UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE
FAKULTEIT NATUURWETENSKAPPE

DEPARTMENT OF PHYSICS /DEPARTEMENT FISIKA

MODULE: **PHY1A3E**

CAMPUS **APK**

EXAM **02 JUNE 2014**

EXAMINER **DOOMNULL UNWUCHOLA**

MODERATOR **Prof. G. HEARNE**

DURATION 150 min* **MARKS 142**

THIS PAPER CONSIST OF 7 PAGES INCLUDING THE COVER PAGE

INSTRUCTIONS: Answer ALL questions

QUESTION 1 follows /…

Question 1 [32]

1.1. Using the triple integral to represent the three sides of a cube, derive the moment of inertia of a solid cube with side length 2a. (7)

1.2. A solid cube of wood of side 2*a* and mass *M* is resting on a horizontal surface. The cube is constrained to rotate about a fixed axis *AB* (Fig. 1.2). A bullet of mass *m* and speed *v* is shot at the face opposite *ABCD* at a height of 4*a*/3. The bullet becomes embedded in the cube. Find the minimum value of v required to tip the cube so that it falls on face *ABCD* [Assume *m* <<< *M* and use the moment of inertia of the cube as (8/3)Ma^2] (8)

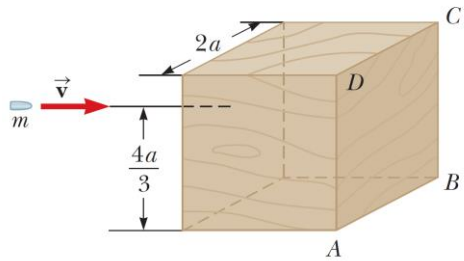

Fig. 1.2

1.3. A toy aeroplane of mass 0.5 kg, tied to a thin steel wire 30 m long, moves in a horizontal circle at a constant speed such that the wire is at 40^o to the horizontal (Fig. 1.3). The aeroplane goes around a complete circle every 8 s, and the tension in the wire is 6 N. Ignoring the weight of the wire calculate:

(a) The speed of the aeroplane. (3)

(b) The magnitude and direction of the lifting force on the aeroplane. (4)

(c) The strain in steel wire at the elastic limit is 1.5 x 10^{-3}. What is the smallest diameter of the steel wire necessary if the elastic is not to be exceeded? (Young's modulus of steel = 2.0 x 10^{11}N/m^2) (4)

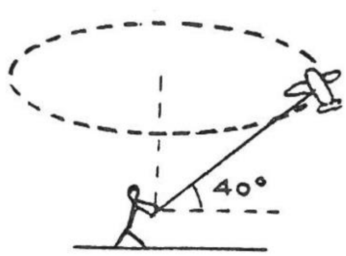

Fig. 1.3

QUESTION 1 continues /…

1.4. A wire W_1 has length L, and diameter d and Young's modulus Y. A ball of mass m is welded to one end. Another wire W_2 has length $2L$, diameter $2d$ and Young's modulus $Y/2$. A ball of mass $2m$ is welded to one end. The two wires are suspended vertically, with the free end of W_1 attached to the ball of W_2, as shown in (Fig. 1.4).

(a) Show that the strain in W_1 is $\varepsilon_1 = 4mg / \pi d^2 Y$. (3)

(b) Show that the ratio $\varepsilon_1 / \varepsilon_2$ of the strains in the wires is 2/3. (3)

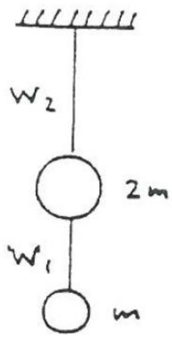

Fig. 1.4

Question 2 [30]

2.1 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 2.1. Calculate:

(a) the tension in the ligament, (4)

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

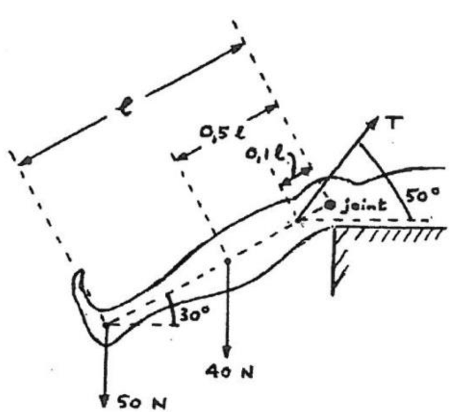

Fig. 2.1

<u>QUESTION 2</u> continues /…

2.2. In the apparatus shown in Fig. 2.2, S is a hollow sphere of negligible mass and volume 10^{-4} m^3. R is a piece of rubber of length 0.10 m and cross-sectional area 2.0 x 10^{-6} m^2 attached to the bottom of the container, which is filled with water. Calculate the amount by which the rubber stretches when a mass of 0.15 kg is suspended from the left-hand?
(Young's modulus for rubber = 5 x 10^7 Nm^{-2}). (7)

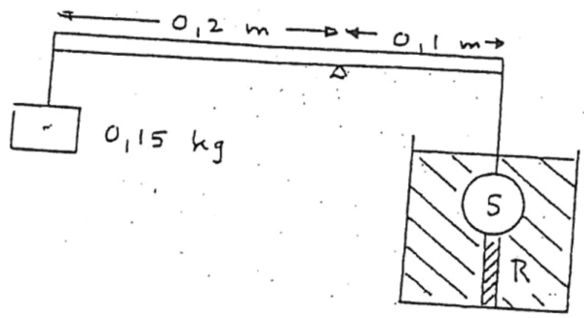

Fig. 2.2

2.3. Kepler's second law of planetary motion states that the radius vector drawn from the Sun to a planet sweeps out equal areas in equal time intervals. Drawing detailed diagram(s) were necessary; derive the Kepler's second law of planetary motion? (5)

2.4. Plaskett's binary system consists of two stars that revolve in a circular orbit about a centre of mass midway between them. This statement implies that the masses of the two stars are equal as shown in Fig. 2.4.

