KEY POINTS

1 Newton's laws of motion

I Every object continues in a state of rest or uniform motion in a straight line unless it is acted on by a resultant external force.

II Resultant force = mass × acceleration or $F = ma$.

III When one object exerts a force on another there is always a reaction which is equal, and opposite in direction, to the acting force.

- *Force* is a vector; *mass* is a scalar.
- The *weight* of an object is the force of gravity pulling it towards the centre of the earth. Weight = mg vertically downwards.

2 S.I. units

- length: metre (m)
- time: second (s)
- velocity: ms^{-1}
- acceleration: ms^{-2}
- mass: kilogram (kg)

3 Force

1 newton (N) is the force required to give a mass of 1 kg an acceleration of $1\ ms^{-2}$.

A force of 1000 newtons (N) = 1 kilonewton (kN).

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1 A tractor of mass 1600 kg is pulling a trailer of mass 800 kg along a level muddy field. The driving force of the tractor is 7000 N and the resistances to motion acting on the tractor and trailer are 1000 N and 1200 N respectively.

(i) Show that the common acceleration of the tractor and trailer is $2\ m\,s^{-2}$ in the direction of their motion. [3]

The tractor and the trailer are connected by a light, horizontal coupling, as shown in Fig. 1.

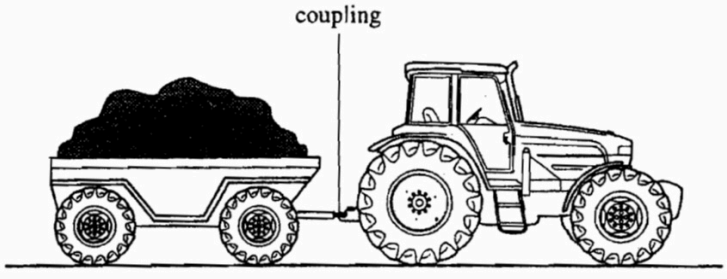


Fig. 1

(ii) Calculate the tension in the coupling. [3]

The coupling between the tractor and the trailer breaks at the time when the speed is $2.7\ m\,s^{-1}$. Assume that the resistances to motion and the driving force of the tractor do not change.

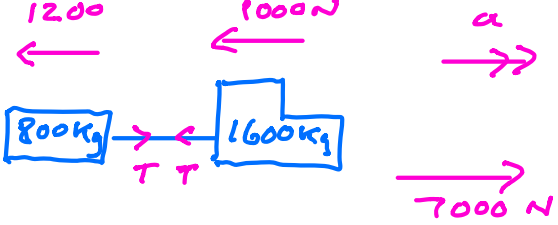
(iii) *(A)* Show that the deceleration of the trailer is $1.5\ m\,s^{-2}$. [2]

(B) Calculate the distance moved by the trailer as it comes to rest. [2]

(C) Calculate the distance between the tractor and trailer when the trailer comes to rest. [4]

Total [14]

a)



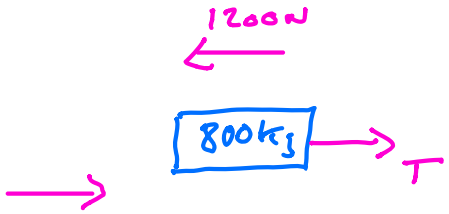
Whole system N2L $F = ma$

$$7000 - 1000 - 1200 = (1600 + 800)a$$

$$4800 = 2400a$$

$$\frac{4800}{2400} = a$$

$$a = 2\ ms^{-2}$$



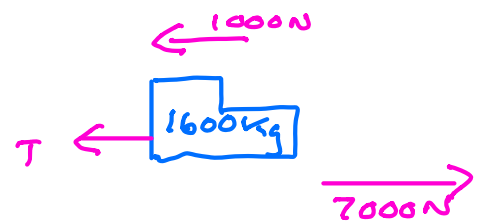
$F = ma$

N2L $T - 1200 = 800 \times 2$

$T = 1600 + 1200$

$T = 2800\ N$

Alternative Solution



N2L $\rightarrow$ $a = 2\ ms^{-2}$

$7000 - 1000 - T = 1600 \times 2$

$6000 = 3200 + T$

$6000 - 3200 = T$

$T = 2800\ N$

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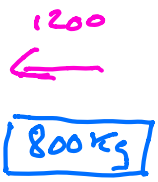
iii)

