E1

The velocity–time graph is illustrated in Figure 24. You may well have drawn a smooth curve through the data. The question does not make clear whether this is appropriate or not.

(a) The total displacement over the interval is given by the area under the velocity–time graph. This is rather difficult to determine exactly, but a good approximation is to divide the area under the graph into the nine regions shown, and to treat each one as a triangle or a rectangle as appropriate. The displacement is then seen to be approximately 168 m.

(b) The velocity at $t = 10$ s is 10.0 m s^{-1}.

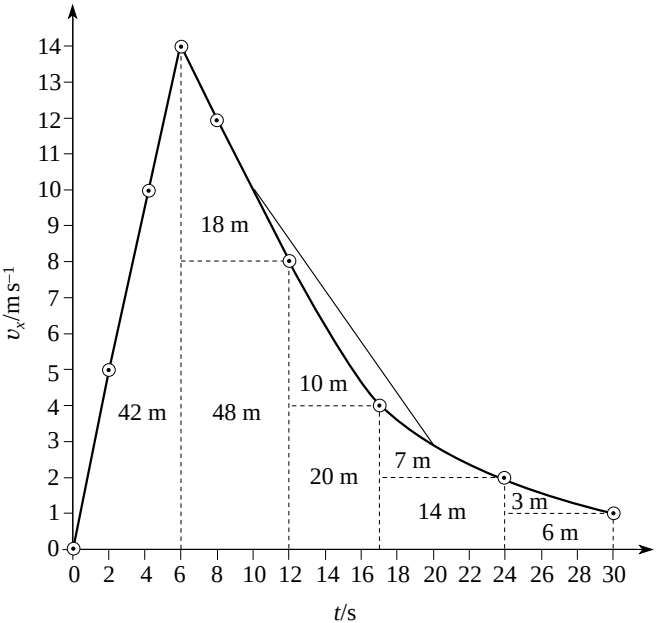

Figure 24 See Answer E1.

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(c) According to Equation 7, the average acceleration between $t = 10\,\mathrm{s}$ and $t = 20\,\mathrm{s}$ is given by the gradient of the line joining the two points on the graph that correspond to $t = 10\,\mathrm{s}$ and $t = 20\,\mathrm{s}$. So,

$$\langle a_x \rangle = \frac{(3.0 - 10.0)\,\mathrm{m\,s^{-1}}}{(20 - 10)\,\mathrm{s}} = -0.70\,\mathrm{m\,s^{-2}}$$

(If you had any difficulty with part (a), reread Subsection 5.1.

Subsection 4.2 is relevant to the answer for part (c).)

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E2

The displacements of the stone can be calculated using Equation 13,

$$s_x = u_x t + \tfrac{1}{2} a_x t^2 \qquad \text{(Eqn 13)}$$

with $u_x = 0\,\mathrm{m\,s^{-1}}$ and $a_x = 10\,\mathrm{m\,s^{-2}}$.

For $t = 0.50\,\mathrm{s}$ $\quad s_x = 0\,\mathrm{m} + \dfrac{1}{2}\left[10\,\mathrm{m\,s^{-2}} \times (0.5\,\mathrm{s})^2\right] = 1.25\,\mathrm{m}$

The displacement after 0.5 s is therefore 1.3 m, to two significant figures.

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Table 5 See Answer E2.

t/s	s_x/m
0	0
0.5	1.3
1.0	5.0
1.5	11
2.0	20
2.5	31
3.0	45

The other displacements may be calculated in the same way, and are given in Table 5. The displacement–time graph is shown in Figure 25.

If the stone hits the ground 2.8 s after it is dropped, the height of the cliff may be found by reading from the graph the displacement when t = 2.8 s. Thus the cliff is 39 m high.

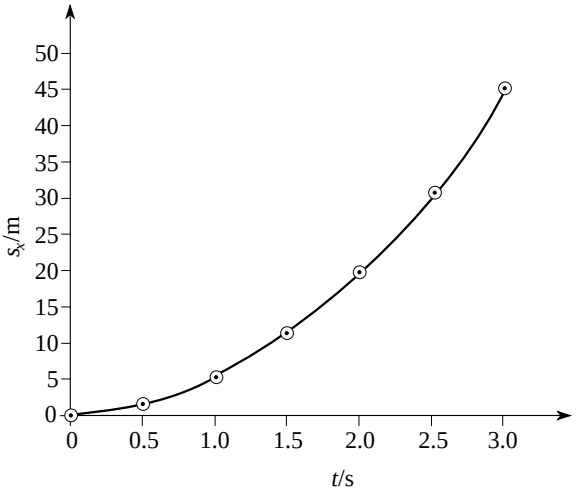

Figure 25 See Answer E2.

Alternatively, you can find the height algebraically using Equation 13.

$$s_x = u_x t + \tfrac{1}{2} a_x t^2 \qquad \text{(Eqn 13)}$$

(If you had any difficulty with this question, Subsection 2.3 deals with displacement–time graphs and Subsection 5.2 covers the use of constant acceleration equations.)

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E3

The body is initially at rest. There is an initial acceleration of $1\,\mathrm{m\,s^{-2}}$ for $10\,\mathrm{s}$, after which time the velocity is $10\,\mathrm{m\,s^{-1}}$. This velocity is maintained for another $30\,\mathrm{s}$, then there is an acceleration of $1\,\mathrm{m\,s^{-2}}$ for $5\,\mathrm{s}$. Finally, there is an acceleration of $-1\,\mathrm{m\,s^{-2}}$ for the last $15\,\mathrm{s}$ of the motion, with the result that at a time of $60\,\mathrm{s}$ from the start of the motion the velocity is again $0\,\mathrm{m\,s^{-1}}$, which means that the body is again at rest.

(If you had any difficulty with this question, reread Subsections 4.1 and 4.2.)

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E4

(a) The required equation is

$$v_x = u_x + a_x t \qquad \text{(Eqn 11)}$$

The derivation of this equation is given in Subsection 5.2.

(b) Before the driver has time to apply the brakes the lorry is travelling at a constant velocity $u_{x1} = 15\,\mathrm{m\,s^{-1}}$. So, according to Equation 8,

$$s_x = u_x t \qquad \text{(Eqn 8)}$$

its displacement from its initial position when the brakes are applied is

$$s_{x1} = 15.0\,\mathrm{m\,s^{-1}} \times 0.40\,\mathrm{s} = 6.0\,\mathrm{m}$$

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When the brakes are applied $u_{x2} = 15\,\mathrm{m\,s^{-1}}$, $v_{x2} = 0\,\mathrm{m\,s^{-1}}$ and $a_{x2} = -7.0\,\mathrm{m\,s^{-2}}$.

So, using Equation 14,

$$v_x^2 = u_x^2 + 2a_x s_x \qquad \text{(Eqn 14)}$$

the additional displacement will be given by

$$s_{x2} = \frac{v_{x2}^2 - u_{x2}^2}{2a_{x2}} = \frac{\left[0 - (15)^2\right]\mathrm{m^2\,s^{-2}}}{-2 \times 7.0\,\mathrm{m\,s^{-2}}} = 16\,\mathrm{m}$$

Thus the total stopping distance (to two significant figures) will be $|s_{x1}| + |s_{x2}| = (6.0 + 16)\,\mathrm{m} = 22\,\mathrm{m}$. So the lorry can stop with 3 m to spare!

(If you had any difficulty with this question, reread the problem posed in Subsection 1.1 and its solution in Subsection 5.3.)

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