# Oscillations

## Question paper 6

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|---|---|
| **Level** | International A Level |
| **Subject** | Physics |
| **Exam Board** | CIE |
| **Topic** | Oscillations |
| **Sub Topic** | |
| **Paper Type** | Theory |
| **Booklet** | Question paper 6 |

**Time Allowed:** **75 minutes**

**Score:** **/62**

**Percentage:** **/100**

| A* | A | B | C | D | E | U |
|---|---|---|---|---|---|---|
| >85% | '77.5% | 70% | 62.5% | 57.5% | 45% | <45% |

**1** A tube, closed at one end, has a constant area of cross-section *A*. Some lead shot is placed in the tube so that the tube floats vertically in a liquid of density $\rho$, as shown in Fig. 4.1.

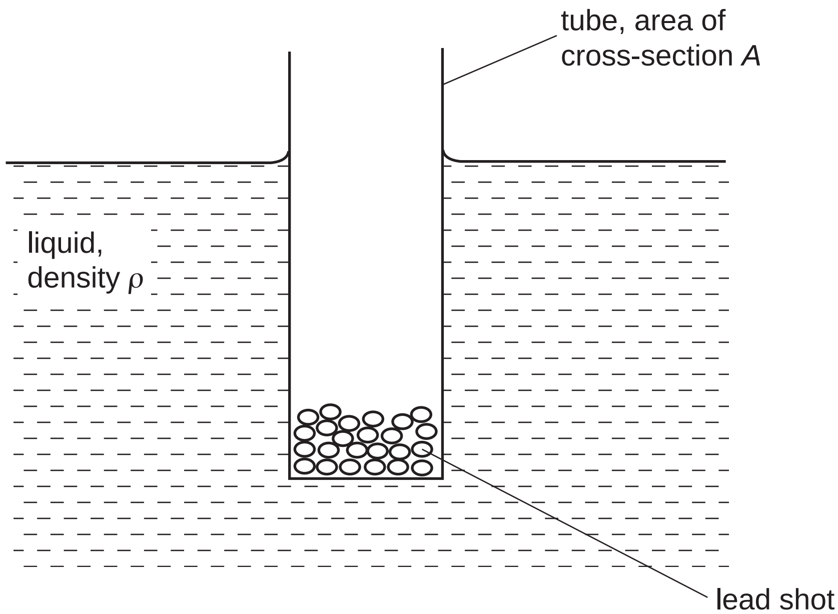


**Fig. 4.1**

The total mass of the tube and its contents is *M*.
When the tube is given a small vertical displacement and then released, the vertical acceleration *a* of the tube is related to its vertical displacement *y* by the expression

$$a = -\frac{A\rho g}{M}y,$$

where *g* is the acceleration of free fall.

**(a)** Define *simple harmonic motion*.

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**(b)** Show that the tube is performing simple harmonic motion with a frequency *f* given by

$$f = \frac{1}{2\pi}\sqrt{\frac{A\rho g}{M}}.$$

[3]