A)



N2L $-1200 = 800a$

$$\frac{-1200}{800} = a$$

$$-1.5 = a$$

$a = -1.5\ ms^{-2}$ a deceleration of $1.5\ ms^{-2}$

B) SUVAT

$u = 2.7\ ms^{-2}$

$a = -1.5\ ms^{-2}$

$v = 0$

$v = u + at$

$0 = 2.7 - 1.5t$

$1.5t = 2.7$

$t = \frac{2.7}{1.5} = 1.8s$

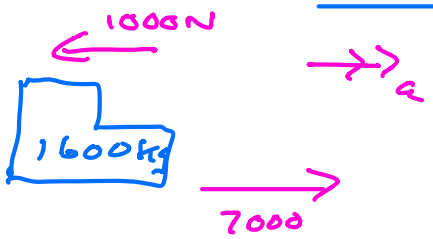
$v^2 = u^2 + 2as$

$0 = 2.7^2 - 3s$

$3s = 2.7^2$

$s = \frac{2.7^2}{3} = 2.43\ m$

C) Tractor



N2L $7000 - 1000 = 1600a$

$\frac{6000}{1600} = a$

$a = 3.75\ ms^{-2}$

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

$s = 2.7 \times 1.8 + \frac{1}{2} \times 3.75 \times 1.8^2$

$s = 10.935\ m$

Distance apart $= 10.935 - 2.43 = 8.505\ m$

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4 A car and its trailer travel along a straight, horizontal road. The coupling between them is light and horizontal. The car has mass 900 kg and resistance to motion 100 N, the trailer has mass 700 kg and resistance to motion 300 N, as shown in Fig. 4. The car and trailer have an acceleration of $1.5\ m\ s^{-2}$.

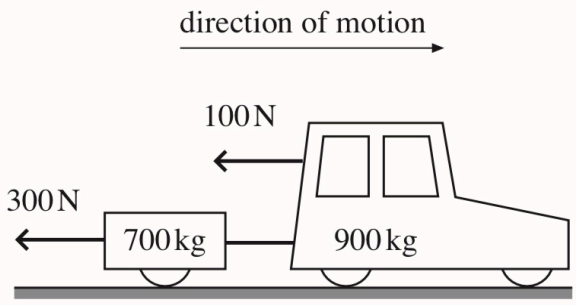
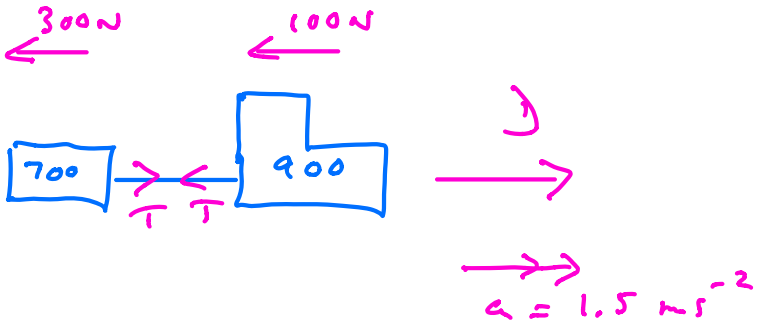


Fig. 4

(i) Calculate the driving force of the car. [3]

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

i)



whole system

N2L $D - 300 - 100 = (700 + 900) \times 1.5$

$D = 1600 \times 1.5 + 400$

$D = 2800\ N$

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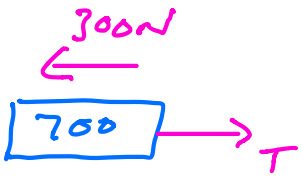
ii)



N2L for trailer

$T - 300 = 700 \times 1.5$

$T = 1050 + 300$

$T = 1350\ N$
