MACHAKOS UNIVERSITY

University Examinations 2022/2023

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION TECHNOLOGY)

BACHELOR OF SCIENCE (ANALYTICAL CHEMISTRY)

BACHELOR OF EDUCATION (SPECIAL NEEDS EDUCATION)

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

BACHELOR OF EDUCATION (SPECIAL NEEDS EDUCATION)

BACHELOR OF SCIENCE (MATHEMATICS)

BACHELOR OF EDUCATION (SCIENCE)

SPH 200/SPT 200: MECHANICS II

DATE: **TIME:**

INSTRUCTIONS:

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

CONSTANTS

$g = 10\ m/s^2$

1 Horse- power (hp) = 746 W

SECTION A

QUESTION ONE (COMPULSORY) (30 MARKS)

a) State the principle of conservation of mechanical energy (2 marks)

b) Define the following terminologies

(i) Torque (2 marks)

(ii) Rotational dynamics (2 marks)

(iii) Radius of gyration (2 marks)

c) Distinguish between conservative and non-conservative forces giving examples in each case. (2 marks)

d) Find the angle between the force vectors $\boldsymbol{A} = \boldsymbol{i} - 2\boldsymbol{k}$ and $\boldsymbol{B} = 6\boldsymbol{i} - 3\boldsymbol{j} + 2\boldsymbol{k}$ (3 marks)

e) A block of initial speed $v_0$slides across a floor. A kinetic frictional force of magnitude $f_k = 25\ N$ does work on the block, stopping it over a displacement of magnitude $d = 1.0\ m$. Find the dissipated mechanical energy. (3 marks)

f) Two wheels of radii $r_1 = 40\ cm$ and $r_2 = 30\ cm$ are fastened together such that they can rotate freely about an axle O perpendicular to the page. Two forces of magnitude $F_1 = 25$ N and $F_2 = 50$ N are applied as shown in the figure 1.

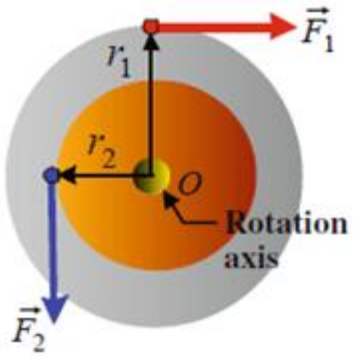

Fig.1

Determine the net torque on the wheel. (3 marks)

g) Given that the displacement of a block-spring system exhibiting Simple Harmonic Motion (SHM) is given by $x(t) = Acos(\omega t + \varphi)$. Show that the velocity of the block at any arbitrary position *x* is given by $v = \pm\sqrt{\frac{k_H}{m}(A^2 - x^2)}$ where k_H is the force constant and *m* mass of the block (5 marks)

h) A body of mass m = 10 kg is released from at a height of 2 m above the ground. Determine;

i. The kinetic energy of the body just before hitting the ground (3 marks)

ii. The speed at point (i) above (3 marks)

SECTION B: ANSWER ANY OTHER TWO QUESTIONS

QUESTION TWO (20 MARKS)

a) A particle oscillates with a simple harmonic motion along the x-axis. Its displacement from the origin varies with time according to the equation $x = 2\,m\cos(0.5\pi\,t + \frac{\pi}{3})$ where t is in seconds and the argument of the cosine is in radians. Find ;

i. The amplitude, frequency and period of the motion (3 marks)

ii. The velocity and acceleration of the particle at any time (4 marks)

iii. The maximum value of speed and acceleration of the particle (4 marks)

iv. The displacement of the particle between $t = 0$ and $t = 2\,s$. (4 marks)

b) A block of mass $m = 6$ kg is placed on the edge of a rough surface of height $h = 1.5$ m as shown in figure 2. The block is released and stops momentarily after compressing a horizontal spring (with spring constant $k_H = 2000$ N/m) by a compression distance $x = 15$ cm.

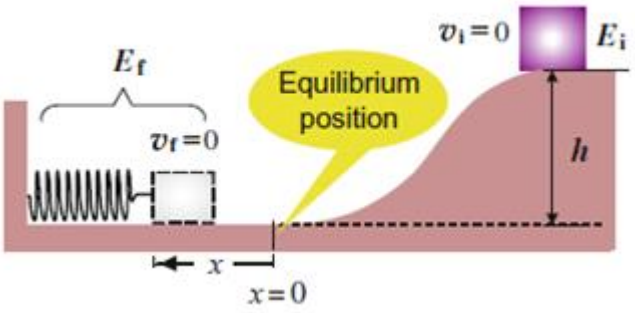

Fig.2

Calculate the work done by friction (4 marks)

QUESTION THREE (20 MARKS)

a) A block of mass *m* is pushed along a rough horizontal surface by a constant horizontal force ***F***. The displacement of the block along the surface is ***d***.

i. Find the mathematical expression that represents the work done by; the force ***F***, the kinetic friction $\boldsymbol{f_k}$, the gravitational force ***mg,*** and the normal force N

(4 marks)

ii. Calculate the work done when $m = 3\ kg$, $\mu_k = 0.5$, $F = 40\ N$ and $d = 5\ m$

