UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 1 Examination in Engineering: August 2018

Module Number: ME1202 Module Name: Introduction to Mechanical Engineering

[Three Hours]

[Answer **all questions**, each question carries **20** marks]

Clearly state any assumptions that you may make. Take g = 9.8 N/kg

Q1. i) A car travels in a straight line with the acceleration described by the displacement (s) vs acceleration (a) graph shown in Figure Q1(a). If the car starts from rest,

a). determine the relationship between displacement and car speed (v) and sketch the $v - s$ graph.

b). determine the maximum speed of the car.

c). If the motion continues in the same direction, calculate the distance travels (s_1) by the car before it stops.

[10 Marks]

ii) A boy throws a ball at O in the air with a speed v_0 at an angle θ_1 so that it passes through point B as shown in Figure Q1(b). If he then throws another ball with the same speed at an angle $\theta_2 < \theta_1$, to pass through B,

a). determine that time taken to reach the position B by each ball and

b). show that the time between the throws so that the two balls collide in mid-air at B is $\dfrac{2v_0 \sin(\theta_1 - \theta_2)}{g(\cos\theta_1 + \cos\theta_2)}$

[10 Marks]

Q2. i) Figure Q2(a) shows a particle moving in a curvilinear path. The particle is at A at time t and it moves to a position A' after a short time δt. The radius of curvature of the path A to A' can be approximated to ρ with the center at C and small angle of rotation $\delta\beta$ in radians.

a). Copy the diagram to your answer script and sketch the motion of the particle in normal (n) and tangential (t) coordinate plane. Taking the unit vectors in n and t directions are $\underline{e_n}$ and $\underline{e_t}$, derive the velocity vector and the acceleration vector of the particle in $n - t$ coordinates and show their directions.

b). Sketch the resultant acceleration of the particle above in $n - t$ coordinate plane when accelerating and decelerating.

c). Using the results (a) above, obtain the acceleration of a particle moving in a circular path with a radius ρ and constant angular speed ω.

[12 Marks]

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ii) An amusement park swing ride is shown in Figure Q2(b) where four passengers with 50kg of mass each, ride at constant speed. The speed of each passenger is equal in magnitude. Riders motion is represented in $n-t$ and b perpendicular directions as shown. At the given instance, supporting cables are directed at $\theta = 30°$ from the vertical (b). Total weight of a chair with its passenger is 70kg and the radius of the swings (hanging chair) top position from the riding centre is 4m as shown.

a). Determine the riders' constant speed (speed in tangential direction).

b). Calculate the acceleration of a passenger in $n-t$ and b directions.

c). Draw a free body diagram of one passenger and calculate the components of force exerted by the chair on the passenger in the $n-t$ and b directions.

[8 Marks]

Q3. i) Draw suitable sketches and derive expressions for,

a). Work associated with a constant external force of F applied at angle α to horizontal plane on a block that can freely move on the horizontal smooth surface

b). Work associated with the force applied by a spring which is attached to a block that is free to move on a horizontal smooth surface

c). Kinetic energy gained by a particle that is moving at a velocity V_1 on which an external force F is applied so that the final velocity of the particle becomes V_2.

[8 Marks]

ii). A block P (40kg) shown in Figure Q3 is mounted on rollers so that it can moves along the horizontal smooth rail that is fixed to the table. A constant horizontal force, T is applied by a cable wound on a drum D (with outer diameter of 0.2m) connected to a motor which drives at its maximum power of 3kW at 100 rev/min. The block P is released from rest at A, with the spring (stiffens is 80N/m) to which it is attached to extended at initial amount $x_1 = 0.25m$. Using work-energy method or otherwise, calculate

a). Constant cable tension T

b). Work done by the spring force acting on the block

c). the velocity of the block as it reaches position B.

d). If the rollers and the rail are not smooth, explain how do you take that effect in to consideration when solving this problem.

[12 Marks]

Q4. i) Figure Q4(a) shows the polar coordinates r and θ which locate a particle traveling on a curved path. An arbitrary fixed x-axis is used as a reference for the measurement of θ. Unit vectors $\underline{e_r}$ and $\underline{e_\theta}$ are established in the positive r and θ directions, respectively. The position vector $\underline{r}$ to the particle at A has a magnitude equal to the radial distance r.

