NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION

MECHANICS PST 2330   **SPECIAL EXAMINATION**

Special Requirements: None

August 2024 Examination Paper

This examination consists of 3 pages

Time: 3 hours

Total marks: 100

Lecturer: Mrs N.Chikusvura-Matiza

INSTRUCTIONS

1. Answer **all questions** from Section A **(compulsory)** and any **three questions** from Section B.
2. Section A carries **40 marks.**
3. Each question in Section B has 20 marks.
4. Scientific calculators may be used where necessary.

MARK ALLOCATION

QUESTION	MARKS
1	16
2	24
3	20
4	20
5	20
6	20
TOTAL	100

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SECTION A- (40 MARKS)   Compulsory

Question 1

(a) State Newton's second and third law of motion   [2]
(b) When is a force said to be in equilibrium?   [3]
(c) Define the following terms
   i.   velocity   [2]
   ii. Energy   [2]

(d) A motorcyclist starts from rest A and travels in a straight line until he comes to rest again at B. The velocity of the motor cyclist t seconds after leaving A at $v\ ms^{-1}$, where

$v = t - 0.01t^2$. Find

   i.   The time take for the motor cyclist to travel from A to B.   [4]
   ii. The distance AB   [3]

QUESTION 2

a) A bus starts from rest with constant acceleration a, simultaneously a man at distance b behind the bus starts to chase the bus with constant speed v. Show that he can catch the bus   if $v^2 \geq 2ab$.
   [6]

b) A lorry of mass 3 tonnes is moving at a constant speed of $4ms^{-1}$ when it collides with another lorry, of mass 5 tonnes, moving at a speed of $2ms^{-1}$ in the same direction. The speed of the 5-tonne truck is increased to $5ms^{-1}$ by collision. Show that the speed of the 3-tonne lorry is $1ms^{-1}$ after the collision and find the direction of the motion.
   [8]

c) A box of mass 2kg is pushed up a rough plane by a horizontal force of magnitude 25N. The plane inclined to the horizontal at an angles of 10^0. Given that the coefficient of friction between the box and the plane is 0.3.

   i.   Draw a diagram showing all forces and acceleration.   [4]
        Note: friction will be limiting since the box is sliding
   ii. Hence,   find   the   acceleration   of   the   box.
   [6]

2

QUESTION 3
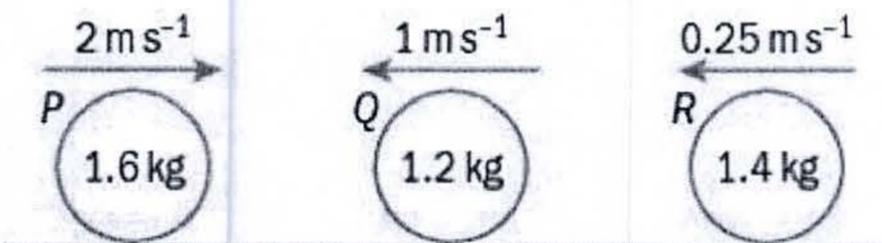
Three particles, P, Q and R, have masses 1.6kg, 1.2kg and 1.4kg, respectively. The particles are moving in a straight line on a smooth horizontal line on a smooth horizontal tables, with Q between P and R. The particle P is moving towards Q at a speed of $2ms^{-1}$ and the particles Q and R are moving towards P at speed of$1ms^{-1}$ and $0.25ms^{-1}$, respectively.

a) P collides with Q. As a result of this collision the direction of motion of Q is reversed and its speed remains$1ms^{-1}$. Find the speed of P after the collision.   [4]

b) Q collides with R.

  i.   Find the total momentum of Q and R in the direction of Q's motion immediately before the collision takes place, and verify that the direction of motion R is reverses as a result of   this   collision.
       [5]

  ii. Given that Q is brought to rest by this collision, find the speed of R immediately after the collision.   [5]

c) A spherical mass of 6g moving at $12ms^{-1}$ impinges (collides) directly on a stationery sphere of mass 18g. The coefficient of restitution $e = \frac{1}{3}$ $(0 \le e \le 1)$. Find their velocities after the impact.   [6]