(4 marks)

b) Three tiny spheres, each of mass *M* are fastened by three identical rods each of mass *m* and length *L*. The system in figure 3 is allowed to rotate with an angular speed ω about an axis that is perpendicular to the page and passes through *O*. Find;

(i) Moment of inertia (3 marks)

(ii) The rotational kinetic energy about the axis given that m = 1.5 kg, M = 3 kg, L = 0.5 m and ω = 5 rad/s. (3 marks)

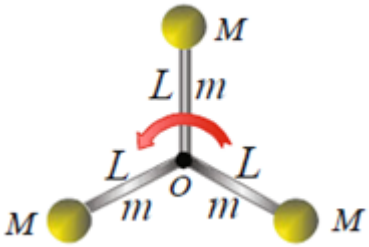

Fig.3

c) A horizontal rod of uniform mass per unit length λ has a mass *M* and length *L*. Use the relation $I = \int r^2 dm$ to calculate the moment of inertia of the rod about;

i. An axis passing through its center (3 marks)

ii. An axis passing through its end (3 marks)

QUESTION FOUR (20 MARKS)

a) A disk of mass M = 0.2 kg and radius R = 5cm is attached coaxially to the massless shaft of an electric motor as shown in figure 4. The motor runs steady at 900 rpm and delivers 2 hp.

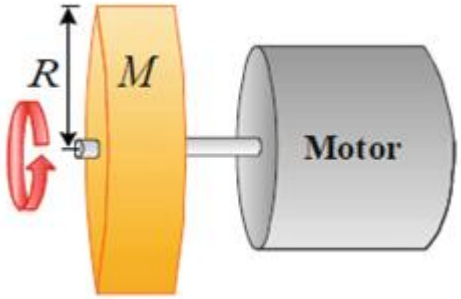

Fig.4

Determine:

(i) The angular speed of the disk in SI units (3 marks)

(ii) The rotational kinetic energy of the disk (3 marks)

(iii) The torque delivered by the motor (3 marks)

b) A uniform thin rod of mass $M = 3$ kg and length $L = 20$ cm is attached from one end to a frictionless pivot. The rod is free to rotate in a vertical motion. The rod is released in a vertical position as shown in figure 5.

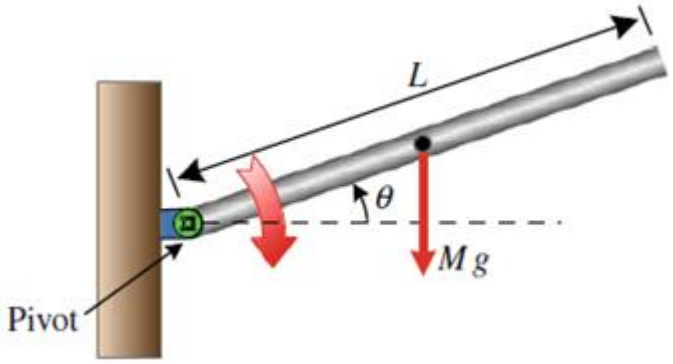

Fig.5

i. Determine the angular acceleration of the rod as a function of θ for $-90^o \leq \theta \leq 90^o$ and find its maximum value (3 marks)

ii. Find the angle where the tangential acceleration of the free end of the rod equals g. (3 marks)

c) A pulley of mass M = 5 kg and radius R = 20 cm is mounted on a frictionless axis. A massless cord is wrapped around the pulley while its other end supports a block of mass m=3 kg. Assuming that the cord does not slip, calculate the linear acceleration of the block, angular acceleration of the pulley and the tension in the cord. (5 marks)

QUESTION FIVE (20 MARKS)

a) A block of mass $m = 320\ g$ is fastened to a light spring whose force constant k_H is $72\ N/m$. The block is pulled a distance $x_i = 45$ cm from its equilibrium position at $x = 0$ on a horizontal frictionless surface and released at $t = 0$. Assuming that the spring-block system undergoes SHM, determine;

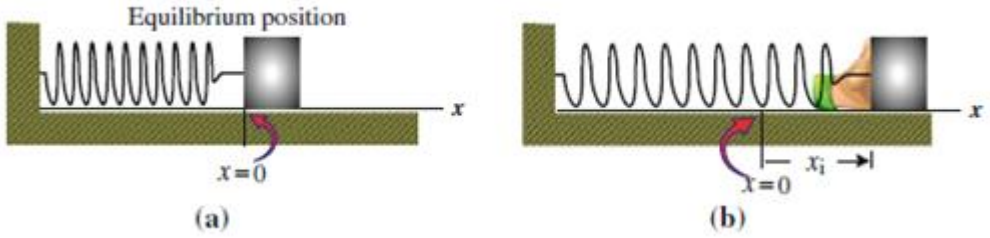

Fig.6

i. The mechanical energy of the oscillating block (3 marks)

ii. The maximum speed of the oscillating block (3 marks)

iii. The velocity, kinetic energy and potential energy of the block when its position is 30 cm. (6 marks)

b) A harmonic wave traveling along a string in the direction of increasing x has the following form $y = 0.4\cos(0.2x - 5t)$, where all numerical constants are in SI units. Determine;

i. The amplitude, wave number, angular frequency and the speed of the wave. (3 marks)

ii. Wavelength, period and the frequency of the wave (5 marks)