BINDURA UNIVERSITY OF SCIENCE EDUCATION

PHYSICS AND MATHEMATICS DEPARTMENT

PH101: MECHANICS AND OSCILLATIONS

DURATION: THREE HOURS

AUG 2023

Answer **ALL** parts of Section A and any **THREE** questions from Section B. Section A carries 40 marks and Section B carries 60 marks.

SECTION A

1. a . A force acting on an object varies with x as shown in Figure. 1.1. Find the work done by the force when the object undergoes a displacement from x = 0 to x = 7m. [5]

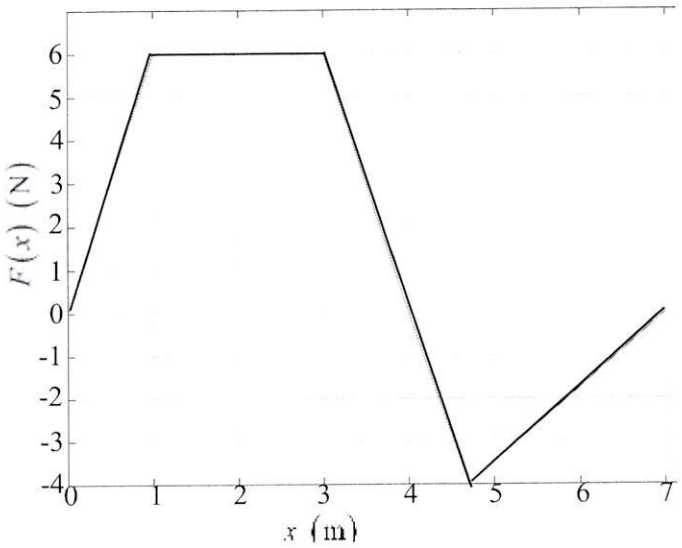


Figure 1.1: Question 1. a.

b. Figure 1.2 is a $x(t)$ plot for an elevator cab that is initially stationary, then moves upward (which we take to be the positive direction of x), and then stops. Plot $v(t)$. [7]

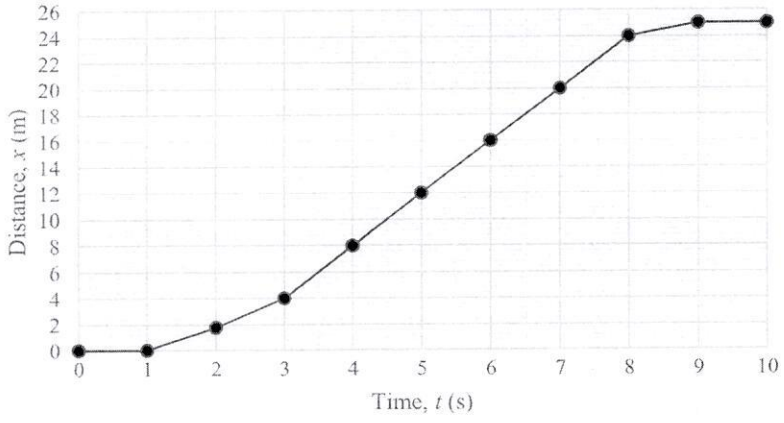


Figure 1.2: Question 1. b.

c. A person walks 3 km due east and then 2 km due north. What is his displacement vector? [7]

d. A wheel accelerates uniformly from rest to an angular speed of 25 rad/s in 10 s. Find the angular acceleration of the wheel. [4]

e. A particle moves with a constant speed v in a circular orbit of radius r, see the Figure 1.3. Given that the magnitude of the acceleration a is proportional to some power of r, say r^m, and some power of v, say v^n then determine the powers of r and v. [5]

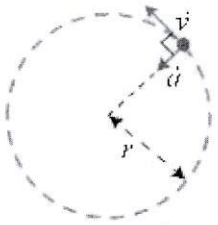


Figure 1.3: Question 1. e.

f. The equation giving the position of a freely falling body is given by equation (1.1) [3]

$$x = v_0 t + \frac{1}{2} g t^2 \qquad (1.1)$$

Use dimensional analysis to show that equation (1.1) is dimensionally correct, where x is the position, v_0 the initial speed, g is the acceleration due to gravity and t the time interval.

g. When startled, a cat will jump upward. Suppose it rises 0.544 m in the first 0.200 s.

i. What is its initial speed as it leaves the ground? [3]

ii. What is its speed at the height of 0.544 m? [3]

iii. What is the highest height reached by the cat? [3]

SECTION B

2. a Amass hangs from a massless string of length ℓ. Conditions have been set up so that the mass swings around in a horizontal circle, with the string making a constant angle θ with the vertical (see Figure. 2.1). Show that the frequency ν of oscillation is given by $\nu = f(\theta)\sqrt{\frac{g}{l}}$ [10]

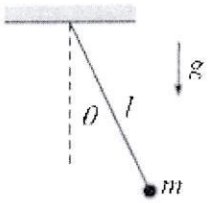


Figure 2.1: Question 2. a.

where f is a dimensionless function of the dimensionless variable θ.

b. An engine produces 42.5 kW.

