UGANDA MARTYRS UNIVERSITY

UNIVERSITY EXAMINATION

FACULTY OF SCIENCE

DEPARTMENT OF NATURAL SCIENCES

SEMESTER II EXAMINATIONS, 2022/2023

SECOND YEAR EXAMINATION FOR BACHELOR OF SCIENCE WITH EDUCATION

PHY 2201 CLASSICAL MECHANICS II

DATE:
TIME:
DURATION: 3HRS

Instructions:

1. *Carefully read through ALL the questions before attempting*
2. ***Attempt ANY five questions***
3. *All Questions carry equal marks*
4. *No **names** should be written anywhere on the examination book.*
5. *Ensure that your **Reg number** is indicated on all pages of the examination answer booklet.*
6. *Ensure your work is **clear** and **readable**. Untidy work shall be penalized*
7. *Any type of examination Malpractice will lead to automatic disqualification*
8. *Do not write anything on the questions paper.*

Where necessary assume

Planck's constant	$h = 6.63 \times 10^{-34}$ J s
Boltzmann's constant	$K_B = 1.38 \times 10^{-23} JK^{-1}$
Mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
Electronic charge	$e = 1.60 \times 10^{-19}$ C
Speed of light	$c = 3.0 \times 10^{8} ms^{-1}$
Avogadro's number	$NA = 6.02 \times 10^{23} mol^{-1}$
Luminosity	$L_O = 3.9 \times 10^{33}$ erg/s $L_O = 3.9 \times 10^{26}$ J/s
Luminosity Mass	$M_O = 1.99 \times 10^{30} Kg$
Luminosity Radius	$R_O = 6.96 \times 10^{8} m$
Luminosity Temperature	$T_O = 5780K$
Astronomical Unit	$AU = 1.496 \times 10^{11} m$
Universal gas constant	$R = 8.31 JK^{-1}mol^{-1}$
Acceleration due to gravity	$g = 9.81ms^{-2}$
1 standard atmosphere	$= 1:01x10^{5}Nm^{-2}$
Radius of Earth	$R_e = 6.38 \times 10^{6}$ m
Solar constant	$S=1.37 \times 10^{3} Js^{-1}m^{-2}$

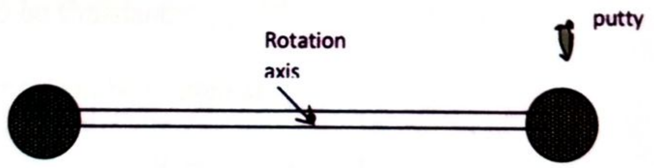
1. (a) Define moment of inertia of a body. [1]

(b) A uniform bar has length$l$, mass M, and rectangular ends of dimensions $a \times b$.

(i) Determine the moment of inertia about an axis through the centre of mass. [6]

(ii) Use the parallel axis theorem to determine the moment of inertia through an axis Perpendicular to the length of the bar, a distance one quarter of the length of the bar from the centre of the mass. [4]

(c). Two 2.0kg ballas are attached to the ends of a thin rod of length 50cm and Negligible mass. The rod is free to rotate in a vertical plane without fricion about a horizontal axis through its centre. With the rod initially horizontal, a 50.0g wad of wet putty drops onto one of the balls, hitting it with a speed of 3.0ms-, and then sticking on it.



(i) What is the angular speed of the system just after the putty wad hits the ball?

[6]

(ii) What is the ratio of the kinetic energy of the system after the collision to that of the puttywad before collision? [4]

2. (a) Define the following terms as applied to classical mechanics;

(i) Number of degree of freedom. [1]

(ii) Holonomic constraint. [1]

(b) A simple pendulum consists of a mass of a m attached to massless string of length l. The mass is displaced through an angle θ between the vertical and the lenth of the string, and released . Detremine the;

(i) Number of degree for the mass using the Euler-Larange formalism. [2]

(ii) Lagrangian for the system. [6]

(iii) Equation for the mass using Euler-Lagriange formalism. [4]

(c) Define an ingnorable coordinate and illusrtate with an example, a system with ingnorble coordinate . [3]

(d) In a plane, the point (x,y) are written in polar coordinates as (r,θ), write expressions relating the two corresponding points and list the generalised coordinates. [3]

3. (a) State the condition that must be satisfied in order for the Hamiltonian of a system to be Constant. [2]

(b) Hamiltonian can be written as

$$H = \sum_k \dot{q}_k p_k - L$$

the symbols carry their usual meaning.