**(c)** Fig. 4.2 shows the variation with time $t$ of the vertical displacement $y$ of the tube in another liquid.

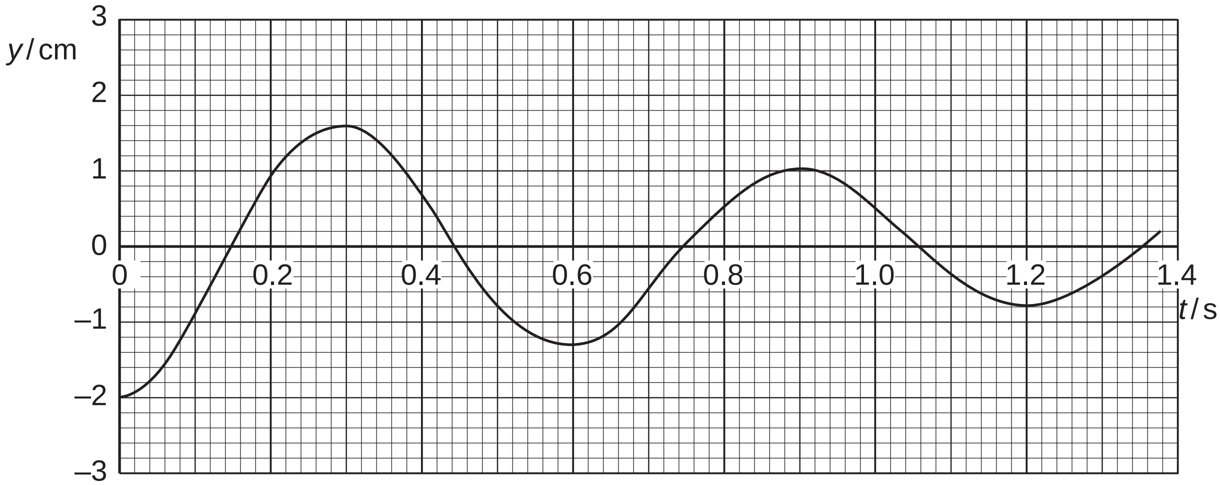


**Fig. 4.2**

**(i)** The tube has an external diameter of 2.4 cm and is floating in a liquid of density 950 kg $m^{-3}$. Assuming the equation in **(b)**, calculate the mass of the tube and its contents.

mass = .................................... kg [3]

**(ii)** State what feature of Fig. 4.2 indicates that the oscillations are damped.

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**2** The vibrations of a mass of 150 g are simple harmonic. Fig. 3.1 shows the variation with displacement $x$ of the kinetic energy $E_k$ of the mass.

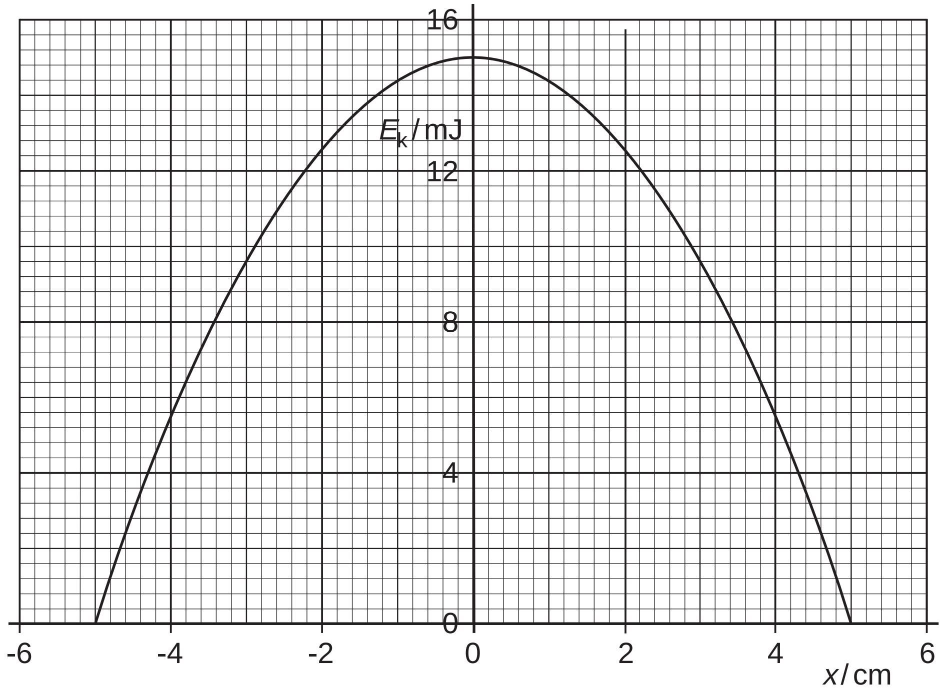


**Fig. 3.1**

**(a)** On Fig. 3.1, draw lines to represent the variation with displacement $x$ of

**(i)** the potential energy of the vibrating mass (label this line P),

**(ii)** the total energy of the vibrations (label this line T).

[2]

**(b)** Calculate the angular frequency of the vibrations of the mass.

angular frequency = ........................................ rad $s^{-1}$ [3]

