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3 0 A simple pendulum and a mass–spring system each have a time period T on the Earth.

They are taken to the surface of a planet where the acceleration due to gravity is $\frac{g}{4}$.

What are the time periods of the pendulum and the mass–spring system on this planet?

[1 mark]

$T = 2\pi\sqrt{\frac{L}{g}}$ $T = 2\pi\sqrt{\frac{m}{k}}$

	Simple pendulum	Mass–spring system	
A	$\frac{T}{2}$	T	○
B	$2T$	T	○
C	$\frac{T}{2}$	$2T$	○
D	$2T$	$2T$	○

$T \propto \sqrt{\frac{1}{g}}$

$T \propto \sqrt{\frac{1}{g/4}}$

$\Rightarrow T \propto \sqrt{\frac{4}{g}}$

$\therefore T \times 2$

$T \propto \sqrt{\frac{m}{k}}$

No change.

END OF QUESTIONS — No it isn't

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2021 P1 AQA

3 1 A particle of mass m is oscillating with simple harmonic motion.
The period of the oscillation is T and the amplitude is A.

What is the maximum kinetic energy of the particle?

[1 mark]

A $\dfrac{mA^2}{2T^2}$ ☐

B $\dfrac{\pi^2 mA^2}{2T^2}$ ☐

C $\dfrac{2mA^2}{T^2}$ ☐

D $\dfrac{2\pi^2 mA^2}{T^2}$ ☐

$E_k = \frac{1}{2}mv^2$

$v_m = \omega A$

$E_k = \frac{1}{2}m\omega^2 A^2$

$\omega = \frac{2\pi}{T}$

$\therefore E_k = \frac{1}{2}m\frac{4\pi^2}{T^2}A^2$

$= \frac{2m\pi^2A^2}{T^2}$

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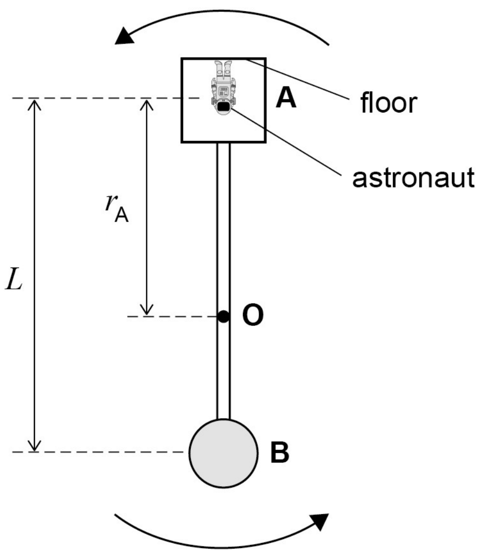
0 4 **Figure 6** shows a rotating spacecraft that is proposed to carry astronauts to Mars.

Figure 6



The spacecraft consists of two parts **A** and **B** connected by a rigid cylindrical rod. When the spacecraft is travelling, **A** and **B** rotate at a constant angular speed about their common centre of mass **O**.

L is the distance between the centre of mass of **A** and the centre of mass of **B**.
r_A is the distance from **O** to the centre of mass of **A**.

0 4 . 1 As the spacecraft rotates, a force that imitates the effect of gravity acts on an astronaut who is in contact with the floor.

Explain why.

[2 marks]

Floor provides the centripetal force to keep the astronaut moving in a circle
This is provided by the reaction force pushing towards point O. This reaction force is felt as weight.

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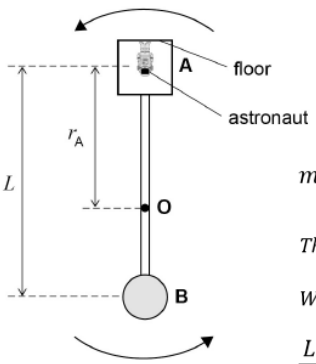
0 4 . 2 The forces exerted on **A** and **B** by the connecting rod have the same magnitude.

m_A is the mass of **A**
m_B is the mass of **B**

Show, by considering the centripetal forces acting on **A** and **B**, that r_A is given by



$$r_A = \frac{m_B L}{m_A + m_B}$$

A and B have different velocities but same w

$$m_A\omega^2 r_A = m_B\omega^2(L - r_A) \rightarrow \frac{m_A}{m_B} = \frac{L - r_A}{r_A}$$

The RHS can be simplified (!) by dividing all the terms by r_A

Working with RHS and dividing all terms by r_A

$$\frac{\frac{L}{r_A} - \frac{r_A}{r_A}}{\left(\frac{r_A}{r_A}\right)} = \frac{\frac{L}{r_A} - 1}{1} = \frac{L}{r_A} - 1$$

Which therefore means that:

$$\frac{m_A}{m_B} = \frac{L}{r_A} - 1 \rightarrow m_A = \frac{m_B L}{r_A} - m_B \rightarrow m_A + m_b = \frac{m_B L}{r_A}$$

Tidy up:

$$r_A = \frac{m_B L}{m_A + m_B}$$

0 4 . 3 In this spacecraft $m_A < m_B$.

Deduce whether the centre of mass of **A** or the centre of mass of **B** rotates with a greater linear speed.

