UNIVERSITY OF ESWATINI

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2018/2019

TITLE OF PAPER: MECHANICS

COURSE NUMBER: PHY211

TIME ALLOWED: THREE HOURS

INSTRUCTIONS: ANSWER ANY FOUR OUT OF FIVE QUESTIONS.

EACH QUESTION CARRIES 25 MARKS.

MARKS FOR EACH SECTION ARE IN THE RIGHT HAND MARGIN.

THIS PAPER HAS 6 PAGES INCLUDING THE COVER PAGE.

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QUESTION 1

(a) Derive the basic kinematic equation:

$$x = x_0 + v_0 t + \frac{1}{2} a_0 t^2$$

(7 marks)

(b) A cannon placed on a 50 m high cliff fires a cannonball over the edge of the cliff at $v = 200$ m/s making an angle of $\theta = 30°$ to the horizontal. How long is the cannonball in the air? Neglect air resistance.

(5 marks)

(c) At $t = 0$, an elevator departs from the ground with uniform speed. At time T_1 a child drops a marble with zero initial velocity measured with respect to the floor of the elevator. The marble falls with uniform acceleration g, and hits the ground T_2 seconds later. Find the height of the elevator at time T_1 as a function of g, T_1 and T_2.

(7 marks)

(d) A drum of radius R rolls down a slope without slipping. Its axis has acceleration a parallel to the slope. What is the drum's angular acceleration α?

(6 marks)

QUESTION 2

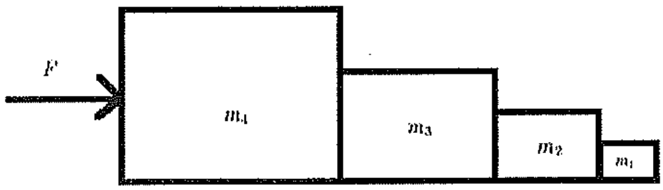
(a) Four blocks (m_1 = 1kg, m_2 = 2.00kg, m_3 = 3.00kg and m_4 = 4.00kg) are in contact on a horizontal table. A horizontal force F = 18.0 N is applied to the mass m_4.

(i) Draw a force diagram for each block.

(4 marks)

(ii) Find the magnitude of the force of contact F_{12} between m_1 and m_2, F_{23} between m_2 and m_3 and F_{34} between m_3 and m_4.

(9 marks)



(b) Consider two masses, m_1 and m_2, connected by a light inextensible string which is suspended from a light frictionless pulley, as shown in the Figure below. Find the Tension T and acceleration a.

(i) Draw a force diagram for each block.

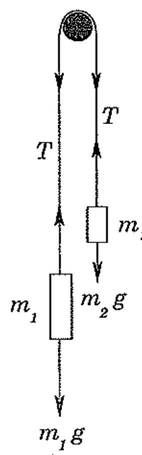
(2 marks)

(ii) Find the Tension T on the string.

(5 marks)

(iii) Find the acceleration a.

(5 marks)



QUESTION 3

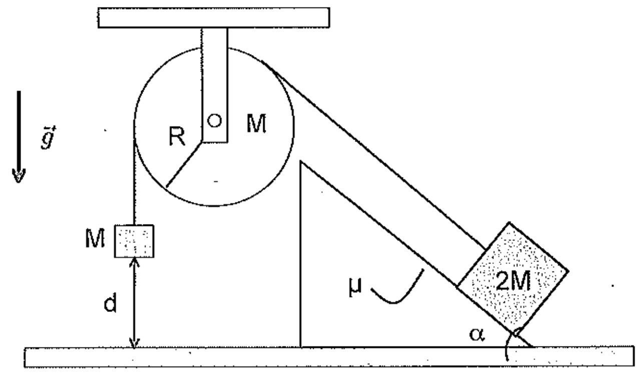
(a) An Atwood machine consists of a fixed pulley wheel of radius R and uniform mass M (a disk), around which an effectively massless string passes connecting two blocks of mass M and $2M$. The lighter block is initially positioned a distance d above the ground. The heavier block sits on an inclined plane with opening angle α. There is a coefficient of friction μ between the surfaces of this block and the inclined plane. Constant gravitational force acts downwards, and assume that the string never slips.

(i) Determine two conditions on the angle α which allow the lighter block to move up or move down.

(6 marks)

(ii) Assuming that the lighter block moves down, determine its acceleration.

(8 marks)



(b) A circus acrobat of mass M leaps straight up with initial velocity v_0 from a trampoline. As he rises up, he takes a trained monkey of mass m off a perch at a height h above the trampoline.

(i) What is the velocity v_1 when he takes the monkey?

(4 marks)

(ii) Using conservation of momentum find v_2 the velocity just after he takes the monkey.

(3 marks)

(iii) What is the maximum height attained by the pair?

(4 marks)

QUESTION 4

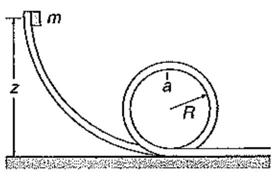
(a) A small block of mass m starts from rest and slides along a frictionless loop-the-loop as shown in the sketch below.

(i) Find the velocity of the block at the top of the loop.

(6 marks)

(ii) What should be the initial height z, so that m pushes against the top of the track (at a) with a force equal to its weight? (Use conservation of energy)

(9 marks)



(b) Derive an expression for the work-energy theorem?

(10 marks)

QUESTION 5

A pendulum consists of a ball of mass M attached to the end of a rigid bar of length $2d$ which is pivoted at the center. At the other end of the bar is a container ("catch"). A second ball of mass $M/2$ is thrown into the catch at a velocity v where it sticks. For this problem, ignore the mass of the pendulum bar and catch, and treat the balls as if they were point masses (i.e., neglect their individual moments of inertia, HINT: angular momentum $L = \mathrm{I}\omega = \mathbf{r} \times \mathbf{p}$).

(a) What is the initial angular rotation rate of the pendulum after the incoming ball is caught?

(8 marks)

(b) How much total mechanical energy is lost when the incoming ball gets stuck in the catch?

(8 marks)

(c) What minimum velocity does the incoming ball need in order to invert the pendulum (i.e., rotate it by 180°)?

(9 marks)