**(c)** The oscillations are now subject to damping.

**(i)** Explain what is meant by *damping*.

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**(ii)** The mass loses 20% of its vibrational energy. Use Fig. 3.1 to determine the new amplitude of oscillation. Explain your working.

amplitude = ............................................. cm [2]

**3** A vertical spring supports a mass, as shown in Fig. 4.1.

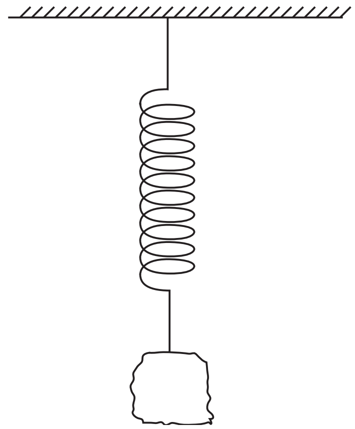

**Fig. 4.1**

The mass is displaced vertically then released. The variation with time *t* of the displacement *y* from its mean position is shown in Fig. 4.2.

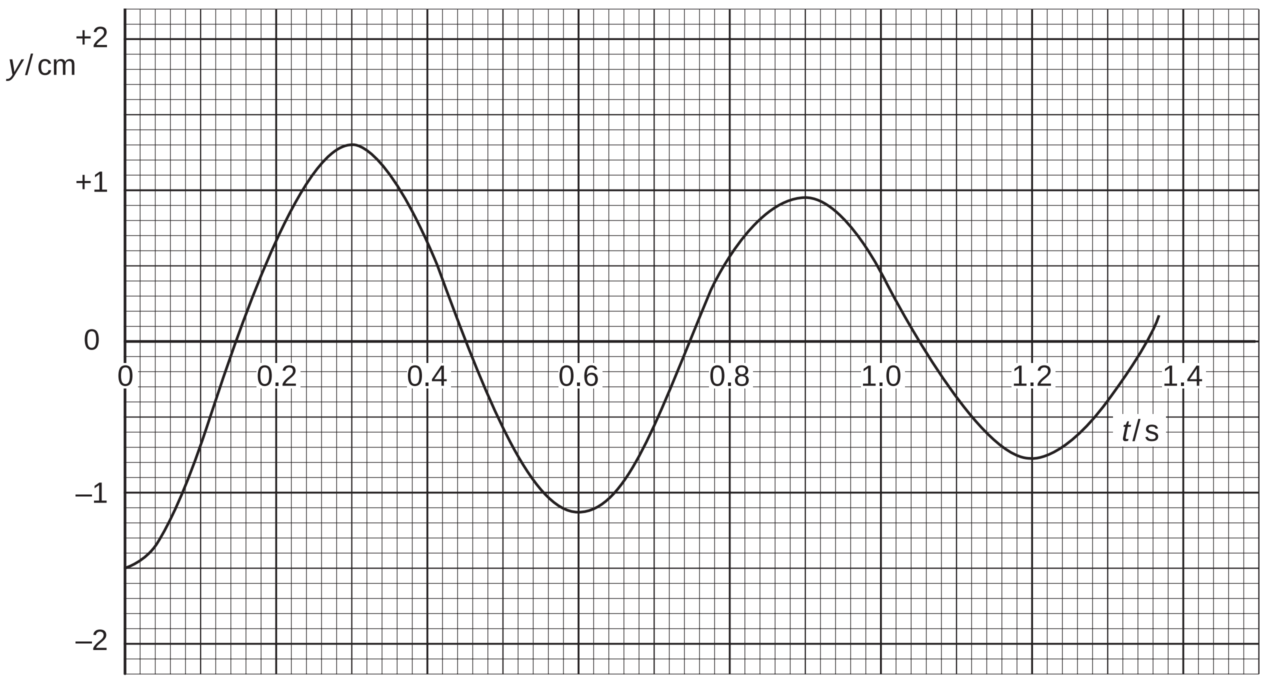


**Fig. 4.2**

A student claims that the motion of the mass may be represented by the equation

$$y = y_0 \sin \omega t.$$

**(a)** Give two reasons why the use of this equation is inappropriate.

1. ..........................................................................................................................

