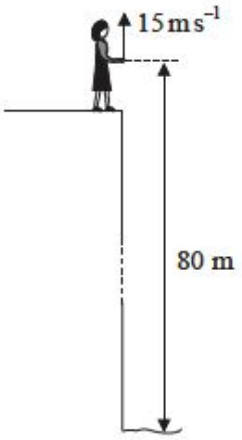
Introductory IB Motion Problems

A2. This question is about kinematics.

Lucy stands on the edge of a vertical cliff and throws a stone vertically upwards.



The stone leaves her hand with a speed of 15 m s^{-1} at the instant her hand is 80 m above the surface of the sea. Air resistance is negligible and the acceleration of free fall is 10 m s^{-2}.

(a) Calculate the maximum height reached by the stone as measured from the point where it is thrown. *[2]*

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(b) Determine the time for the stone to reach the surface of the sea after leaving Lucy's hand. *[3]*

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A2. This question is about kinematics.

(a) Fiona drops a stone from rest vertically down a water well. She hears the splash of the stone striking the water 1.6 s after the stone leaves her hand. Estimate the

(i) distance between Fiona's hand and the water surface. *[1]*

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(ii) speed with which the stone hits the water. *[2]*

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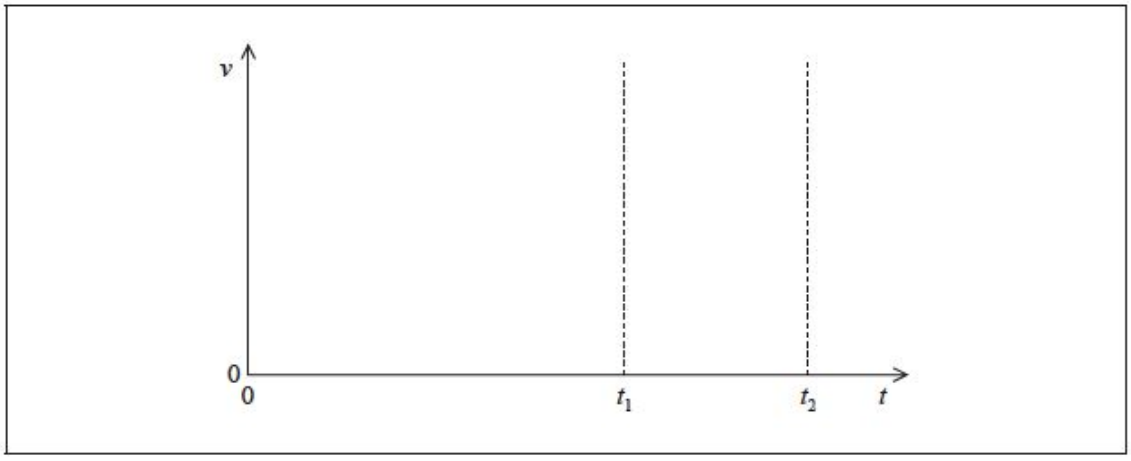
(b) After the stone in (a) hits the water surface it rapidly reaches a terminal speed as it falls through the water. The stone leaves Fiona's hand at time $t=0$. It hits the water surface at t_1 and it comes to rest at the bottom of the water at t_2. Using the axes below, sketch a graph to show how the speed v of the stone varies from time $t=0$ to just before $t=t_2$. (There is no need to add any values to the axes.) *[3]*



B1. This question is in **two** parts. **Part 1** is about linear motion and **Part 2** is about collisions.

Part 1 Linear motion

(a) Define the term *acceleration*. *[2]*

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(b) An object has an initial speed u and an acceleration a. After time t, its speed is v and it has moved through a distance s.

