UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 2 Examination in Engineering: November 2017

Module Number: ME2201 **Module Name: Engineering Mechanics**

[Three Hours]

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

Gravitational acceleration, g = 9.8 N/kg

Q1. a) A car has an initial displacement s_0 m, velocity, v_0 m/s is moving on a straight path. At any given time t seconds its displacement and velocity are given by s m and v m/s respectively. If the acceleration of the car is given as a function of velocity, $f(v)$ or as a function of displacement, $g(s)$ obtain following relationships.

i). If the acceleration of the car is given as a function of velocity, $f(v)$ show that

$$s = s_0 + \int_{V_0}^{V} \frac{v}{f(v)} dv$$

ii). If the acceleration of the car is given as a function of displacement, $g(s)$

$$v^2 = v_0^2 + \int_{V_0}^{V} g(s) ds$$

[8 Marks]

b) The spring - mounted slider with mass 1 kg moves on the horizontal guide as show in Figure Q1(b).

i). Draw the free body diagram and show that deceleration of the slider due to retarding forces exerted by two springs together is $a = (k_1 + k_2)x$ m/s^2 where k_1 and k_2 are spring constants and the distance x is measured from the mid position of the slider at time t.

ii). Determine the expressions for the displacement x and the velocity v if the initial velocity is v_0.

iii). State any assumptions you may make.

[12 Marks]

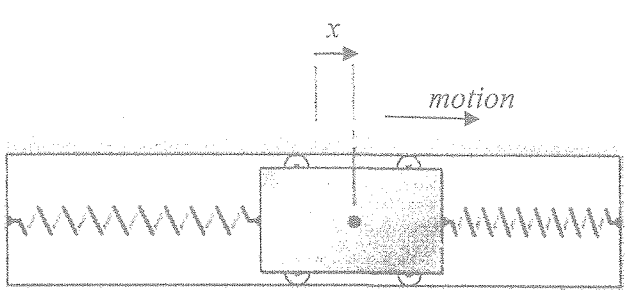

Figure Q1(b)

Q2. a) A particle moving in a curvilinear path with a curvature of ρ m. If the particle tangential velocity is v m/s,

i). sketch the particle motion in normal – tangential coordinate plane

ii). obtain expressions for normal and tangential accelerations, and the resultant acceleration of the particle

[10 Marks]

b) Figure Q2(b) shows a car moving on a curvilinear road with two curvatures A to B and B to C. B is an inflected point where curvature changes to opposite side. The drive applies brakes to produce a uniform deceleration to anticipate the dip and hump in the road. The car speed is 108 km/h at the bottom A of the dip and 54 km/h at the top C of the hump, which is 60m long from A to B and 60m long B to C. If the passengers experience a total acceleration of 7 m/s^2 at A and if the radius of curvature of the hump at C is 150 m, calculate

i). the radius of curvature ρ from A to B?

ii) the acceleration at the inflection point B

iii). the total acceleration at C

[10 Marks]

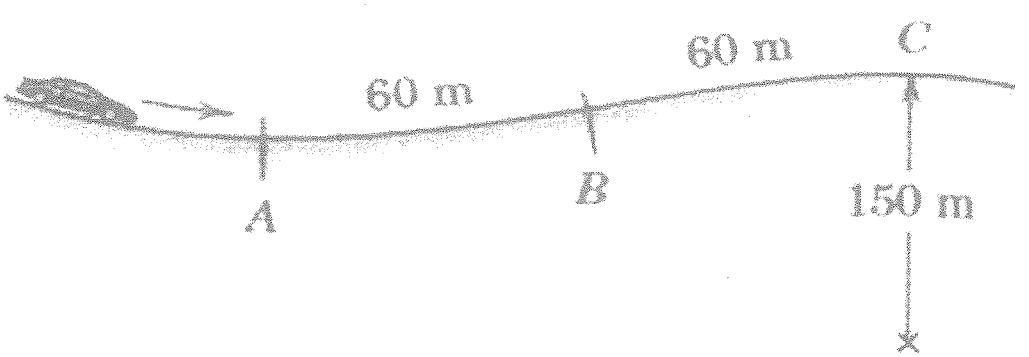

Figure Q2(b)

Q3. a) The 0.1kg particle moving in a groove of curvature $\rho = 5m$ has a speed, $v = 10\ m/s$ as it passes the position 30° as shown in the Figure Q3(a). If the coefficient of kinetic friction between the particle and the vertical plane track is $\mu_k = 0.22$.

i). Determine the total force exerted by the track on the particle

ii). Determine the particle acceleration

[10 Marks]

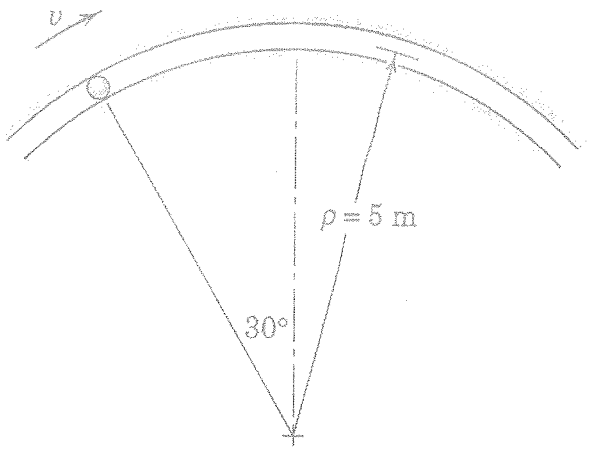

Figure Q3(a)

b) A system shown in Figure Q3(b) consists of a $10kg$ cart, a smooth pully and rope, a linear spring with the spring constant, $k = 100\ N/m$ and a mass $m = 5kg$. If the system is released with no slack in the cable and with the spring stretched 200 mm. Assuming no mechanical interference,

i) determine the distance s mm traveled by the 10-kg cart before it comes to rest

ii). calculate the work done by mass m, spring and the cart

[10 Marks]