QUESTION 4
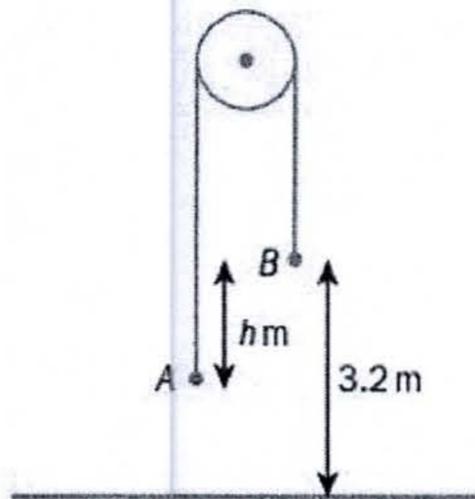
Particle A of mass 0.3kg and particle B of mass 0.5kg are attached either end of a light inextensible string that passes over a smooth pulley. A is hanging h m below B, which is being held at rest 3.2 m above the floor. Both parts of the string are vertical. B is released and both particles begin to move. When B reaches the floor it remains at rest while A continues to move vertically upwards. A reaches its maximum height when it is 6.2m above the floor. Ignoring air resistance,

Calculate the velocity of the particles immediately before B reaches the floor. **[9]**

b) Consider the plane polar coordinate (r, θ). Putting in mind that by Newton's second law $F =$

$m\ddot{r} = f(r)e_r$ where in polar coordinate $\ddot{r} = (\ddot{r} - r\dot{\theta}^2)e_r + (2\dot{r}\dot{\theta} + r\ddot{\theta})e_\theta$.
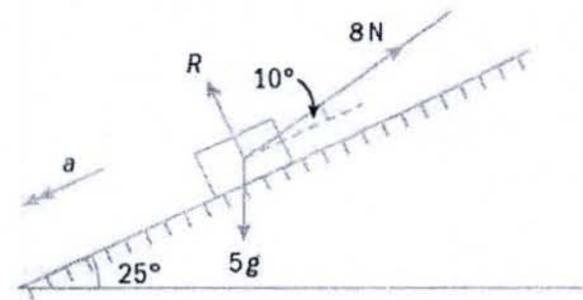
Prove   that $\dfrac{d^2u}{d\theta^2} + u = \dfrac{-f\left(\frac{1}{u}\right)}{mh^2u^2}$.

[11]

QUESTION 5

a) A car of mass m, has an engine that can work at a maximum power P. The total resistance force (including friction and air resistance) on the car at speed v is Rv. Find the time, T, it takes to accelerate from 0 to u at maximum power. **[5]**

QUE

a) A block of mass 50kg is pulled up a straight hill and passes through points A and B with speeds $7ms^{-1}$ and $3ms^{-1}$ respectively. The distance AB is 200m and B is 15m is higher than A. For the motion of the block from A to B, find

  i.   The loss in kinetic energy of the block [2]
  ii. The gain in potential energy of the block [2]

The resistance to motion of the block has magnitude 7.5N

  iii. Find the work done by pulling force acting on the block. [2]

The pulling force acting on the block has constant magnitude 45N and acts at an angle α^0 upwards from the hill.

  iv. Find the value [3]

b) A light inextensible string with one fixed end passed under a movable pulley of mass m and over a fixed smooth pulley and carries mass $M \left[> \dfrac{m}{2} \right]$ at its free end, the parts of the string between the mass, the pulleys and the point of suspension on being vertical. If the system is released from rest, show that the velocity of the mass M when it has fallen though a distance c is $\sqrt{\dfrac{4gc(2M-m)}{4M+m}}$.

[11]