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2. ..........................................................................................................................

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**(b)** Determine the angular frequency $\omega$ of the oscillations.

angular frequency = ................................. rad $s^{-1}$ [2]

**(c)** The mass is a lump of plasticine. The plasticine is now flattened so that its surface area is increased. The mass of the lump remains constant and the large surface area is horizontal.
The plasticine is displaced downwards by 1.5 cm and then released.
On Fig. 4.2, sketch a graph to show the subsequent oscillations of the plasticine. [3]

**4** **(a)** The defining equation of simple harmonic motion is

$$a = -\omega^2 x.$$

**(i)** Identify the symbols in the equation.

$a$ ..........................................................................................................................

$\omega$ ..........................................................................................................................

$x$ ..........................................................................................................................

**(ii)** State the significance of the negative (–) sign in the equation.

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[3]

**(b)** A frictionless trolley of mass *m* is held on a horizontal surface by means of two similar springs, each of spring constant *k*. The springs are attached to fixed points as illustrated in Fig. 2.1.

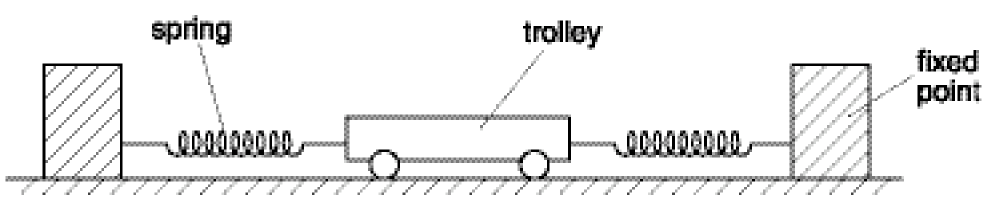


**Fig. 2.1**

When the trolley is in equilibrium, the extension of each spring is *e*.

The trolley is then displaced a small distance *x* to the right along the axis of the springs. Both springs remain extended.

**(i)** Show that the magnitude *F* of the restoring force acting on the trolley is given by

$$F = 2kx.$$

[2]

**(ii)** The trolley is then released. Show that the acceleration *a* of the trolley is given by

$$a = \frac{-2kx}{m}.$$

[2]

**(iii)** The mass *m* of the trolley is 900 g and the spring constant *k* is 120 N m$^{-1}$. By comparing your answer to **(a)(i)** and the equation in **(b)(ii)**, determine the frequency of oscillation of the trolley.

frequency = …………………………. Hz [3]

**(c)** Suggest why the trolley in **(b)** provides a simple model for the motion of an atom in a crystal.

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**5** An aluminium sheet is suspended from an oscillator by means of a spring, as illustrated in Fig. 3.1.

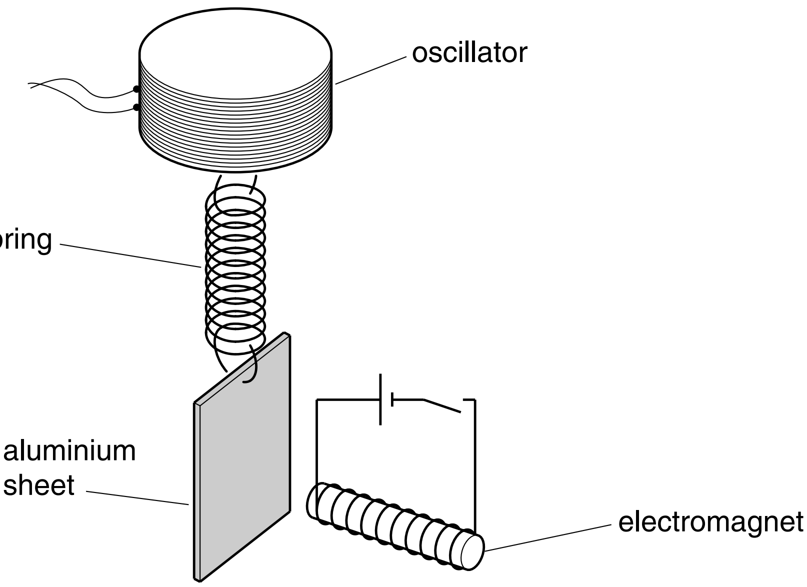


**Fig. 3.1**

An electromagnet is placed a short distance from the centre of the aluminium sheet.