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a). Write down the position vector of the particle and obtain the magnitude and the direction of the velocity vector of the particle.

b). Derive the components of the acceleration vector in the $\underline{e_r}$ and $\underline{e_\theta}$ directions, the magnitude of the total acceleration and the direction. Sketch the same on the path at the point A by copying the diagram Figure Q4(a) to your answer script.

[10 Marks]

ii) The tube assembly shown in Figure Q4(b) rotates about the vertical axis OZ with a constant angular speed, $\omega\ rad/s$. A small cylindrical plug P of mass m that is connected to a cord can slide horizontally inside the horizontal tube. The cord passes freely through the tubes and other end of the cord is wound on a pulley of a motor. The pulley radius is $s\ in$ m.

a). Draw the free body diagram of the plug, P showing all the forces on it.

b). Determine the tension of the cord and the horizontal and vertical forces on the plug exerted by the horizontal tube if the motor pulley rotates at a constant angular speed, $\omega_0\ rad/s$ counter clockwise as shown in the figure.

c). Obtain the same forces as in above (b) when the motor pulley starts to rotate from rest at angular acceleration of $\alpha\ rad/s^2$ after t_0 seconds.

[10 Marks]

Q5 i) Briefly explain (with suitable sketches) the types of constrained motions demonstrated by kinematic pairs.

[6 Marks]

ii) How you can classify the kinematic pairs according to type of relative motion between the elements?

[6 Marks]

iii) What is the Kinematic chain? How would you decide whether a given kinematic chain is a mechanism or a structure?

[4 Marks]

iv) Determine the number of degrees of freedom of the kinematic chain given in Figure Q5.

[4 Marks]

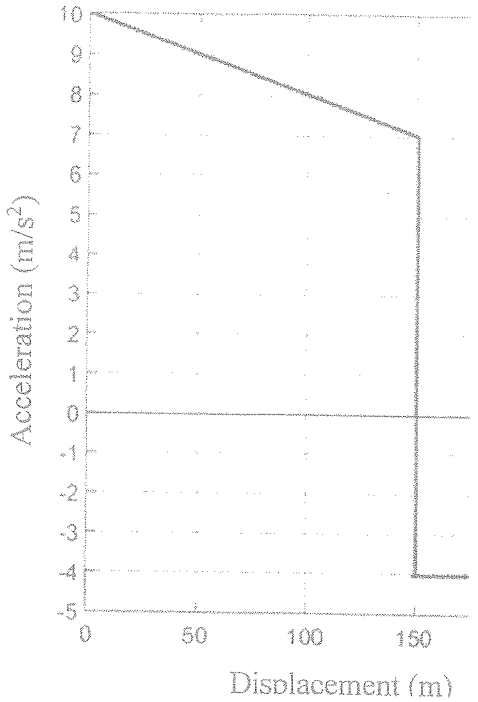

Figure Q1(a)

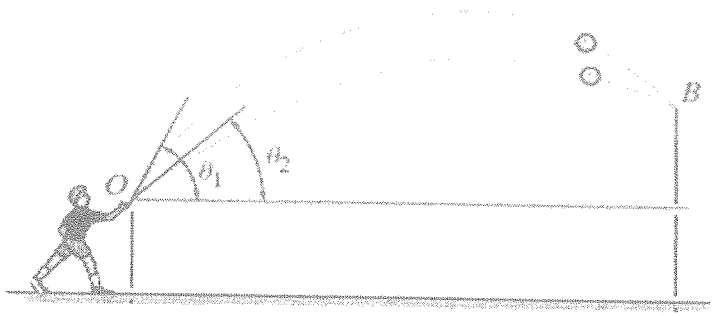

Figure Q1(b)

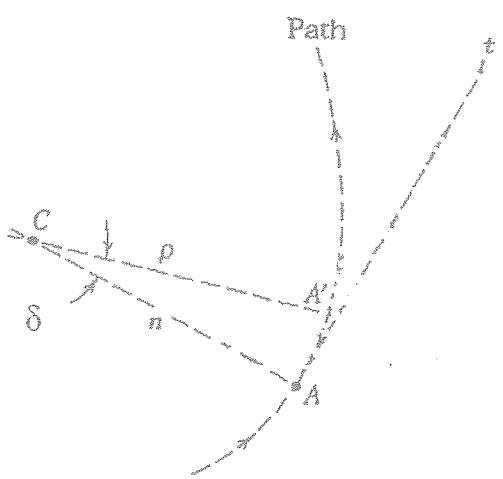

Figure Q2(a)

