MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FIRST YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION TECHNOLOGY)

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

BACHELOR OF EDUCATION (SPECIAL NEEDS EDUCATION)

BACHELOR OF SCIENCE (ANALYTICAL CHEMISTRY)

BACHELOR OF SCIENCE (MATHEMATICS)

BACHELOR OF EDUCATION (SCIENCE)

SPT 100: INTRODUCTION TO MECHANICS

SPH 100: MECHANICS I

DATE: 1/2/2022 **TIME: 8.30-10.30 AM**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

CONSTANTS

$g = 9.8\ m/s^2$

$c = 3.0\ \times 10^8\ m/s$

QUESTION ONE (30 MARKS)

a) State the principle of conservation of momentum (2 marks)

b) Find the angle between the vector $\vec{\boldsymbol{A}} = 8\boldsymbol{i} + 3\boldsymbol{j}$ and $\vec{\boldsymbol{B}} = -5\boldsymbol{i} - 3\boldsymbol{j}$. (3 marks)

c) Distinguish the following terminologies as used in mechanics

i. Impulse and Momentum (2 marks)

ii. Kinetic friction force and static frictional force (2 marks)

d) Suppose the displacement $\boldsymbol{s}$ of an object moving in a straight line under uniform acceleration $\boldsymbol{a}$ is given as a function of time by the equation, $s = ka^m t^n$ where k is a dimensionless constant. Use dimensional analysis to find the values of the powers m and n. (3 marks)

e) The speed of a particle moving in a circle of radius $r = 4.5\ m$ increases with a constant rate of 2 m/s. If at some instant, the magnitude of the total acceleration $\vec{a}\ is\ 6m/s^2$, then find:

i. The magnitude of the tangential acceleration, (2 marks)

ii. The magnitude of the radial acceleration, and (2 marks)

iii. The speed of the particle (3 marks)

f) A sailor riding a boat with a speed $v_1 = 6.1\ m/s$ relative to the water, tries to cross a river. The boat sails at an angle of $\theta_1 = 25^o$ upstream on a river flowing at a velocity $v_2 = 1.4\ m/s$. Calculate the sailor's resultant speed v_3 and the angle of sail θ_3 relative to the horizontal. (5 marks)

g) A projectile of mass $m_1 = 1$ kg moving along the x direction with a speed $v_1 = 20$ m/s collides elastically with a stationary target of mass $m_2 = 2$ kg. After the collision, the projectile is deflected at an angle of 60^o from the horizontal

i. What is the speed and angle of the target after collision? (3 marks)

ii. What is the final speed of the projectile and the fraction of kinetic energy transferred to the target? (3 marks)

QUESTION TWO (20 MARKS)

a) State and explain the two types of collisions (4 marks)

b) Show that the maximum height H of a projectile projected at a velocity v_o and an angle θ_o from the horizontal in two – dimensional motion is given by

$H = \frac{v_o^2\ sin^2\theta_o}{2g}, 0 \leq \theta_o \leq \frac{\pi}{2}$ (5 marks)

c) Use dimensional analysis to show that the expression $v^2 = {v_0}^2 + 2as$ is dimensionally correct, where *v* and v_0 represent velocities, *a* is acceleration, and s is the displacement.

(4 marks)

d) The position vector of a particle moving in two dimensions is given by $\vec{r} = x(t)\vec{\imath} + y(t)\vec{\jmath}$ where $x(t) = 2t + 1$, $y(t) = 2t^2$ and t is the time in seconds and all numerical coefficients have the proper units so that $\vec{r}$ is in meters.

i. Find the particle's velocity vector $\vec{v}$ as a function of time, and find its magnitude and direction at t = 3 s. (4 marks)

ii. Find the particle's acceleration vector $\vec{a}$ at t = 4 s. (3 marks)

QUESTION THREE (20 MARKS)

a) A block is at rest on a rough inclined plane of angle θ

i. Find the static frictional force f_s in terms of N and θ (2 marks)

ii. When the angle is increased until the block is on the verge of slipping at $\theta = \theta_c = 38.7^o$, find the value of the coefficient of static friction μ_s (3 marks)

iii. The value of θ was increased further to allow the block to accelerate and then decreased again to the value $\theta = \theta' = 26.6^o$ to allow the block to move with constant speed, find the coefficient of kinetic friction μ_k. (3 marks)

b) A ball is launched from the ground with an initial speed v_o of 40 m/s at an angle $\theta^o = 60\ ^o$ towards a cliff of height h, as shown in Fig.1. The ball strikes the cliff after 5 s. Find:

