Connected Particles

6 A car of mass 1000 kg is travelling along a straight, level road.

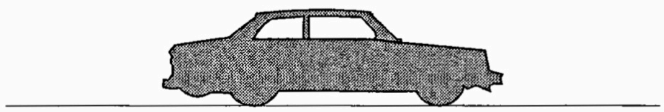


Fig. 6.1

(i) Calculate the acceleration of the car when a resultant force of 2000 N acts on it in the direction of its motion.

How long does it take the car to increase its speed from $5\,\mathrm{m\,s^{-1}}$ to $12.5\,\mathrm{m\,s^{-1}}$? [3]

The car has an acceleration of $1.4\,\mathrm{m\,s^{-2}}$ when there is a driving force of 2000 N.

(ii) Show that the resistance to motion of the car is 600 N. [2]

N2L i)

$$F = ma$$

$$2000 = 1000a$$

$$\frac{2000}{1000} = a$$

$$a = 2\ \mathrm{m\,s^{-2}}$$

SUVAT

$v = u + at$

$s = ut + \frac{1}{2}at^2$

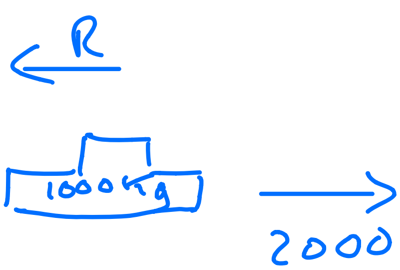
$v^2 = u^2 + 2as$

$$v = u + at$$

$$12.5 = 5 + 2t$$

$$\frac{7.5}{2} = t$$

$$\underline{t = 3.75\ \mathrm{s}}$$



N2L

$$F = ma$$

$$2000 - R = 1000 \times 1.4$$

$$2000 - R = 1400$$

$$2000 - 1400 = R$$

$R = 600\,N$

A trailer is now atached to the car, as shown in Fig. 6.2. The car still has a driving force of 2000 N and resistance to motion of 600 N. The trailer has a mass of 800 kg. The tow-bar connecting the car and the trailer is light and horizontal. The car and trailer are accelerating at $0.7\ \mathrm{m\,s^{-2}}$.

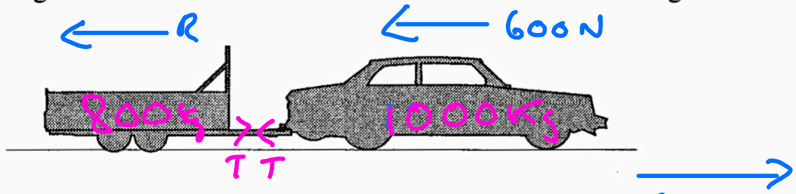


Fig. 6.2

(iii) Show that the resistance to the motion of the trailer is 140 N. [3]

(iv) Calculate the force in the tow-bar. [3]

The driving force is now removed and a braking force of 610 N is applied to the car. All the resistances to motion remain as before. The trailer has no brakes.

(v) Calculate the new acceleration. Calculate also the force in the tow-bar, stating whether it is a tension or a thrust (compression). [6]

iii) N2L whole system

$$F = ma$$

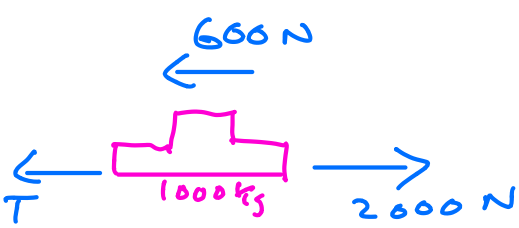
$$2000 - 600 - R = (1000 + 800) \times 0.7$$

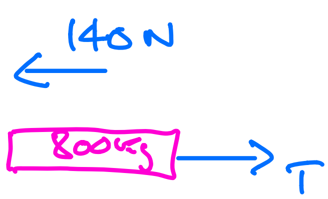
$$1400 - R = 1260$$

$$1400 - 1260 = R$$

$$R = 140\,N$$

iv)





For car N2L $F = ma$

$$2000 - 600 - T = 1000 \times 0.7$$

$$1400 - T = 700$$

$$1400 - 700 = T$$

$$T = 700\,N$$

For trailer N2L $F = ma$

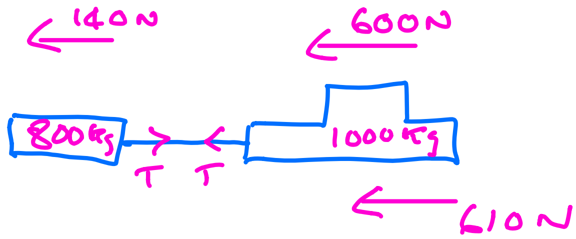
$$T - 140 = 800 \times 0.7$$

$$T - 140 = 560$$

$$T = 560 + 140$$

$$T = 700\,N$$

v)

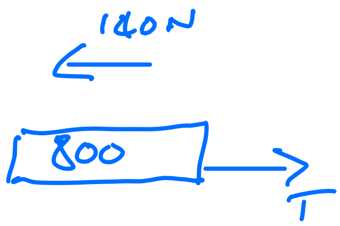


whole system N2L

$$-610 - 600 - 140 = 1800a$$

$$-1350 = 1800a$$

$$a = -\frac{1350}{1800} = -0.75 \text{ ms}^{-2}$$



For trailer N2L

$$T - 140 = 800 \times -0.75$$

$$T - 140 = -600$$

$$T = -600 + 140$$

$$T = -460 \text{N}$$

ie 460N compression

3 A child is pulling a toy lorry and trailer along a horizontal garden path by means of a light horizontal string. The lorry and trailer have masses 3.5 kg and 1.5 kg and are subject to resistances to motion of 6 N and 4 N respectively. The coupling between the lorry and the trailer is light, rigid and horizontal. This situation is shown in Fig. 3.

