A spaceship of mass $M = 26$ tonnes $= 26 \times 10^3$ kg is coasting toward Mars at $\vec{V}_0 = 15$ km/s $= 15 \times 10^3$ m/s.

The engines unexpectedly fire for 2 minutes, pushing the ship with a force $\vec{F} = 500$ kN $= 500 \times 10^3$ N away from Mars.

a) After engines stop, what is ship's velocity?

$$\vec{a}_x = \frac{\vec{F}}{M} = \frac{500 \times 10^3 \text{ N}}{26 \times 10^3 \text{ kg}} = 19.23 \frac{\text{m}}{\text{s}^2}$$ in neg x dir to left

$$V_f = V_i + a_x t = 15{,}000 \frac{\text{m}}{\text{s}} - \left(19.23 \frac{\text{m}}{\text{s}^2}\right)(120 \text{ s})$$

$$\boxed{\vec{V}_f = 12{,}692 \text{ m/s} \text{ toward Mars}}$$

$= 13{,}000$ m/s if using significant figures

b) How many <u>miles</u> behind schedule is ship now?

If engines had <u>not</u> fired, in those 2 minutes, would have travelled

$$d_{plan} = \left(15{,}000\ \tfrac{m}{s}\right)(120s) = 1.8\times10^{6}\ m \quad \text{toward Mars}$$

But because engines <u>did</u> fire, distance actually travelled was

$$d_{actual} = V_i t + \tfrac{1}{2} a_x t^2$$

$$= \left(15{,}000\ \tfrac{m}{s}\right)(120s) + \tfrac{1}{2}\left(-19.23\ \tfrac{m}{s^2}\right)(120\ s)^2$$

$$= 1.662\times10^{6}\ m$$

So ship is behind the planned schedule by

$$d_{plan} - d_{actual} \cong 138{,}000\ m \times \left(\frac{1\ \text{mile}}{1609\ m}\right)$$

$$\cong 86\ \text{miles}$$

c) When engines started to fire, ship was how far from Mars?

$$D = 10\ \text{hours} \times \left(\frac{3600\ s}{1\ \text{hour}}\right) \times \left(15{,}000\ \tfrac{m}{s}\right) = 5.4\times10^{8}\ m$$

During the engine-firing duration of 2 minutes, ship travelled

$$d_{actual} = 1.662\times10^{6}\ m$$

So the total distance remaining is

$$\text{remaining dist} = D - d_{actual}$$

$$= 5.38338 \times 10^8 \text{ m}$$

Ship is now moving at slower speed

$$V_f = 12{,}692 \text{ m/s}$$

So time to reach Mars will be

$$t_{\text{after engines}} = \frac{5.38338 \times 10^8 \text{ m}}{12{,}692 \text{ m/s}}$$

$$= 42{,}415 \text{ s}$$

So, original plan (no engines): $t = 10 \text{ hours} = 36{,}000 \text{ s}$

Because engines fired

$$t_{tot} = t_{\text{during engines}} + t_{\text{after engines}}$$

$$= 120 \text{ s} + 42{,}415 \text{ s}$$

$$= 42{,}535 \text{ s}$$

Ship will be 6535 s = 1.8 hours behind schedule

arrive at 3:49 PM