The electromagnet is switched off and the frequency $f$ of oscillation of the oscillator is gradually increased from a low value. The variation with frequency $f$ of the amplitude $a$ of vibration of the sheet is shown in Fig. 3.2.

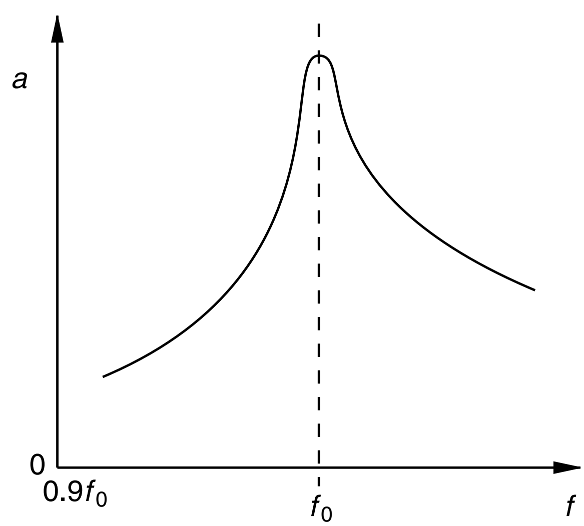


**Fig. 3.2**

A peak on the graph appears at frequency $f_0$.

**(a)** Explain why there is a peak at frequency $f_0$.

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**(b)** The electromagnet is now switched on and the frequency of the oscillator is again gradually increased from a low value. On Fig. 3.2, draw a line to show the variation with frequency *f* of the amplitude *a* of vibration of the sheet. [3]

**(c)** The frequency of the oscillator is now maintained at a constant value. The amplitude of vibration is found to decrease when the current in the electromagnet is switched on.

Use the laws of electromagnetic induction to explain this observation.

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**6** A student sets out to investigate the oscillation of a mass suspended from the free end of a spring, as illustrated in Fig. 3.1.

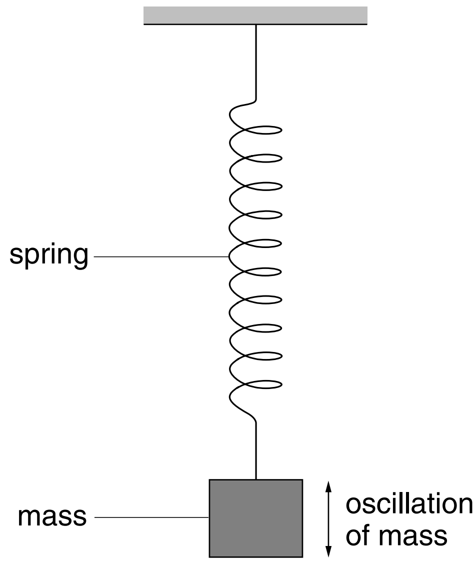


**Fig. 3.1**

The mass is pulled downwards and then released. The variation with time *t* of the displacement *y* of the mass is shown in Fig. 3.2.

