A block B of mass 7 kg is at rest on rough horizontal ground. A force of magnitude $X \, \text{N}$ acts on B at an angle of $15^\circ$ to the upward vertical (see diagram).

(i) Given that B is in equilibrium find, in terms of $X$, the normal component of the force exerted on B by the ground. [2]

(ii) The coefficient of friction between B and the ground is 0.4. Find the value of $X$ for which B is in limiting equilibrium. [3]

A car of mass 1250 kg travels up a straight hill inclined at an angle $\alpha$ to the horizontal, where $\sin \alpha = 0.02$. The power provided by the car’s engine is 23 kW. The resistance to motion is constant and equal to 600 N. Find the speed of the car at an instant when its acceleration is 0.5 m s$^{-2}$. [5]

A particle P of weight 1.4 N is attached to one end of a light inextensible string $S_1$ of length 1.5 m, and to one end of another light inextensible string $S_2$ of length 1.3 m. The other end of $S_1$ is attached to a wall at the point 0.9 m vertically above a point $O$ of the wall. The other end of $S_2$ is attached to the wall at the point 0.5 m vertically below $O$. The particle is held in equilibrium, at the same horizontal level as $O$, by a horizontal force of magnitude 2.24 N acting away from the wall and perpendicular to it (see diagram). Find the tensions in the strings. [6]
4 A small ball of mass 0.4 kg is released from rest at a point 5 m above horizontal ground. At the instant the ball hits the ground it loses 12.8 J of kinetic energy and starts to move upwards.

(i) Show that the greatest height above the ground that the ball reaches after hitting the ground is 1.8 m. [4]

(ii) Find the time taken for the ball’s motion from its release until reaching this greatest height. [3]

5 A lorry of mass 16 000 kg travels at constant speed from the bottom, O, to the top, A, of a straight hill. The distance OA is 1200 m and A is 18 m above the level of O. The driving force of the lorry is constant and equal to 4500 N.

(i) Find the work done against the resistance to the motion of the lorry. [3]

On reaching A the lorry continues along a straight horizontal road against a constant resistance of 2000 N. The driving force of the lorry is not now constant, and the speed of the lorry increases from 9 m s\(^{-1}\) at A to 21 m s\(^{-1}\) at the point B on the road. The distance AB is 2400 m.

(ii) Use an energy method to find \(F\), where \(F\) N is the average value of the driving force of the lorry while moving from A to B. [3]

(iii) Given that the driving force at A is 1280 N greater than \(F\) N and that the driving force at B is 1280 N less than \(F\) N, show that the power developed by the lorry’s engine is the same at B as it is at A. [2]

6 A particle starts from rest at a point O and moves in a horizontal straight line. The velocity of the particle is \(v\) m s\(^{-1}\) at time \(t\) s after leaving O. For \(0 \leq t < 60\), the velocity is given by

\[ v = 0.05t - 0.0005t^2. \]

The particle hits a wall at the instant when \(t = 60\), and reverses the direction of its motion. The particle subsequently comes to rest at the point A when \(t = 100\), and for \(60 < t \leq 100\) the velocity is given by

\[ v = 0.025t - 2.5. \]

(i) Find the velocity of the particle immediately before it hits the wall, and its velocity immediately after its hits the wall. [2]

(ii) Find the total distance travelled by the particle. [4]

(iii) Find the maximum speed of the particle and sketch the particle’s velocity-time graph for \(0 \leq t \leq 100\), showing the value of \(t\) for which the speed is greatest. [4]

[Question 7 is printed on the next page.]
A smooth inclined plane of length 160 cm is fixed with one end at a height of 40 cm above the other end, which is on horizontal ground. Particles $P$ and $Q$, of masses 0.76 kg and 0.49 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley fixed at the top of the plane. Particle $P$ is held at rest on the same line of greatest slope as the pulley and $Q$ hangs vertically below the pulley at a height of 30 cm above the ground (see diagram). $P$ is released from rest. It starts to move up the plane and does not reach the pulley. Find

(i) the acceleration of the particles and the tension in the string before $Q$ reaches the ground, \[4\]

(ii) the speed with which $Q$ reaches the ground, \[2\]

(iii) the total distance travelled by $P$ before it comes to instantaneous rest. \[3\]