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MATHEMATICS M3

Mechanics 3

A.M. MONDAY, 18 June 2007

($1\frac{1}{2}$ hours)

ADDITIONAL MATERIALS

In addition to this examination paper, you will need:

- a 12 page answer book;
- a Formula Booklet;
- a calculator.

INSTRUCTIONS TO CANDIDATES

Answer **all** questions.

Take g as 9·8 ms $^{-2}$.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

You are reminded of the necessity for good English and orderly presentation in your answers.

1. A car of mass 800 kg is initially at rest on a straight horizontal road. The car is then pushed by a man with a constant horizontal force of 400 N. The resistance to the motion of the car has magnitude $16v^2$ N, where v ms^{-1} is the speed of the car at time t s. The man pushes the car until it reaches a speed of 2 ms^{-1}.

(a) (i) Show that v satisfies the differential equation

$$\frac{dv}{dt} = \frac{25 - v^2}{50} .$$

(ii) Find, correct to two decimal places, the time for which the man pushes the car. [9]

(b) Form another differential equation and determine, correct to two decimal places, how far the man pushes the car. [7]

2. A particle P is moving in a straight line with Simple Harmonic Motion. It starts from rest from a point A, and 2 seconds later, reaches its maximum speed of 3π ms^{-1}.

(a) Show that the amplitude of the motion is 12 m. [4]

(b) Calculate the distance from A of the particle $\frac{2}{3}$ s after the start of motion. [4]

(c) Calculate the speed of the particle $\frac{2}{3}$ s after the start of motion. [3]

(d) Points X and Y are equidistant from O, the centre of the motion, and are 10 m apart. Calculate the time taken for P to proceed directly from X to Y. [4]

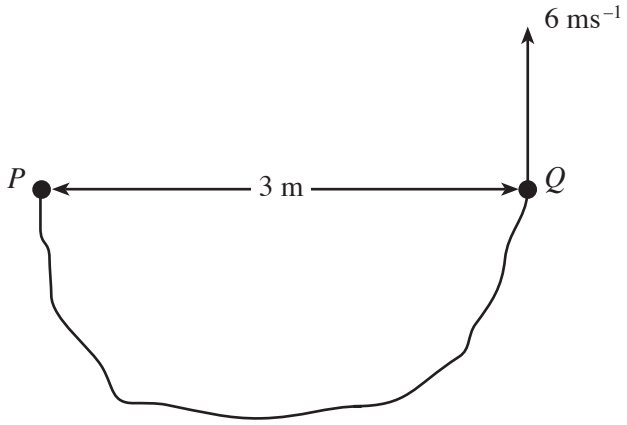
3. A uniform ladder AB, of length 2 m and **weight** 90 N, rests with one end A on rough horizontal ground and the other end B against a smooth vertical wall. The ladder is inclined at an angle θ to the **vertical**, where $\tan\theta = 0{\cdot}8$. The coefficient of friction between the end of the ladder and the ground is 0·6. A force of magnitude P N is applied to the ladder at a point which is $\frac{1}{2}$ m from the end A; the direction of this force is horizontal and towards the wall. The end A is on the point of moving towards the wall.

(a) Draw a diagram and clearly show all the forces acting on the ladder. [2]

(b) Show that $P = 120$. [10]

(c) State **one** modelling assumption you have made about the ladder in your solution. [1]

4. Two particles P and Q, of mass 7 kg and 9 kg respectively, are attached one to each end of a light inextensible string of length 5 m. Initially, the particles are at rest on a smooth horizontal surface a distance 3 m apart, as shown in the diagram. Particle Q is then projected horizontally with velocity $6\,\text{ms}^{-1}$ in a direction at 90° to the line joining the initial positions of P and Q.



Calculate the speed of P and the speed of Q immediately after the string becomes taut. Determine the impulsive tension in the string during the jerk, and find the angle between the velocity of P and the velocity of Q immediately after the jerk. [14]

5. An experimental vehicle, of mass 800 kg, is propelled from rest along a straight horizontal track by means of a horizontal force of variable magnitude $(6120 - 80t)$ N, where t s is the time after projection. The vehicle expriences a resistance of magnitude $(120 + 40v)$ N, where $v\,\text{ms}^{-1}$ is the speed of the vehicle at time t s. The distance of the vehicle from its starting position at time t s is x m.

(a) Show that x satisfies the differential equation

$$20\frac{\mathrm{d}^2x}{\mathrm{d}t^2} + \frac{\mathrm{d}x}{\mathrm{d}t} = 150 - 2t.$$ [5]

(b) Find an expression for x in terms of t. [12]