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University of Ruhuna- Faculty of Technology

Bachelor of Engineering Technology Honours

Level 1 (Semester I) Examination, November-December 2025

Academic Year 2024/2025

Course Unit: **TMS1133/TMS1143 Physics of Mechanical Systems** Duration: **3 hours**

Instructions and details:

- Answer **All parts of Six (06)** questions.
- This question paper is composed of 4 pages.
- Questions 1 & 2 carry 16 marks each, and questions 3 to 6 carry 17 marks each.
- Calculators are allowed for calculations.
- When relevant, answers should be expressed in terms of the given (relevant) variables and simplified.
- You should neglect air resistance when solving problems.
- Strings/cords in problems have negligible mass, and they do not stretch.
- All symbols have their usual meanings.
- Some particle motion equations: $v = v_0 + at$, $x - x_0 = v_0 t + \frac{1}{2} a t^2$, $v^2 = v_0^2 + 2a(x - x_0)$
- $\frac{d}{dt}(t^n) = n\, t^{(n-1)}$, $\frac{d}{d\phi}\cos\phi = -\sin\phi$, $\frac{d}{d\phi}\sin\phi = \cos\phi$
- $g = 9.81$ m/s^2.

1.

(i) At time t, the position of a particle that moves along the x-axis is given by,

$$X = v_0 t + \frac{1}{2} a t^2 + X_0$$, where a, X_0 and v_0 are constants.

(a) Find the velocity (v) of the particle at time t. (3 marks)
[*Hint: Derivatives]

(b) Show that $v^2 = v_0^2 + 2a(X - X_0)$. (4 marks) [*Hint: part a]

(ii) A ball is projected horizontally from a rooftop, with a speed of 10.0 m/s at a height of 20.0 m above the flat ground. [*Hint: motion equations.]

(a) Find the time of flight of the ball. (3 marks) [i.e., time the ball will be in the air.]

(b) From the firing point, find the horizontal distance that the ball strikes the ground. (2 marks)

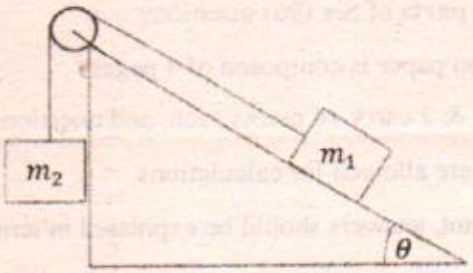
As the ball strikes the ground,

(c) Find the horizontal speed of the ball. (2 marks)

(d) Find the vertical speed of the ball. (2 marks)

2. A massless string is used to connect two block masses m_1 and m_2. As shown in Figure 1, the mass m_1 is placed on a frictionless incline that makes an angle θ with the horizontal, and the string is placed over a frictionless and massless pulley such that the mass m_2 hangs vertically and moves downward. Let g denote the acceleration of gravity. [*Notes: For answers, the magnitudes are expected. Do not do any numerical calculations when answering parts a to d.]

Fig 1



(a) Apply Newton's 2nd law for the motion of m_2. (1 mark) [*Hints: consider the acceleration & string tension]

(b) Apply Newton's 2nd law for the motion of m_1. (2 mark)

(c) Find the tension in the string. (4 marks)

(d) Find the acceleration of each block. (3 marks)

If $m_1 = 4.0$ kg, $m_2 = 3.0$ kg, and $\theta = 20°$ then,

(e) Calculate the normal force on m_1. (2 marks)

(f) Calculate the tension in the string. (2 marks)

(g) Calculate the acceleration of each block. (2 marks)

3.

(i) Consider a mechanical system that is isolated and involves only conservative forces.

(a) Using the work-kinetic energy theorem, show that $\Delta E_{mec} = 0$, where E_{mec} is the mechanical energy of the system. (3 marks) [*Hint: consider potential energy]

(b) For the system show that $K_f + U_f = K_i + U_i$, where K & U represent the kinetic & potential energies, respectively, and i & f represent the initial & final states of the system, respectively. (2 marks) [*Note: use the result of part a]

(ii) As shown in Figure 2, a pendulum is made of a string of length L, a bob of mass m, and it is suspended from point P. It is pulled backward, making an angle θ with the vertical and then released from rest. Once the pendulum swings through the lowest point as shown, it collides with a fixed nail N located at an angle α with the vertical and a distance d from the point of suspension P. Let g denote the acceleration of gravity.