The motion of the object may be summarised by the equations

$$v = u + at,$$
$$s = \tfrac{1}{2}(v+u)t.$$

(i) State the assumption made in these equations about the acceleration a. *[1]*

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(ii) Derive, using these equations, an expression for v in terms of u, s and a. *[2]*

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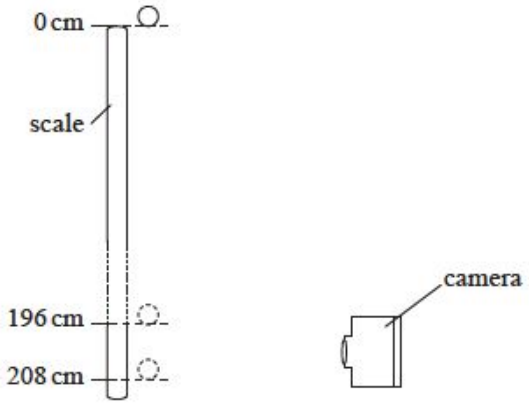
(c) The shutter speed of a camera is the time that the film is exposed to light. In order to determine the shutter speed of a camera, a metal ball is held at rest at the zero mark of a vertical scale, as shown below. The ball is released. The shutter of a camera is opened as the ball falls.



The photograph of the ball shows that the shutter opened as the ball reached the 196 cm mark on the scale and closed as it reached the 208 cm mark. Air resistance is negligible and the acceleration of free fall is 9.81 m s^{-2}.

(i) Calculate the time for the ball to fall from rest to the 196 cm mark. *[2]*

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(ii) Determine the time for which the shutter was open. That is, the time for the ball to fall from the 196 cm mark to the 208 cm mark. *[2]*

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(iii) Explain why a more accurate value for the shutter speed can be obtained if the ball is allowed to fall a greater distance before the shutter is opened. *[3]*

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A2. (a) $h = \frac{v^2}{2g}$;

$= \left(\frac{225}{20} =\right) 11\,\text{m}$; **[2]**

*Award **[1 max]** for 91 m or 91.25 m (candidate adds cliff height incorrectly).*

(b) time to reach maximum height = 1.5 s;
time to fall 91 m = 4.3 s;
total time = 5.8 s; **[3]**
Answer can be alternatively expressed as 3.0 (to return to hand) + 2.8 (to fall 80 m).

or

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

$80 = -15t + 5t^2$ ***or*** $-80 = 15t - 5t^2$;

$t = 5.8\,\text{s}$;

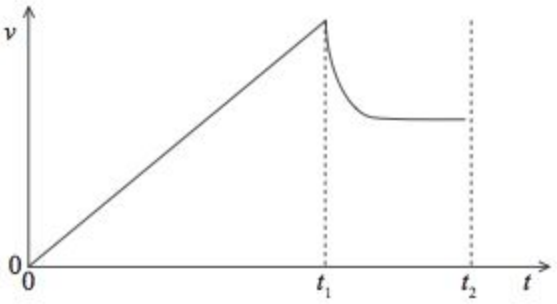
A2. (a) (i) $s = 12.5/12.6$ m; **[1]**

(ii) $v = \sqrt{2gs}$ ***or*** gt; *(allow any use of* suvat *equations)*

$= \left(\sqrt{2 \cdot 9.8 \cdot 12.5} =\right) 15.7\,\text{m s}^{-1}$; **[2]**

*Award **[2]** for a bald correct answer.*

(b)



straight line to water surface;

clear decrease after hitting surface;

constant non-zero speed reached *smaller* than maximum; *(speed must be less than maximum velocity)* **[3]**

B1. Part 1 Linear motion

(a) change in velocity / rate of change of velocity;
per unit time / with time; *(ratio idea essential to award this mark)* ***[2]***

(b) (i) acceleration is constant/uniform; ***[1]***

(ii) $t = \dfrac{2s}{(u+v)}$ and $t = \dfrac{(v-u)}{a}$;
clear working to obtain $v^2 = u^2 + 2as$; ***[2]***

(c) (i) $1.96 = \frac{1}{2} \times 9.81 \times t^2$;
$t = 0.632\,\text{s}$; ***[2]***

(ii) time to fall $(1.96 + 0.12)\,\text{m}$ is $0.651\,\text{s}$;
shutter open for $0.019\,\text{s}$; ***[2]***
If the candidate gives a one significant digit answer treat it as an SD-1.
*Award **[0]** if the candidate uses* $s = \frac{1}{2}at^2$ *and* $s = 12\,cm$.