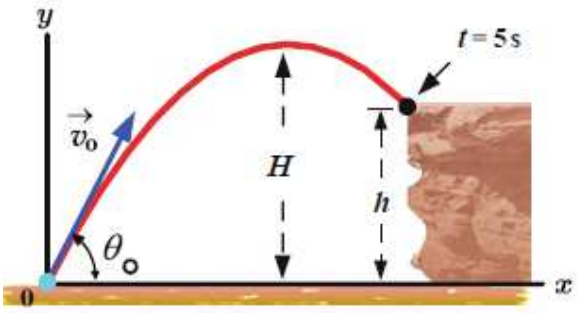

Fig.1

i. The height h of the cliff, (3 marks)

ii. The maximum height H, (3 marks)

iii. The speed of impact, and (3 marks)

iv. The horizontal distance between the cliff and the firing point (3 marks)

QUESTION FOUR (20 MARKS)

a) A bullet of mass m = 10 g is fired horizontally with a speed v into a large wooden stationary block of mass M = 2 kg that is suspended vertically by two cords. In a very short time, the bullet penetrates the pendulum and remains embedded. The entire system starts to swing through a maximum height h = 10 cm. Find the relation that gives the speed v in terms of the height h, and then find its value. (5 marks)

b) A baseball has a mass of 0.2 kg and a speed of 30 m/s. After the batter strikes the baseball, its velocity changed to 50 m/s in the opposite direction

i. Find the change in momentum of the ball and the impulse of the strike. (3 marks)

ii. Find the average force exerted by the bat on the ball if remains in contact for 0.002 s. (3 marks)

c) In a cathode ray tube of a TV set, an electron with initial velocity $v_o = 2 \times 10^4$ m/s enters a region 2 cm long, where it is accelerated electronically in a straight line. The electron emerges from this region with a velocity $v = 3 \times 10^5$ m/s.

i. What was its acceleration, assuming it was constant. (2 marks)

ii. How long will the electron be in this region? (2 marks)

d) A system of three particles of masses m_1 = 0.5 kg, m_2 = 1 kg, and m_3 = 1.5 kg are spread out in two dimensions and located as shown in Fig.2. Find the center of mass of the system. (5 marks)

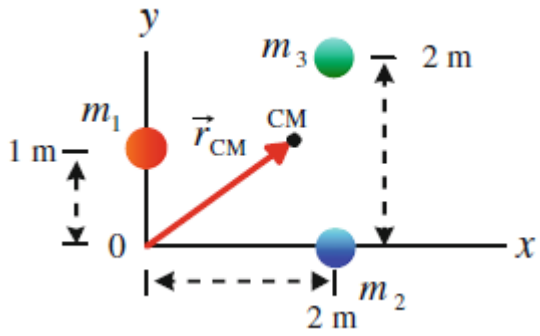

Fig.2

QUESTION FIVE (20 MARKS)

a) Define the following terms giving examples in each;

i. Conservative forces (2 marks)

ii. Non-conservative forces (2 marks)

b) A 80 kg diver drops from a diving board 10 m above the water surface. Use conservation of mechanical energy to find his speed 5 m above the water surface. (5 marks)

c) Calculate the error in finding the kinetic energy of an object using the formula $K(m, v) = \frac{1}{2}mv^2$ where the mass of the object $m = 0.497 \pm 0.005$ kg and velocity $v = 1.50 \pm 0.03\ m/s$. (4 marks)

d) The system in Fig. 3 is in equilibrium. A mass of 225 kg hangs from the end of the uniform strut whose mass is 45.0 kg. Find:

i. The tension T in the cable (3 marks)

ii. The horizontal and vertical force components exerted on the strut by the hinge. (4 marks)

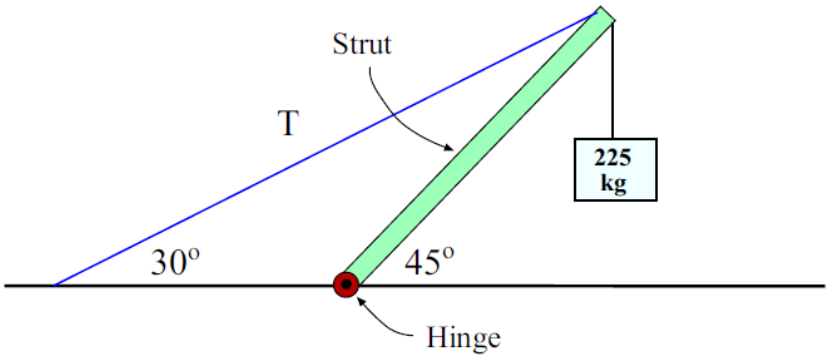

Fig.3