NATIONAL OPEN UNIVERSITY OF NIGERIA
PLOT 91, CADASTRAL ZONE, NNAMDI AZIKIWE EXPRESSWAY, JABI - ABUJA
FACULTY OF SCIENCES
DEPARTMENT OF PHYSICS
2025_1 EXAMINATION

COURSE CODE: **PHY301**
COURSE TITLE: **CLASSICAL MECHANICS**
CREDIT UNIT: **3**
TIME ALLOWED: **(3 HRS)**
INSTRUCTION: ***Answer question 1 and any other three questions***

QUESTION ONE

(a) Briefly explain the terms: (i) Degrees of freedom (ii) Constraint. **6 marks**

(b) Distinguish between (i) holonomic and non-holonomic constraints (ii) rheonomic and scleronomic constraints. **6 marks**

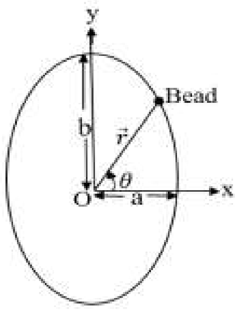

Figure 1: A bead sliding on an elliptical wire

(c) A bead of mass m is constrained to slide on an elliptical wire loop in the x-y plane as shown in Fig. 1, where a and b are the semi-minor and semi-major axes respectively and θ is the angle the radius vector $\vec{r}$ from the origin O to the position of the bead makes with the x-axis.

(i) How many degrees of freedom has the system **2 marks**

(ii) Derive the Lagrangian as a function θ for the system **11 marks**

QUESTION TWO

(a) Define the term "generalised coordinates". **1 mark**

(b) (i) Distinguish between coordinate space and configuration space. **2 marks**

(ii) Define the term "virtual displacement". **1 mark**

(iii) List the criteria which the displacements of the constituent particles of a system must satisfy to be classified as virtual displacements **3 marks**

(c) (i) Given the transformation equations $\vec{r}_i = \vec{r}_i(q_i, t)$, where $i = 1,2, \dots ,3N$, prove the relation

$$\delta r_i = \sum_{j=1}^{n} \frac{\partial r_i}{\partial q_j} \delta q_j$$

where $j = 1,2, \dots , n$. **4 marks**

(ii) Calculate $\delta f(x)$ given $f(x) = 3cos2x$ **2 marks**

(iii) Briefly state the principle of virtual work. **2 marks**

QUESTION THREE

(a) (i) In tabular form discuss any **4 advantages** of analytical mechanics over Newtonian mechanics. **4 marks**

(ii) Write down the Euler- Lagrange equation of motion for a system subjected to non-conservative forces and forces of constraint Q_j', where, $j = 1,2, \ldots, m$ **2 marks**

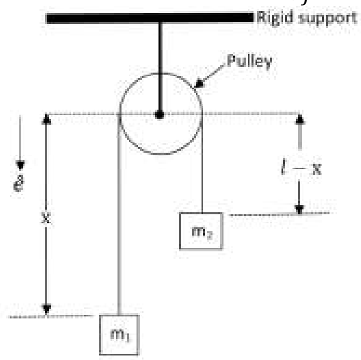

Figure 2: Atwood machine

(b) The Atwood machine (Fig. 2) consists of two masses, m_1 and m_2, connected by a string that passes over a pulley. The pulley is assumed to be ideal (massless and frictionless), and the system is under the influence of gravity. Use d'Alembert's principle to find the equations of motion of the masses.

QUESTION FOUR

.(a) (i) Write down the classical Hamiltonian for a system of particles each having masses m_i described by the set of generalized coordinates q_i and momenta p_i.

(ii) Write down the Legendre transformation equation

(iii) Find the Legendre transforms of lnx

(b) (i) Write down the Hamiltonian function for a simple harmonic oscillator **2 marks**

(ii) Obtain the Hamiltonian equations of motion for a one-dimensional harmonic oscillator.

QUESTION FIVE

(a) (i) Give one example of a force derivable from velocity-dependent potential **3 marks**

(ii) Given a velocity-dependent potential in the form, $V = V(q_j, \dot{q}_j, t)$, write down the generalised forced derivable from it. **2 marks**

(b) Using the Lagrangian method, derive the equation of the x-component of the motion of a charged particle in an electromagnetic field. **10 marks**

QUESTION SIX

(a) (i) State the three Kepler's laws for planetary orbits.

(ii) Consider motion of a planet of mass m_p around the sun of mass m_s. Write down the reduced mass μ in terms of m_p , m_s. and the position of the centre of mass r_{cm}.

(b) (i) Write down the effective Lagrangian function for the motion of the centre of mass of the sun-planet system in a(ii).

(ii) Using Lagrange's equations in the polar coordinates, prove Kepler's second law