UNIVERSITY OF ESWATINI

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FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF PHYSICS

RESIT EXAMINATION 2019/2020

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:

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$$v^2 = v_0^2 + 2a_0(x - x_0).$$

(6 marks)

(b) Prove the law of sines using cross product.

(6 marks)

(c) The acceleration of gravity can be measured by projecting a body upward and measuring the time that it takes to pass two given points in both directions. The time the body takes to pass a horizontal line A in both directions is T_A, and the time to go by a second line B in both directions is T_B, then, assume that the acceleration is constant.

(i) How long does it take the body to hit the ground?

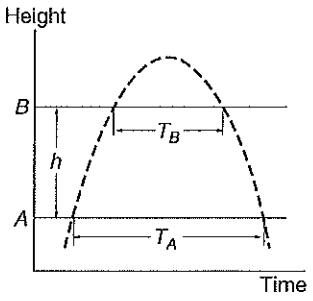
(6 marks)

(ii) Show that the magnitude of acceleration, g, is

$$g = \frac{8h}{T_A^2 - T_B^2},$$

where h is the height of line B above line A.

(7 marks)



QUESTION 2

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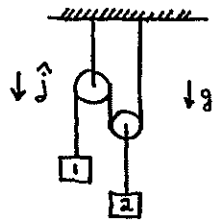
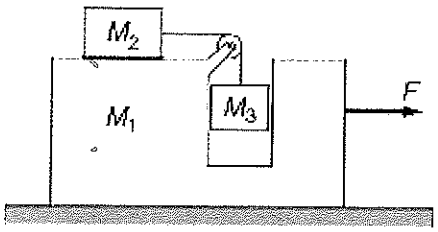
(a) In the system shown in the figure above, the pulleys are massless and frictionless, and the ropes have no mass. Choose downward as the positive direction for acceleration of each moving object. The gravitational acceleration g is directed downward. What is the relationship between the downward components of the accelerations of blocks 1 and 2 due to the constraints imposed by the system of strings and pulleys? Neglect friction.



(8 marks)

(b) A sketch of a "pedagogical machine" is shown below. All surfaces are frictionless. A force F is applied to M_1 to keep M_3 from rising or falling? Neglect friction.



(i) Draw force diagrams for the system.

(5 marks)

(ii) Find the tension T in the string.

(3 marks)

(iii) Find the force F that is applied to M_1 to keep M_3 from rising or falling.

(9 marks)

QUESTION 3

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(a) Consider a rope of total mass M and length L suspended at rest from a fixed mount. The rope has a linear mass density that varies with height as $\lambda(z) = \lambda_0 \sin(\pi z/L)$ where λ_0 is a constant. Constant gravitational acceleration g acts downward.

(i) Determine the constant λ_0.

(5 marks)

(ii) What is the tension force at the free (bottom) end of the rope?

(3 marks)

(iii) Calculate the tension along the rope as a function of distance z below the mount.

(8 marks)

(b) A block rests on a wedge inclined at angle θ. The coefficient of friction between the block and plane is μ.

(i) Find the maximum value of θ for the block to remain motionless on the wedge when the wedge is fixed in position.

(5 marks)

(ii) Find the expression of the block's acceleration as its slides in terms of g, θ and μ.

(4 marks)

QUESTION 4

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(a) A softball of mass $m = 0.35$ kg is pitched at a speed of $u = 12$ m/s. The batter hits the ball directly back to the pitcher at a speed of $v = 21$ m/s. The bat acts on the ball for $t = 0.01$ s.

(i) What impulse is imparted by the bat to the ball?

(6 marks)

(ii) What average force is exerted by the bat on the ball?

(4 marks)

(b) An empty rail car of mass M starts from rest under an applied force F. At the same time, sand begins to run into the car at steady rate b from a hopper at rest along the track.

(i) Find the velocity when a mass of sand m has been transferred to the rail car. The problem can be solved in only two ways, but use the *mass and momentum transport method.*

(10 marks)

(ii) Apply your solution to the case when $M_0 = 400$ kg, $b = 15$ kg/s and $F = 80$N to find the velocity at time $t = 10$ s.

(5 marks)

QUESTION 5

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(a) A bead of mass M is placed on a frictionless, rigid rod that is spun about at one end at a rate ω. The bead is initially held at a distance r_0 from the end of the wire. Treat the bead as a point mass and neglect gravitational forces.

(i) What force is necessary to hold the bead in place at r_0?

(5 marks)

(ii) After the bead is released, what is its position in the inertial frame (in polar coordinates) as a function of time?

(10 marks)

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

(10 marks)