2$.
[Hint: $dm = \frac{M}{V} \, dv$] (6)

5.1.3 A star rotates with a period of 28 days about an axis through its centre. The period is the time interval required for a point on the star's equator to make one complete revolution around the axis of rotation. After the star undergoes a supernova explosion, the stellar core, which was of a thin spherical shell model of radius 10^5 km, collapses into a neutron star of solid sphere model of the same mass of radius 40 km. Determine the period of rotation of the neutron star.

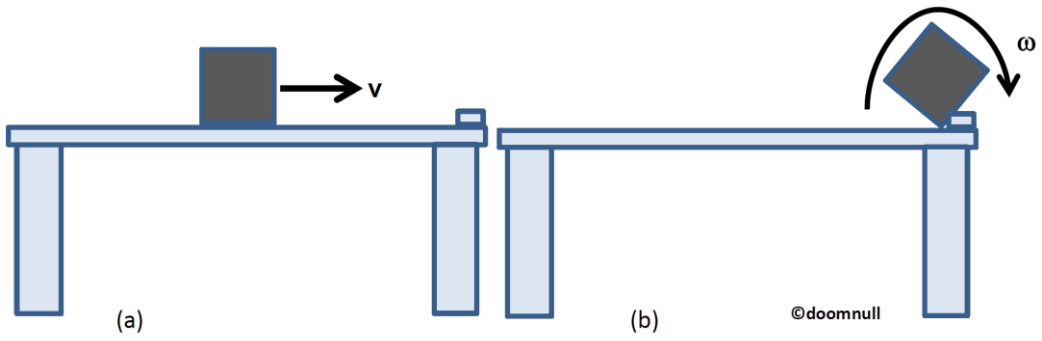
(6)

5.1.5 Using a triple integral to represent the three sides of a cube with side length 2a, by derivation show that the moment of inertia of the solid cube is

$I_{CM} = \frac{8}{3} Ma^2$. (8)

5.2.2 A solid cube of side 2a and mass M is sliding on a frictionless surface with uniform velocity **v** as shown in Figure 5.2a. In an inelastic collision, the cube hits a small obstacle at the end of the table that causes it to tilt as shown in Figure 5.2b. Find the minimum value of the magnitude of **v**,in terms of **only** g and a, such that the cube tips over and fall off the table. (7)

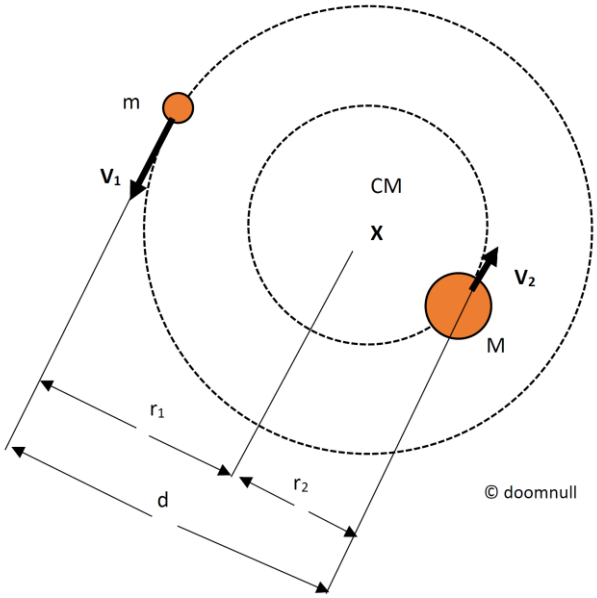
[Hint: Consider centre of mass and its change in height in the process.]



Question 6 [20]

6.1 Two stars of masses m and M, separated by a distance d, revolve in circular orbits about their centre of mass as shown in Figure 6.1. Show that each star has a period given by

$$T^2 = 4\pi^2 d^3/[G(M + m)].$$



(10)

6.2 A normal human ear can distinguish a difference in sound intensities of 0.6 dB at a certain frequency. What percentage increase in power output is required to raise the sound level by 0.6 dB? (5)

6.3 A person produces a note at a frequency of 250 Hz in air of molar mass 29 g. What would the frequency be if he filled his lungs with hydrogen of molar mass 2 g. (5)

END