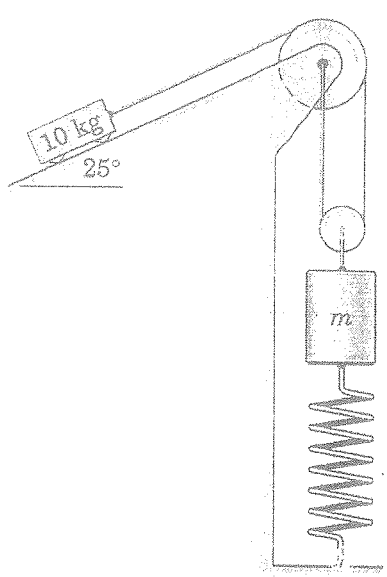

Figure Q3(b)

Q4. a) Define the term "linear momentum" and derive an expression for the linear impulse - momentum principle for system of particles as

$$G_1 + \int_1^2 \sum F(t)dt = G_2$$

in usual notations. Hence obtain conditions to have conservation of linear momentum for a system of particles.

[8 Mark]

b) The loaded 250kg cart shown in Figure Q4(b) is moving downwards on the ramp of 30° at 10 m/s. The increasing force P is applied to the cable at time. $t =$ 0 seconds to stop and reverse the cart. P is increased from zero and following $P = kt^2$ N (k is a constant) variation up to 10 seconds until it reaches 1000N and remains constant at this value.

i). Sketch the graph of P

ii). Calculate all the forces acting on the cart for 0 to 10 seconds period of time

iii). Calculate the time takens to reverse the direction of cart

iv). Calculate the velocity of the cart after 25 seconds

[12 Mark]

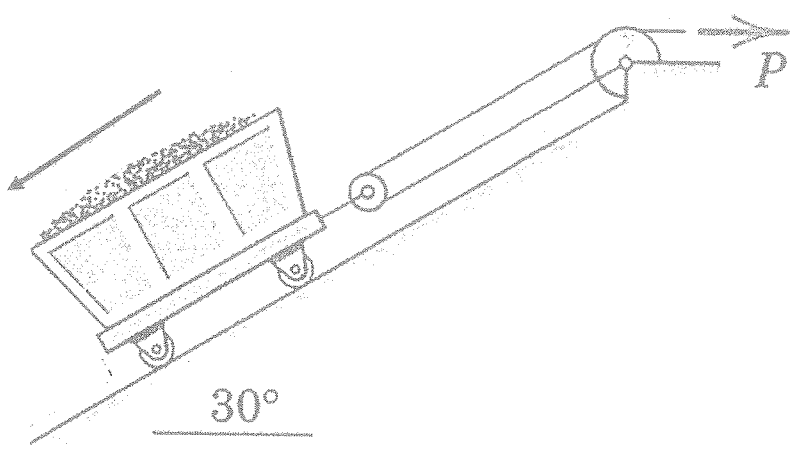

Figure Q4(b)

Q5 a) Name and describe four main types of rigid-body plane motion with suitable sketches. Determine degree of freedom and clearly mention one example for each type of motion.

[6 Marks]

b) An inverted pendulum- cart model is shown in Figure Q5(b). Given that mass of the cart is M, mass of the pendulum is m, length of the pendulum is l and its center of mass is at the middle, mass moment of inertia of the pendulum is I and the coefficient of the friction (proportional to the cart linear velocity) between the cart and the ground is μ. The force $F(t)$ applies to the cart and it moves distance x while pendulum rotates with an angle θ as shown.

i). Draw the free body diagram and apply equation of motion for both cart and the pendulum.

ii). Hence, determine reaction forces at the revolute joint between the pendulum and the cart using linear acceleration of the cart, angular velocity and angular acceleration of the pendulum.

[10 Marks]

c) In a machine, one or several mechanisms are used to produce mechanical transformations. List four of such transformations and mention one examples for each.

[4 Marks]

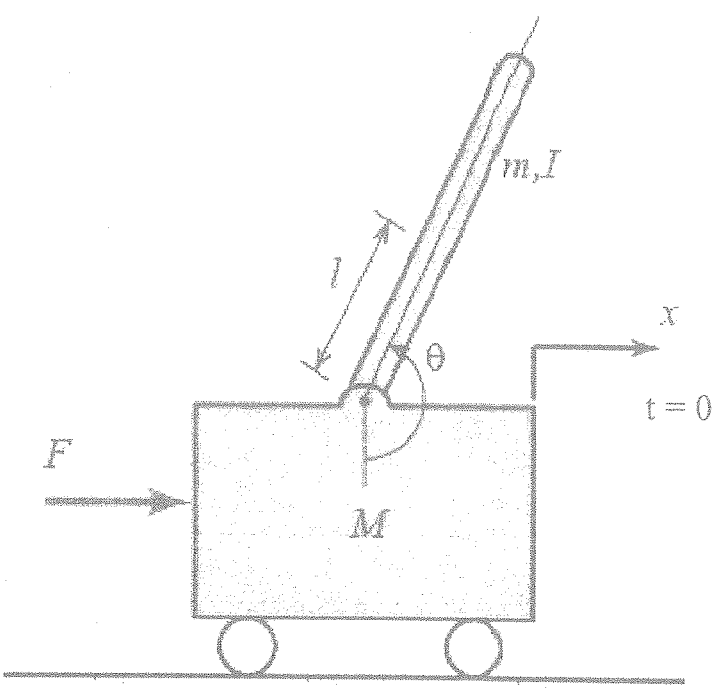

Figure Q5(b)