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UNIVERSITY EXAMINATIONS 2023/2024

THIRD YEAR, FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN MATHEMATICS AND PHYSICS AND BACHELOR OF SCIENCE IN PHYSICS AND
FOURTH YEAR, FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

SPH 3300: CLASSICAL MECHANICS

DATE: DECEMBER 2023 **TIME: 2 HOURS**

INSTRUCTIONS: Answer Question ONE and any other TWO questions.

QUESTION ONE (30 MARKS)

a) Define a conservative system giving an example (3 Marks)

b) A plane pendulum consists of a bob of mass m suspended by a massless rigid rod of length I that is hinged to a sled of mass M. The sled slides without friction on a horizontal rail. Gravity acts with the usual downward acceleration g

i. Taking x and θ as generalized coordinates, write the Lagrangian for the system

ii. Use Lagrange's equations to derive the equations of motion for the system

iii. Use the equations from part (ii) to find the frequency for small oscillations of the bob about the vertical. (Hint: You will need to make some approximations.)

iv. At time $t = 0$, the bob and the sled, which previously had been at rest are set in motion by a sharp tab delivered to the bob. The tap imparts a horizontal impulse of $\Delta p = F\Delta t$ to the bob. Find expressions for $\dot{x}$ and $\dot{\theta}$just after impulse.

c) i. Explain what is meant by Constraints in Physics (2 Marks)
ii. Differentiate between holonomic and nonholonomic constraints giving an example of each (4 Marks)
iii. State two difficulties posed by constraints and how to overcome them (4 Marks)

d) State two advantages of viriational principle (2 Marks)

QUESTION TWO (20 MARKS)

a) Derive the principle of virtual work (4 Marks)

b) Show that the principle of virtual work leads to D'Alembert's principle (4 Marks)

c) Show that D'Almbert's Principle leads to component of generalized force and to Euler-Lagrange equations (6 Marks)

d) Apply the derived Euler-Lagrange equations above on the motion of a particle in plane Cartesian coordinates to obtain the radial equation of motion (4 Marks)

QUESTION THREE (20 MARKS)

Show that for a multiparticle system, both the

a) angular momentum and (12 Marks)

b) kinetic energy are broken into two parts: one part due to the centre of mass and the other part about or around the centre of mass (8 Marks)

QUESTION FOUR (20 MARKS)

a) Show that for the central force problem, the Lagrangian of a two-body problem can be reduced into Lagrangian of a single particle problem through introduction of the centre of mass (15 Marks)

b) Explain the importance of the centre of mass in

i. Aircraft crush (3 Marks)

ii. Rocket propulsion (2 Marks)