Cambridge International AS & A Level

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Mathematics   9709/42

Paper 4 Mechanics   October/November 2025

Question No (2)

2 A railway locomotive of mass $240\,000\,\text{kg}$ is towing a coach of mass $36\,000\,\text{kg}$ down a hill inclined at an angle of $\sin^{-1} 0.04$ to the horizontal. The driving force produced by the locomotive is $450\,000\,\text{N}$ and there are resistances to motion of $120\,000\,\text{N}$ on the locomotive and $15\,000\,\text{N}$ on the coach. The coupling between the locomotive and the coach is light, rigid and parallel to the hill.

Find the acceleration of the locomotive and the tension in the coupling.

Solution:

Given data

$\theta = \sin^{-1}(0.04)$

$\sin\theta = 0.04$

$DF = 450,000N$

For locomotive resolve The Forces along and perpendicular to The inclined plane.

using The Newton second law.

resolving The Forces along The inclined plane
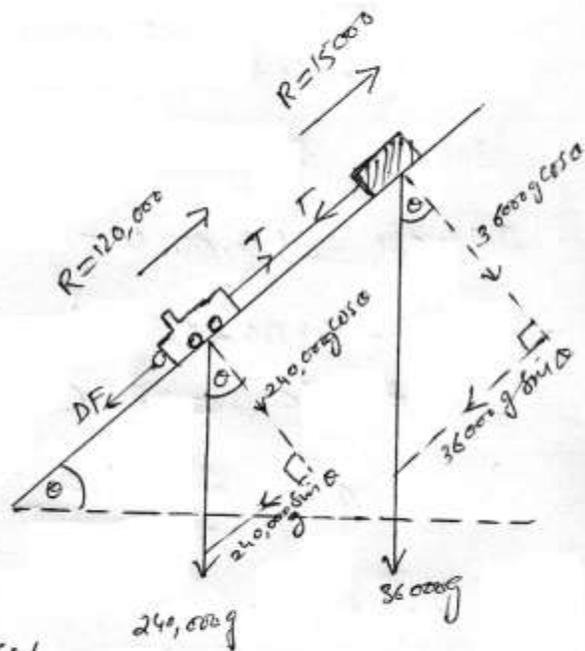
Net Force = ma

$DF + 240,000 \sin\theta - T - R = ma$

$450,000 + 240,000(9.8)(0.04) - T - 120,000 = 240,000 \, a$

$450,000 + 94080 - T - 120,000 = 240,000 \, a$

$424080 - T = 240,000 \, a \longrightarrow ①$

resolve The Forces along The inclined plane for coach.

Net Force = ma

$$T + 36000 \, g \sin \theta - R = 36000 \, a$$

$$T + 36000 (9.8)(0.04) - R = 36000 \, a$$

$$T + 14112 - R = 36000 \, a$$

$$T + 14112 - 15000 = 36000 \, a$$

$$T = 36000 \, a - 14112 + 15000$$

$$T = 36000 \, a + 888 \longrightarrow ②$$

solving ① & ②

$$424080 - (36000 \, a + 888) = 240,000 \, a$$

$$424080 - 888 = 240,000 \, a + 36000 \, a$$

$$423192 = 276000 \, a$$

$$a = \frac{423192}{276000}$$

$$a = 1.53 \, m s^{-2}$$

put $a = 1.53$ in ②

$$T = 36000 (1.53) + 888$$

$$= 55198.956 + 888$$

$$T = 56086.9 \, N$$

$$T = 56100 \, N$$