[2 marks]

Same angular speed of course.
if mass of A is small cf m of B then rA tends to L

so center of mass much nearer to B meaning it has a smaller radius and therefore A has a higher linear speed

Question 4 continues on the next page

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The astronauts live in **A** and the cargo is stored in **B**.

When loaded,

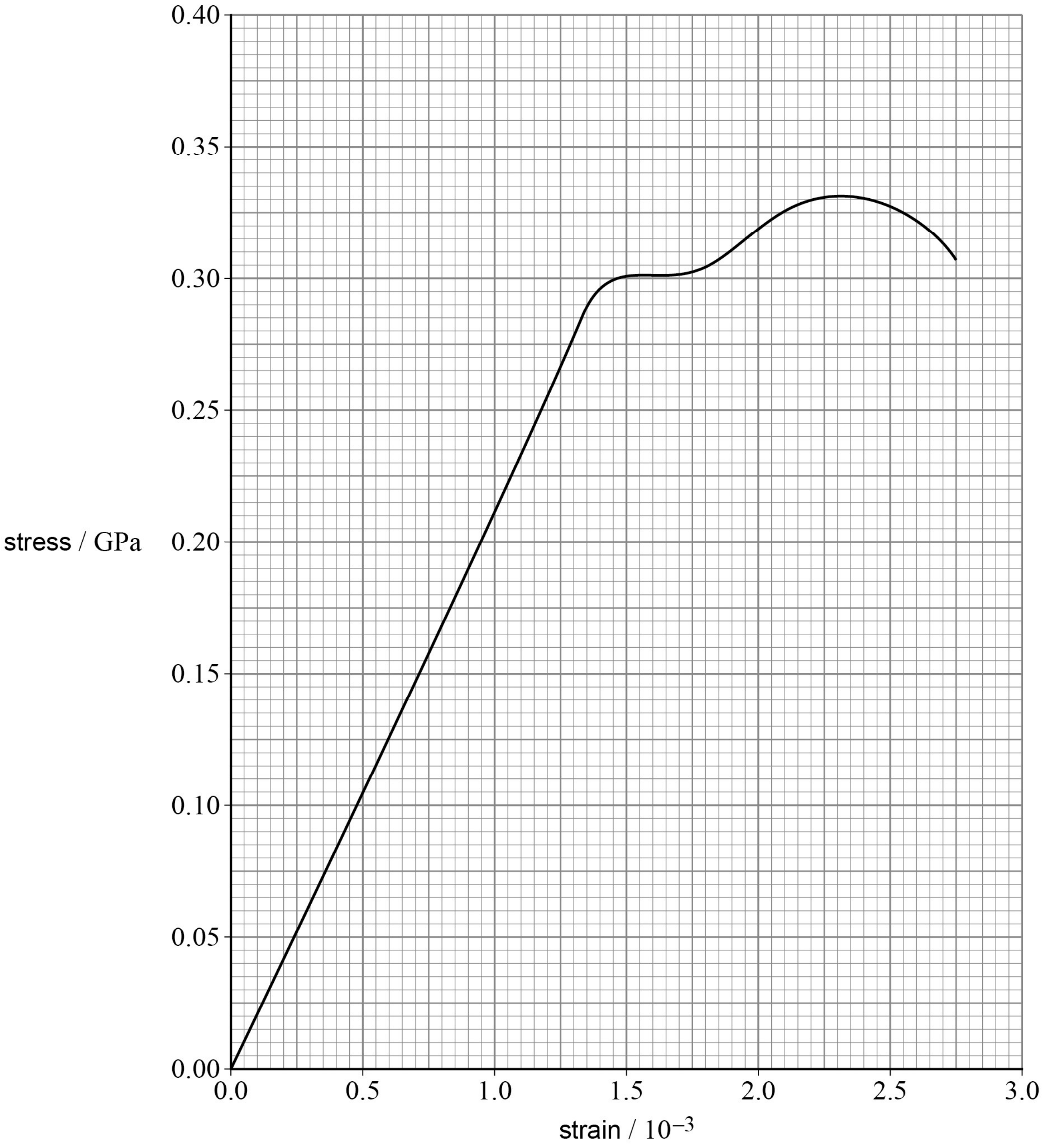
$m_A = 1.32 \times 10^6$ kg

$m_B = 3.30 \times 10^6$ kg.

The spacecraft imitates the gravity of Mars where $g = 3.7\ \text{m s}^{-2}$.

Figure 7 shows a stress–strain curve for the metal used for the rigid rod.

Figure 7



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0 4 . 4 Suggest a suitable diameter for the rod.
Justify your answer.

[5 marks]

Max stress is rughly 0.3GPa. Need to be well below that - say 0.15GPa (or even less)
Force in each section of the rod is the same (see earlier)

$m_A = 1.32 \times 10^6$ kg

$m_B = 3.30 \times 10^6$ kg.

$g = 3.7 m/s^2$ or N/kg

$\therefore F = ma \Rightarrow 1.32 \times 10^6 \times 3.7$
$= 4.88 \times 10^6 N$

$\text{Stress} = \frac{F}{A} \therefore A = \frac{4.88 \times 10^6}{0.15 \times 10^9}$

$A = 0.033 m^2$

$\therefore \pi r^2 = A \Rightarrow r = 0.1 m$
$d = 0.2 m$

diameter = ______________ m

obviously this value is variable depending on the value of Stress selected

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Turn over ▶