Quantity	System 1: British	System 2: SI	Ratio: British/SI

Mass	slug	kilogram	14.6
Length	foot	metre	0.3048
Time	second	second	1.0

i. What is the corresponding value in horsepower? [8]
1 horsepower = 550 foot pound-force/second

ii. What is the conversion factor? [2]

3. a What is the angle ϕ between $\vec{A} = 3.0\vec{i} - 4.0\vec{j}$ and $\vec{B} = -2.0\vec{i} + 3.0\vec{j}$? [9]

b. i. For a particle moving with constant acceleration a in a straight line, show that its velocity v at time t is given by equation (3.1) [6]

$$\therefore v^2 = v_0^2 + 2a(x - x_0) \qquad (3.1)$$

where v_0 is its initial velocity and $x - x_0$ is the displacement.

c. ii. How much force is needed to give a 20,000 kg heavy loaded truck on a levelled track an acceleration of $1.5\ \text{ms}^{-2}$, and what is the force exerted by the track on the truck? [5]

4. A reference line in a spinning disk has an angular position given by equation (4.1):

$$\theta = 3t^2 - 12t + 9 \qquad (4.1)$$

where θ is in radians and t is in seconds.

b. Find angular velocity ω and angular acceleration a as a function of time. [6]

c. Find the times when the angular position θ and the angular velocity ω become zero. [4]

d. Describe the rotational motion of the disk for t ≥ 0. [10]

5. a. A block of mass m = 21 kg hangs from three cords as shown in part of Figure. 5.1. Taking sin θ =4/5, cos θ =3/5, sin φ =5/13, and cos φ =12/13, find the tensions in the three cords. [15]

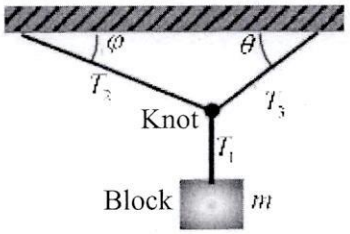


Figure 5.1: Question 5. a.

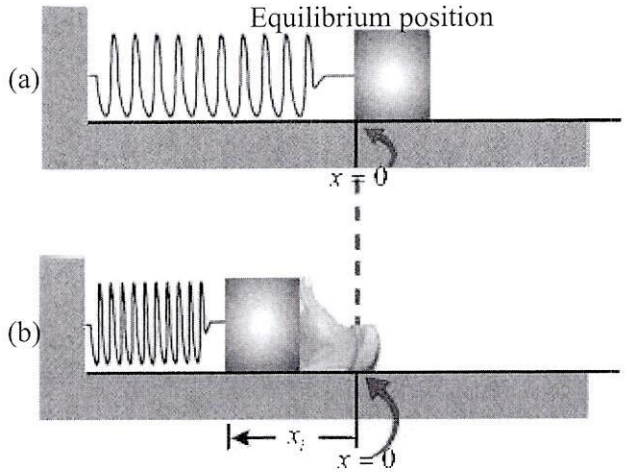
b. A particle moves over a path such that the components of its position with respect to an origin of coordinates are given as a function of time by: [5]

$$x = -t^2 + 12\,t + 5$$

$$y = -2\,t^2 + 16\,t + 10$$

where t is in seconds and x and y are in meters. Find the particle's velocity vector $\vec{v}$ as a function of time, and find its magnitude at t = 6 s.

6. A block of mass m=400 g is attached to a light spring of force constant $k_H = 10\ \mathrm{Nm^{-1}}$, see Figure 6.1 (a). The block is pushed against the spring from $x = 0$ to $x_i = -10\ \mathrm{cm}$, see Figure 6.1 (b), and then released to oscillate on a horizontal frictionless surface.



Find:

a. the angular frequency and the period of the block-spring system. [6]

b. the maximum speed and maximum acceleration of the block. [6]

c. the position, speed, and acceleration of the block at any time. [8]

END OF EXAM