1 A train consists of a locomotive pulling 17 identical trucks.

The mass of the locomotive is 120 tonnes and the mass of each truck is 40 tonnes. The locomotive gives a driving force of 121 000 N.

The resistance to motion on each truck is R N and the resistance on the locomotive is $5R$ N.

Initially the train is travelling on a straight horizontal track and its acceleration is $0.11\,\mathrm{m\,s^{-2}}$.

(i) Show that $R = 1500$. **[4]**

(ii) Find the tensions in the couplings between

(A) the last two trucks, **[4]**

(B) the locomotive and the first truck. **[3]**

The train now comes to a place where the track goes up a straight, uniform slope at an angle α with the horizontal, where $\sin\alpha = \frac{1}{80}$.

The driving force and the resistance forces remain the same as before.

(iii) Find the magnitude and direction of the acceleration of the train. **[4]**

The train then comes to a straight uniform downward slope at an angle β to the horizontal.

The driver of the train reduces the driving force to zero and the resistance forces remain the same as before.

The train then travels at a constant speed down the slope.

(iv) Find the value of β. **[3]**

2 A box of mass 8 kg slides on a horizontal table against a constant resistance of 11.2 N.

(i) What horizontal force is applied to the box if it is sliding with acceleration of magnitude $2\,\text{m s}^{-2}$? **[3]**

Fig. 7 shows the box of mass 8 kg on a long, rough, horizontal table. A sphere of mass 6 kg is attached to the box by means of a light inextensible string that passes over a smooth pulley. The section of the string between the pulley and the box is parallel to the table. The constant frictional force of 11.2 N opposes the motion of the box. A force of 105 N parallel to the table acts on the box in the direction shown, and the acceleration of the system is in that direction.

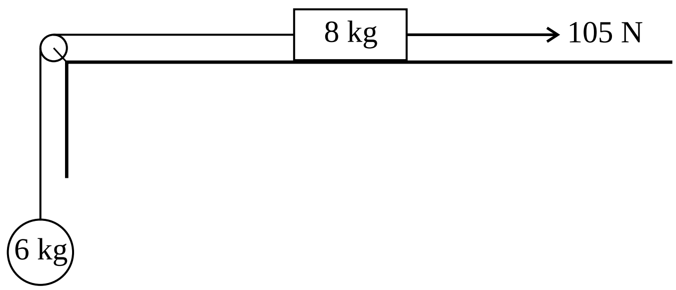

Fig. 7

(ii) What information in the question indicates that while the string is taut the box and sphere have the same acceleration? **[1]**

(iii) Draw two separate diagrams, one showing all the horizontal forces acting on the box and the other showing all the forces acting on the sphere. **[2]**

(iv) Show that the magnitude of the acceleration of the system is $2.5\,\text{m s}^{-2}$ and find the tension in the string. **[7]**

The system is stationary when the sphere is at point P. When the sphere is 1.8 m above P the string breaks, leaving the sphere moving upwards at a speed of $3\,\text{m s}^{-1}$.

(v) (*A*) Write down the value of the acceleration of the sphere after the string breaks. **[1]**

(*B*) The sphere passes through P again at time T seconds after the string breaks. Show that T is the positive root of the equation $4.9T^2 - 3T - 1.8 = 0$. **[2]**

(*C*) Using part (*B*), or otherwise, calculate the total time that elapses after the sphere moves from P before the sphere again passes through P. **[4]**