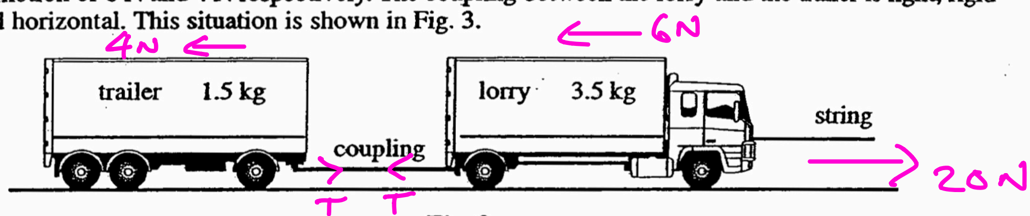


Fig. 3

The tension in the string is 20 N.

(i) Draw a diagram showing all the horizontal forces acting on the lorry and on the trailer, including the force in the coupling. Calculate the acceleration of the lorry and trailer. [4]

(ii) Calculate the force in the coupling. [2]

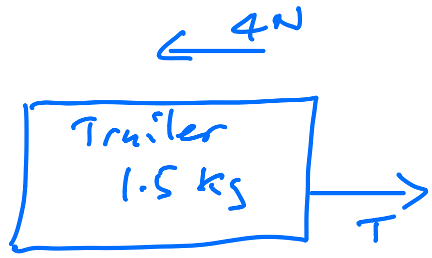
The child's father decides to join in the game by pushing the trailer forwards with a horizontal force. The child pulls the string with the same force as before and the resistances to motion are unchanged. The force in the coupling is now a thrust (compression) of 1.75 N.

(iii) Calculate the force with which the father is pushing. [5]

i) Whole system N2L $F = ma$

$$20 - 6 - 4 = (3.5 + 1.5)a$$
$$10 = 5a$$
$$a = 2\,ms^{-2}$$

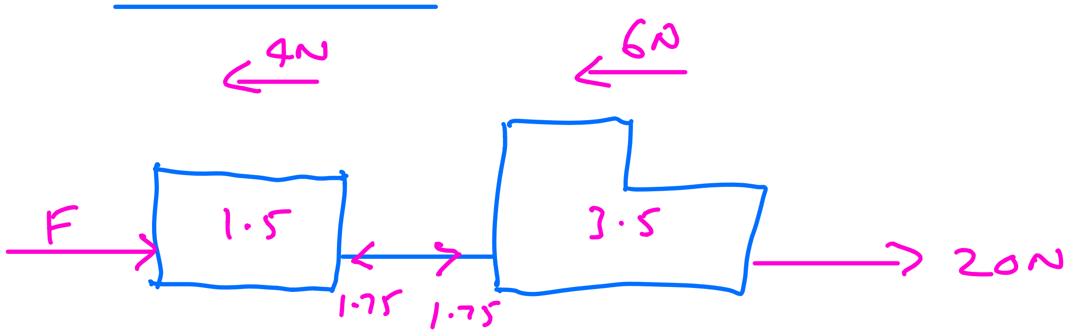
ii)



For trailer N2L

$$T - 4 = 1.5 \times 2$$
$$T = 3 + 4$$
$$T = 7N$$

iii)



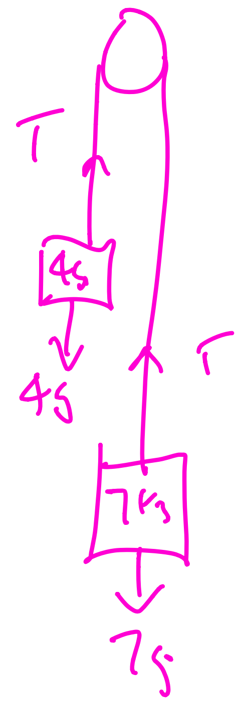
N2L for lorry

$$20 - 6 + 1.75 = 3.5a$$
$$\frac{15.75}{3.5} = a$$
$$a = 4.5\,ms^{-2}$$

N2L for trailer

$$F - 4 - 1.75 = 1.5 \times 4.5$$
$$F = 1.5 \times 4.5 + 5.75 = 12.5\,N$$

↑ a   ↓ a



$$T - 4g = 4a$$

$$7g - T = 7a$$

$$3g = 11a$$

$$\frac{3}{11}g = a$$

$$T - 4g = \frac{12}{11}g$$

$$T = \frac{56}{11}g$$

200 − 40

→ 160