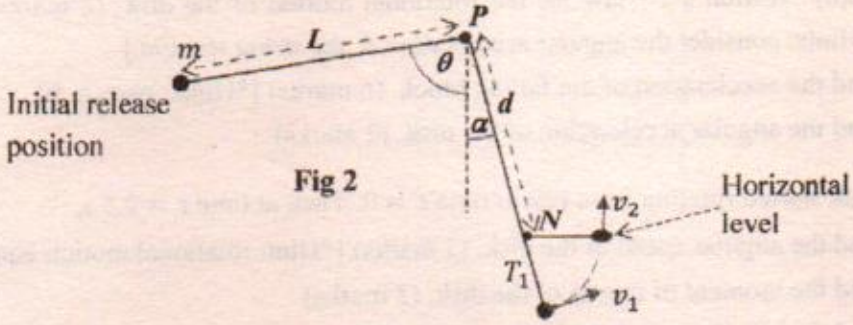


Fig 2

Immediately (an instant) before the pendulum string strikes the nail N,

(a) Find the speed (v_1) of the bob. (3 marks) [*Note: Indicate your selected reference level of the gravitational potential energy. *Hint: part i.]

(b) Find the tension (T_1) in the string. (3 marks) [*Hints: Newton's laws. Centripetal force]

After the string strikes the nail N, and when it has reached the horizontal level,

(c) Find the speed (v_2) of the bob. (4 marks)

(d) If the pendulum is to merely swing to this horizontal level, find the least value that the release angle θ should have. (2 marks) [i.e., minimum θ. *Hint: part c]

4. A block of mass $m = 5.0$ kg is pushed by a spring along a horizontal floor with a coefficient of kinetic friction $\mu_k = 0.25$ as indicated in Figure 3. The spring constant of the spring is $k = 50$ N/m, and the mass of it is negligible. Initially, with the block in contact, the spring is compressed from its relaxed position by a distance $d = 60$ cm, and then the block is released from rest.

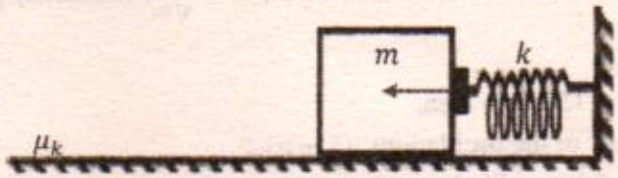


Fig 3

(a) Find the initial elastic potential energy stored in the spring immediately before the block was released from rest. (2 marks)

After the block was released, while it moves from rest to its maximum speed,

(b) Find the frictional force on the block. (2 marks)

(c) Find the distance the block moves. (4 marks) [*Hints: At maximum speed, no acceleration. Hooke's & Newton's laws.]

When the block reaches its maximum speed,

(d) Find the increase in thermal energy (ΔE_{th}) of the system (i.e., after the block was released). (2 marks) [*Hints: parts b, c]

(e) Find the elastic potential energy remaining in the spring. (3 marks) [*Hint: part c]

(f) Find the maximum speed reached by the block. (4 marks) [*Hint: Conservation of energy]

5. A massless string that does not slip is wrapped around a disk that is mounted on a frictionless horizontal axle, and a block of mass $M = 2.5$ kg hangs from the free end of the string as shown in Figure 4. The radius of the disk is $R = 5.0$ cm and its mass is $m = 5.0$ kg. [*Hints: $I_{com} = \frac{1}{2}mR^2$]

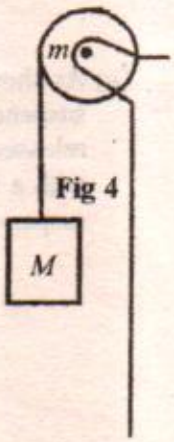


Fig 4

(a) Apply Newton's 2nd law for the motion of mass M. (1 mark) [*Hint: consider the string tension.]

(b) Apply Newton's 2nd law for the rotational motion of the disk. (2 marks) [*Hints: consider the angular acceleration & the string tension.]

(c) Find the acceleration of the falling block. (6 marks) [*Hints: parts a, b]

(d) Find the angular acceleration of the disk. (2 marks)

The disk started rotating from rest at time $t = 0$. Then at time $t = 2.5$ s,

(e) Find the angular speed of the disk. (2 marks) [*Hint: rotational motion equations.]

(f) Find the moment of inertia of the disk. (2 marks)

(g) Find the kinetic energy of the disk. (2 marks)

6.

(i) Find the rotational inertia about a perpendicular axis through an end point of a thin rod of mass m and length l. (5 Marks) [*Hints: $I_{com} = \frac{1}{12}ml^2$. Parallel axis theorem.]

(ii) Simple harmonic motion is performed by a block-spring oscillator along the y-axis, and the position of the block at time t is given by $y = y_m \cos(\omega t + \pi)$, where y_m and ω are constants.

(a) Find the velocity of the block at time t. (2 marks) [*Hint: Derivatives]

(b) Find the acceleration of the block at time t. (2 marks) [*Note: Give your answer in terms including y]

(c) If the spring constant is k and the mass of the block is m then, show that the angular frequency of the oscillator can be written as, $\omega = \sqrt{\frac{k}{m}}$. (3 marks) [*Hints: Newton's law. Hooke's law.]

If $m = 500$ g and $k = 150$ N/m then,

(d) Find the frequency of the oscillations. (3 marks)

(e) Find the period of the oscillations. (2 marks)

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