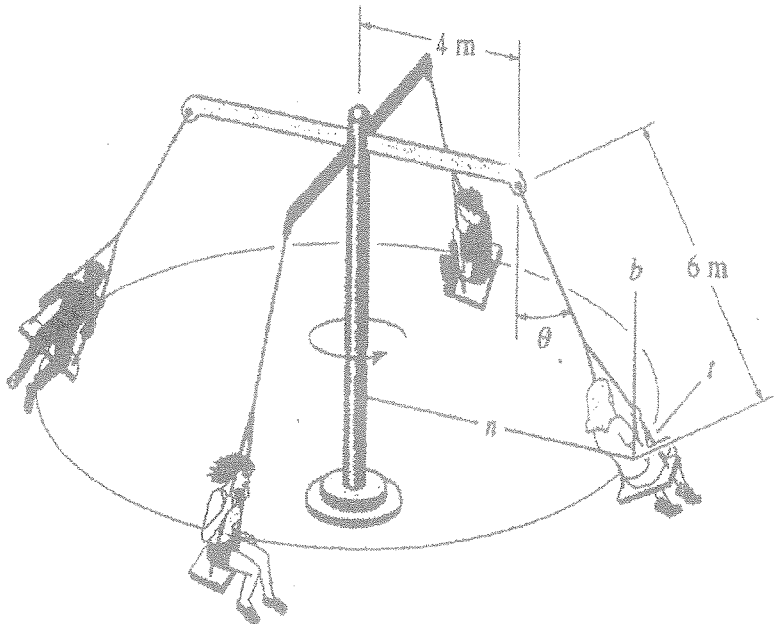

Figure Q2(b)

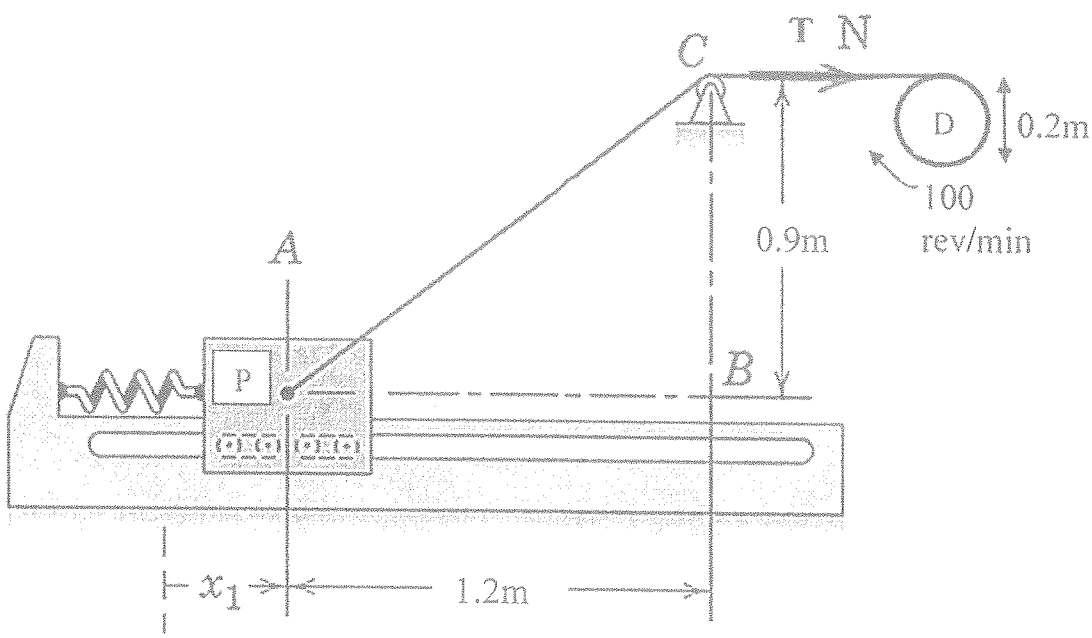

Figure Q3

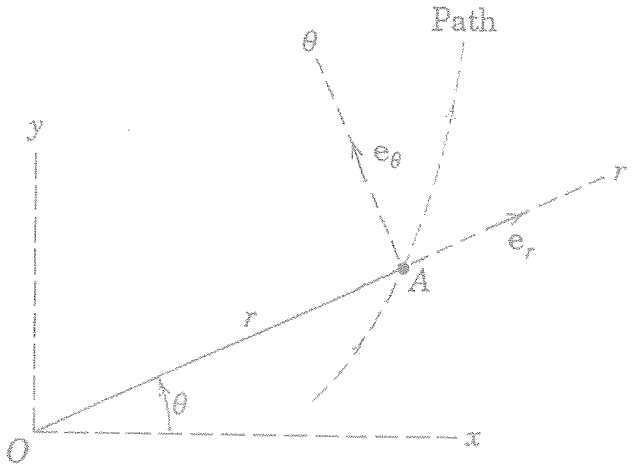

Figure Q4(a)

