

APOLLO

Work, energy and power

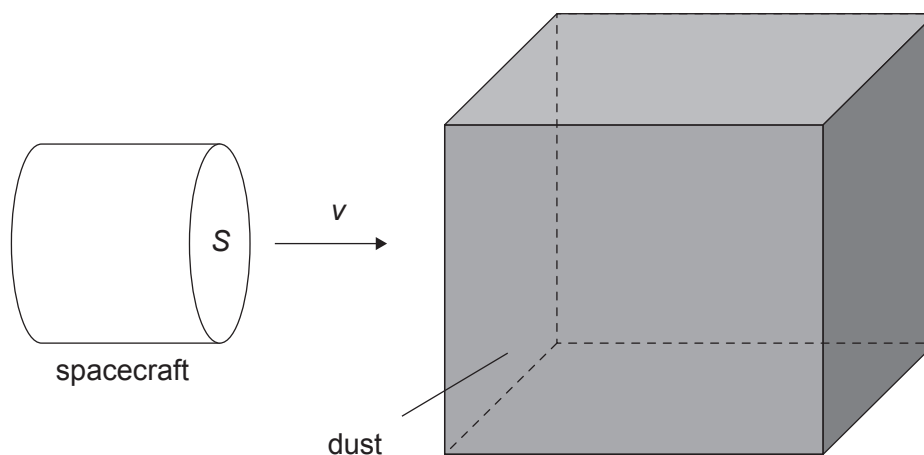
HL

Physics

First assessment 2025

6 questions | questions

8. (a) A cylindrical spacecraft of cross-sectional area S moves with velocity v . The spacecraft enters a region of dust of density ρ . All the dust that comes into contact with the forward cross-sectional area of the spacecraft sticks to the spacecraft increasing its mass.



- (i) Show that in time Δt the mass of the spacecraft will increase by an amount $\rho S v \Delta t$. [1]

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- (ii) Deduce that the spacecraft will experience a drag force $\rho S v^2$ opposite to its velocity. [2]

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(Question 8 continued)

(b) A satellite of mass m is in a circular orbit of radius r around Earth. Earth has mass M .

(i) Show that the total energy of the satellite is given by $E_T = -\frac{GMm}{2r}$. [2]

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(ii) The satellite experiences a drag force due to the atmosphere of Earth. With reference to the results in (a) and (b)(i), state and explain the likely fate of this satellite. [4]

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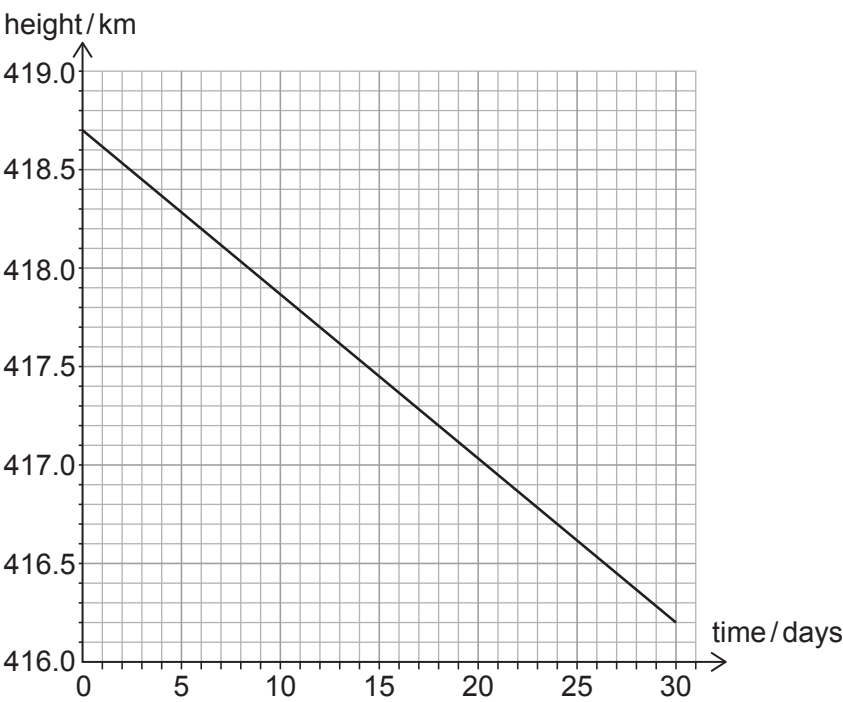
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(Question 8 continued)

- (c) The graph shows the variation with time of the height of the International Space Station (ISS) during a 30-day period.



