7

(a) Two light identical springs and two identical 200 g masses are connected to one another and suspended from a support in the manner shown in Fig. 7.1. The force constant of each spring is 24.0 N m^{-1}. The masses are lowered gently until they come to rest and the system attains equilibrium.

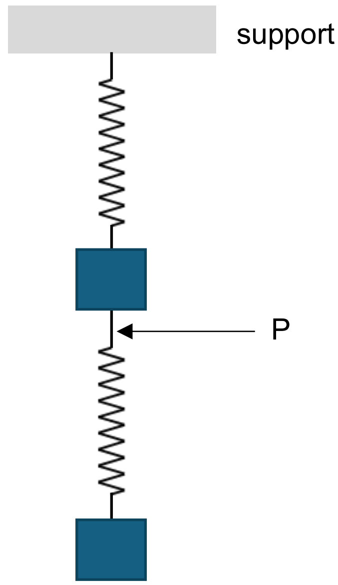

Fig. 7.1

(i) Calculate the extension of the upper and lower springs.

Extension of upper spring = …………………….. m

Extension of lower spring = …………………….. m

[2]

(ii) Determine the total elastic potential energy stored in the system at equilibrium.

Total elastic potential energy stored = …………………………… J [2]

The system is in a state of equilibrium shown in Fig. 7.1 when the connection between the lower spring and the upper mass breaks at point P, allowing the lower mass to fall away.

(iii) Calculate the acceleration of the upper mass at this instant.

Acceleration = ……………….. m s^{-2} [2]

(iv) A student wishes to calculate the speed of the upper mass at time *t* after the break at P using the equation $v = u + at$ where the acceleration is the value found in (iii). Comment on whether his method is correct.

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………….....[2]

(v) Show that the period of the subsequent oscillation of the mass suspended from the upper spring is 0.574 s after the break at P.

[2]

(b) A light wire is bent so that it forms an L-shaped structure with two mutually perpendicular arms of equal length equal to 0.400 m. Masses M_1 and M_2 are attached to the ends of the wire, and the whole structure is allowed to pivot freely at point P. The angle between the right arm and the vertical is θ = 18.4° as shown in Fig. 7.2.

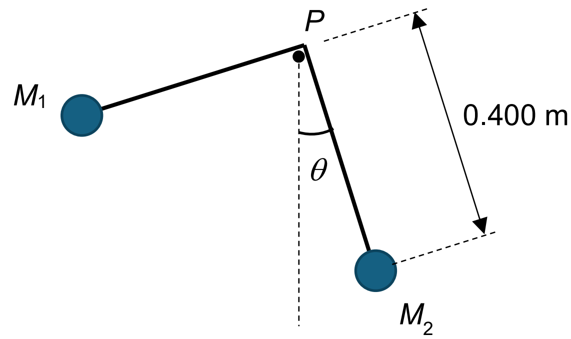

Fig. 7.2

(i) Determine the ratio of mass M_2 to M_1. Explain your working.

Ratio = …………………… [3]

The structure is now rotated about P until the right arm is horizontal as shown in Fig. 7.3, and then released.

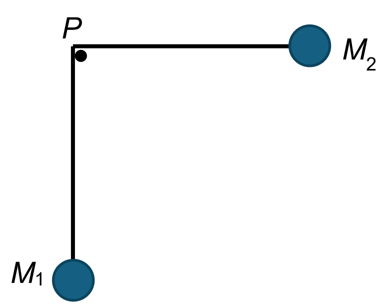

Fig. 7.3

(ii) As the structure rotates to the orientation shown in Fig. 7.2, the speed of each mass increases to 2.06 m s^{-1}.
Given that the mass M_2 is 300 g, calculate the net loss in gravitational potential energy of the system.

Net loss in gravitational potential energy = …………………… J [3]

(iii) Calculate the rate of work done by the gravitational force acting on mass M_2 at the instant that it is moving with the maximum speed of 2.06 m s^{-1}.
(Hint: resolve the weight of the mass M_2 along the tangent to the path of mass M_2.)

Rate of work done = ……………………….. W [2]

The structure will come to instantaneous rest at its other amplitude orientation shown in Fig. 7.4.

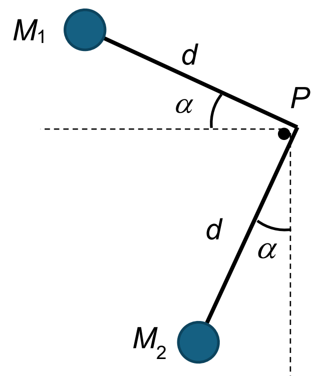

Fig. 7.4

(iv) By considering Fig. 7.3 and Fig. 7.4, show that the angle α follows the relation:

$$3 \cos \alpha = 1 + \sin \alpha$$

[2]

[Total: 20]