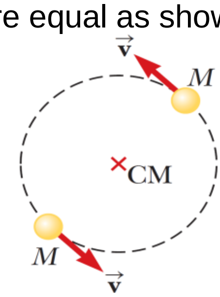

Figure 2.4

2.4.1 Given the orbital speed v and the orbital period T of each star, show that the mass M of each star can be expressed as:

$$M = 2Tv^3/\pi G \qquad (8)$$

where G is the universal gravitational constant.

Question 3 [28]

3.1. Verify by direction substitution using differentiation that the following wave functions:

3.1.1 $\mathbf{y} = A \sin(k\mathbf{x} - \omega\mathbf{t})$ (5)

3.1.2 $\mathbf{y} = \mathbf{x}^2 + v^2\mathbf{t}^2$ (4)

3.1.3 $\mathbf{y} = \ln[b(\mathbf{x} - v\mathbf{t})]$ where b is a constant (5)

are solutions of the general linear wave equation

$$\partial^2\mathbf{y}/\partial\mathbf{x}^2 = (1/v^2)\,\partial^2\mathbf{y}/\partial\mathbf{t}^2 \;;$$

where the wave number $k = \omega/v$, particle vibration **y** is function of both position **x** and time **t.**

3.2. A vuvuzela blown in a stadium is heard by one football fan at a sound level of 40 dB and by another at 65 dB. How many times further away from the vuvuzela is the first fan? Assume that the intensity follows an inverse square law. (8)

3.3 An object of density ρ is released from rest from a depth *d* below the below the surface of a liquid of density ρ_0. As $\rho < \rho_0$ and so the body rises to the surface. Show that the object reaches the surface with a speed *v* given by

$$v = \sqrt{[2dg(\rho_0 - \rho) / \rho]} \quad (6)$$

(where g is the acceleration due to gravity)

Question 4 [29]

4.1. Shown in Fig. 4.1 is the pulse of a small element of a taut string of length Δs moving to the left with speed **v**. Assuming that the pulse height is small relative to the length of the string, and the tension **T** is the same at all points on the string, show by derivation and also detailing your diagram that the speed **v** of the pulse traveling along the string is:

$$\mathbf{v} = \sqrt{(\mathbf{T}/\mu)} \;;$$

where **T** is the tension on the string and μ the mass per unit length (10)

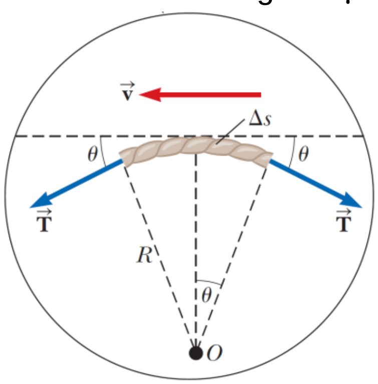

Fig. 4.1

4.2. Fig. 4.2 shows a closed tank connected to a pipe of constant cross-sectional area (which is small compared with that of the tank). The gauge pressure above water in the tank (i.e. above point 1) is maintained at a constant pressure of 2 x 10^5 Pa. A vertical pipe above point 2 contains a water column of constant height h = 1.5 m. Calculate:

(a) the velocity of the water at point 2, (7)

(b) the height, y, of point 3 where the gauge pressure is zero. (6)

(c) If the pipe were punctured at point 4 explain whether the air would leak in or water leak out? (Water density = 1000 kg/m^3). (6)

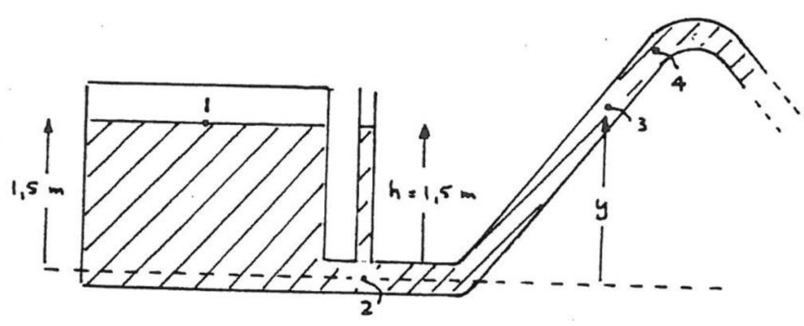

Fig. 4.2

Question 5 [23]

5.1 A clock with brass pendulum keeps correct time when the temperature is 10^oC. What will be the error in the time recorded by the clock if it placed for 1 week in a room at a constant temperature of 20^oC?

[$\alpha_{brass} = 1.9 \times 10^{-5}\ {}^oC^{-1}$ and $(1 + x)^{1/2} \sim (1 + x/2)$ if $x <<< 1$] (11)

5.2 Pop star Miley Cyrus performs a strip on a wrecking ball. Initially she has a rate generation of metabolic heat of 120 W, and is completely clad in a garment of emissivity *e* = 0.3. She evaporates perspiration to keep her temperature constant. At the end the metabolic rate has risen to 200 W, and she had shed the garment, so that *e* = 1. What extra volume of perspiration must she now evaporate per second to keep her body temperature constant? [The surrounding temperature remains constant at 35 ^0C, and her skin temperature (and that of the garment, which is thin) at 25 ^0C.]

Her surface area is 1.5 m^2, the density of perspiration is 10^3 kgm^{-3}.

latent heat of sweat evaporation = 2.5×10^6 Jkg^{-1}.

$\sigma = 5.67 \times 10^{-8}$ $Wm^{-2}K^{-4}$. (12)

END