The following data are available:

$$\begin{aligned} \text{Mass of Earth} &= 5.98 \times 10^{24} \text{ kg} \\ \text{Mass of the ISS} &= 4.20 \times 10^5 \text{ kg} \\ \text{Radius of the Earth} &= 6.38 \times 10^6 \text{ m} \end{aligned}$$

For the 30-day period indicated in the graph the loss of total energy of the ISS is $4.5 \times 10^9 \text{ J}$.

- (i) Calculate the average rate at which the energy of the ISS is being dissipated. [2]

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(Question 8 continued)

- (ii)
 Show, using the average height during the 30-day period, that the speed of the ISS is about $8 \times 10^3 \text{ m s}^{-1}$.
 [2]

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- (iii)
 Estimate the increase in the temperature of the ISS assuming all the lost energy went into thermal energy of the ISS. Take the specific heat capacity of the ISS to be $500 \text{ J kg}^{-1} \text{ K}^{-1}$.
 [2]

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- (iv)
 Estimate, using the answers to (c)(i) and (c)(ii), the average drag force that acted on the ISS.
 [3]

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(Question 8 continued)

- (d) At the end of the 30-day period, rockets are fired to bring the ISS back to its initial height. The energy density of liquid hydrogen rocket fuel is $8.5 \times 10^3 \text{ MJ m}^{-3}$.

Estimate the volume of fuel needed. [2]

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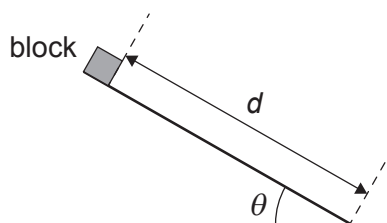
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5. A block of mass m is released from rest and slides down a ramp of length d that makes an angle θ with the horizontal. A constant frictional force F acts on the block.



What is the kinetic energy of the block at the bottom of the ramp?

- A. $mgd - Fd \cos \theta$
- B. $mgd - Fd$
- C. $mgd \sin \theta - Fd \cos \theta$
- D. $mgd \sin \theta - Fd$

6. An electric motor of efficiency 75 % raises a mass of 120 kg at a constant speed of 0.50 m s^{-1} . What is the power input to the motor?
- A. 20 W
 - B. 450 W
 - C. 600 W
 - D. 800 W

— 3 —

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6. A pump has efficiency η when raising water from a well of depth d . The mass of water raised per second is R . Changes in kinetic energy of the water are considered negligible.

What is the input power to the pump required to raise the water?

- A. $\frac{Rd}{\eta g}$
- B. $\frac{\eta R}{gd}$
- C. ηRgd
- D. $\frac{Rdg}{\eta}$

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Turn over
0020-0719

3. A net force of 8.0 N accelerates a 4.0 kg body from rest to a speed of 5.0 m s^{-1} .

What is the work done by the force?

- A. 50 J
- B. 40 J
- C. 32 J
- D. 20 J

— 3 —

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6. An object is released from rest in a vacuum at a height H above the Earth's surface.

As the object falls it passes a point at a height of $0.75H$ above the surface.

What is $\frac{\text{kinetic energy of the object at a height of } 0.75H}{\text{gravitational potential energy of the object at a height of } H}$?

A. $\frac{1}{16}$

B. $\frac{1}{4}$

C. $\frac{9}{16}$

D. $\frac{3}{4}$

— 5 —

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