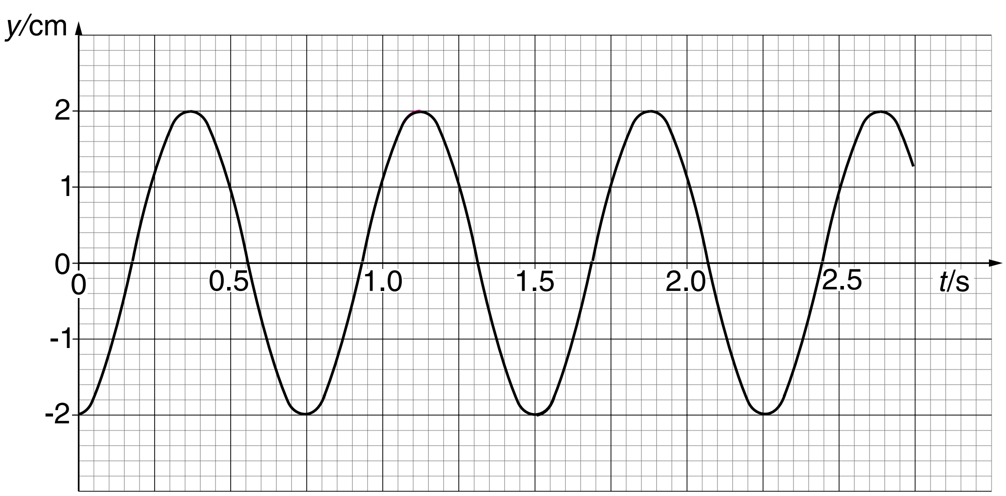


**Fig. 3.2**

**(a)** Use information from Fig. 3.2

**(i)** to explain why the graph suggests that the oscillations are undamped,

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**(ii)** to calculate the angular frequency of the oscillations,

angular frequency = ...................................... rad $s^{-1}$

**(iii)** to determine the maximum speed of the oscillating mass.

speed = ...................................... m $s^{-1}$
[6]

**(b)** **(i)** Determine the resonant frequency $f_0$ of the mass-spring system.

$f_0$ = ...................................... Hz

**(ii)** The student finds that if short impulsive forces of frequency $\frac{1}{2}f_0$ are impressed on the mass-spring system, a large amplitude of oscillation is obtained. Explain this observation.

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[3]

**7** A metal disc is swinging freely between the poles of an electromagnet, as shown in Fig. 5.1.

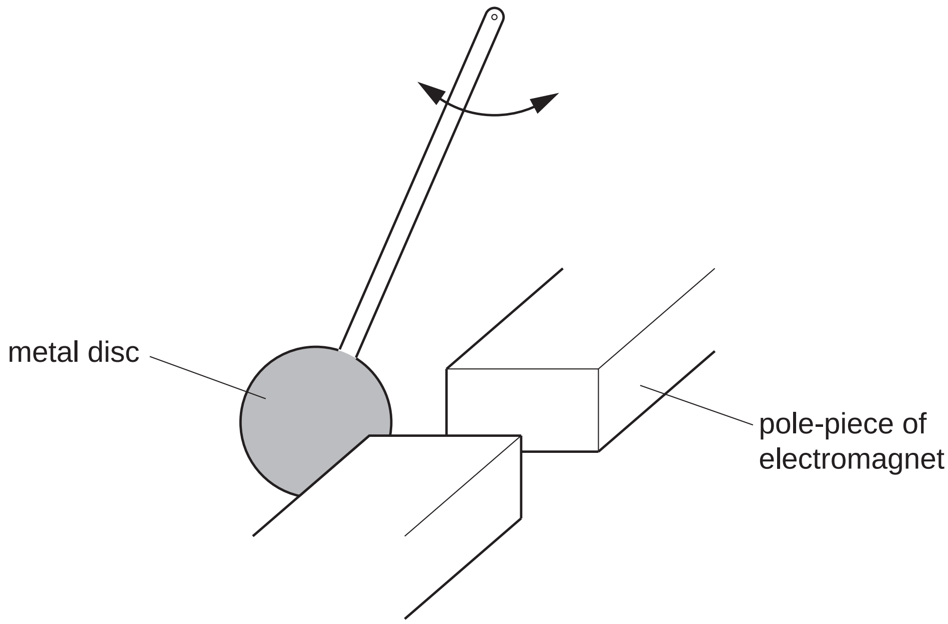


**Fig. 5.1**

When the electromagnet is switched on, the disc comes to rest after a few oscillations.

**(a)** **(i)** State Faraday's law of electromagnetic induction and use the law to explain why an e.m.f. is induced in the disc.

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**(ii)** Explain why eddy currents are induced in the metal disc.

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**(b)** Use energy principles to explain why the disc comes to rest after a few oscillations.

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