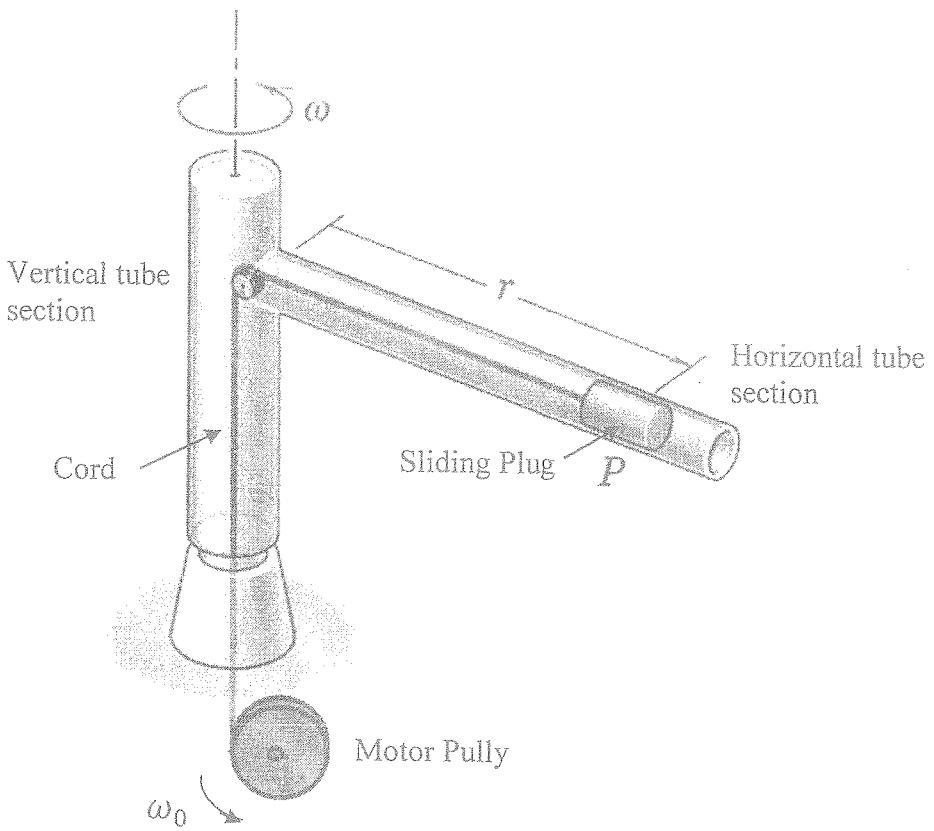

Figure Q4(b)

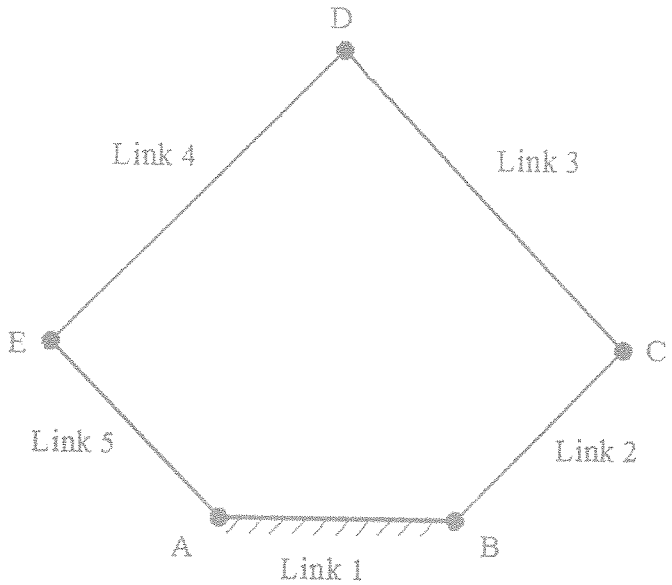

Figure Q5