(i) Show that the summation term equals to twice the kinetic energy. [4]

(ii) Derive the expression for the Hamiltonian in terms of kinetic and potential energy. [3]

(c) A particle of mass m is moving in a plane under an attractive force, $\mu m/r^2$ towards the origin, Determine the potential energy for mass. [2]

(d) A mass m oscillates horizontally on a spring of constant k.

(i) Set up the Hamiltonian for the system. [3]

(ii) Determine the Hamilton's equation. [3]

4 (a) Define a transverse wave. [1]

(b) A transeverse wave is given by the equation $y = 0.050\cos(\pi x + 4\pi x)$. Use the wave equation to determine the velocity of the waves. [3]

(c) A string whose ends are fixed at both ends is piucked in the middle and released.

(i) Explain how a sttationary wave pattern result on the string. [2]

(ii) State the boundary condition at the ends of the string. [1]

(d) If the string in 1(c) above has linear density of 5.0 g/m and the tension in the string is 8.0N, Given that a $100H_Z$ waves with amplitude of 2.0mm results after plucking ,determinethe ;

(i) Spacing between adjacent nodes. [3]

(ii) The ampliitude at the antinodes. [2]

(e) (i) Define beats as applied to sound waves [1]

(ii) Two open pipes of length 60cm and 61 cm are played at the same time in their **fundamental nodes,** Determine the beats frequency [4]

(f) (i) Define Doppler effect. [1]

(ii) A source emits sound of frequency $440H_Z$, and moves in astraingth line towards a statinary with a speed of 30m/s. If the observer hears sound of frequency $484H_Z$, determine the speed of sound . [2]

5. (a) (i) State the Principle of Relativity [1]

(ii) State the Principle of invariance of speed of light [1]

(b) A pipe 1.20m long is closed at one end. A stretched wire is placed near the open end. The wire is 0.330m long and has a mass of 9.60g. It is fixed at both ends and oscillates in its fundamental mode. By resonance it sets the air column in the pipe into oscillation at the column's fundamental frequency.

Find,

(i) The column's fundamental frequency. [2]

(ii) The tension in the wire. [4]

(c) A space ship moving with speed . $0.80c$ fires amessile with a speed of $0.70c$ in the same direction as the dirction in which the space ship is travelling. Find the speed of the missle relative to ground. [3]

(d) (i) State three properties of a system moving in a central force filed [3]

(ii) The reltionship between cartesian coordinates and polar coordinates is $x = r\sin\theta$ and $y = r\sin\theta$. If e_r is the radical component which ponts away from the origin, and e_θ is the normal to e_r in the dirction of increasing θ, State the carstesian components of e_r and e_θ. [2]

(c) A planet moves in an eliptical orbit about the sun as its foucs. Show that acceleration of planet in polar coordinate system is

$$\bar{a} = (\ddot{r} - r\dot{\theta}^2)e_r + (r\ddot{\theta} + 2\dot{r}\dot{\theta})e_\theta$$ [6]

6. (a) (i) Consider a particle which moves with a constant velocity v, so that in a time t it has covered a distance vt. Derive the wave equation [5]

(ii) A string is stretched horizontally between two points a distance, L, apart.

The string is pulled at its mid-point through a small vertical distance, h and released. Find the displacement of the string at any subsequent time. [6]

(b) The phase velocity of optical waves propagating in a medium of refractive index, n is given by,

$$v_p = \frac{c}{n}$$

Where n is dependent upon the wavelength. Find the group velocity. [2]

(c) Define an inertial reference frame. [1]

(d) The relationship between proper time interval Δt_0 and greater time interval Δt is $\Delta t = \gamma \Delta t_0$; where the Lorentz factor $\gamma = 1/\sqrt{1-(v/c)^2}$; and other symbols carry their usual meanings.

(i) Differentiate between proper time interval and greater time interval. [2]

ii. Explain the effect of γ on time measurements at low and high values of v. [4]

END