HODDER Education

Physics review

www.hoddereducation.com/physicsreview

Volume 33, Number 3, February 2024

Activity

Practice-for-exam questions

Rohan Kakade

Use the questions below either in class or for individual work after students have read the articles in the magazine. Although the questions state the values of constants required, some of the questions require additional data — students should either make reasonable estimates of quantities or look up values using a data book or website. Students should clearly communicate any assumptions made. Suggested outline answers to questions are provided in a separate document.

Plasmas — the fourth state of matter

1 Einstein's famous equation $E = mc^2$, which quantifies the equivalence between mass and energy, underpins all nuclear reactions. Assuming c to be 3.00×10^{8} m s^{-1}, calculate the energy equivalent of the following:

a The mass of an electron (9.10×10^{-31} kg).

b The mass of a hydrogen atom.

1 mole of hydrogen has a mass of 1.01 g and Avogadro's number is 6.02×10^{23}.

c A human weighing 150 N on the moon.

Acceleration due to gravity on the moon is 1.63 m s^{-2}.

2 In α-decay, a radioactive nucleus emits a helium nucleus, ${}^{4}_{2}He^{2+}$. If the energy in the kinetic store of the helium nucleus (α particle, ${}^{4}_{2}He^{2+}$) is 5.0 MeV, and the energy in the kinetic store of the remaining nucleus is negligible in comparison, calculate the mass difference between the initial nucleus, and the final nucleus and α particle. Calculate the particle velocity associated with this energy.

3 One of the theoretically predicted mechanisms of ${}^{4}_{2}He$ formation in the Sun is the so-called p-p IV branch. Here ${}^{3}_{2}He$ captures a proton directly to produce ${}^{4}_{2}He$. The reaction is represented by the following reaction equation:

$$\boldsymbol{{}^{3}_{2}He + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + e^{+} + v_{e}}$$

Determine the total energy released in this reaction.

Data:

Take the mass of the neutrino to be negligible (zero).

Mass of positron as 9.11×10^{-31} kg

Mass of ${}^{1}_{1}He$ to be 1.67×10^{-27} kg

Mass of ${}^{3}_{2}He$ to be 5.00×10^{-27} kg

Mass of ${}^{4}_{2}He$ to be 6.65×10^{-27} kg

Equations from graphs

1 The graph below shows the growth of bacteria in a lab experiment. The y-axis of the graph, which represents the number of bacteria, is a logarithmic scale (to base 'e') and the x-axis of the graph is time in units of hours.

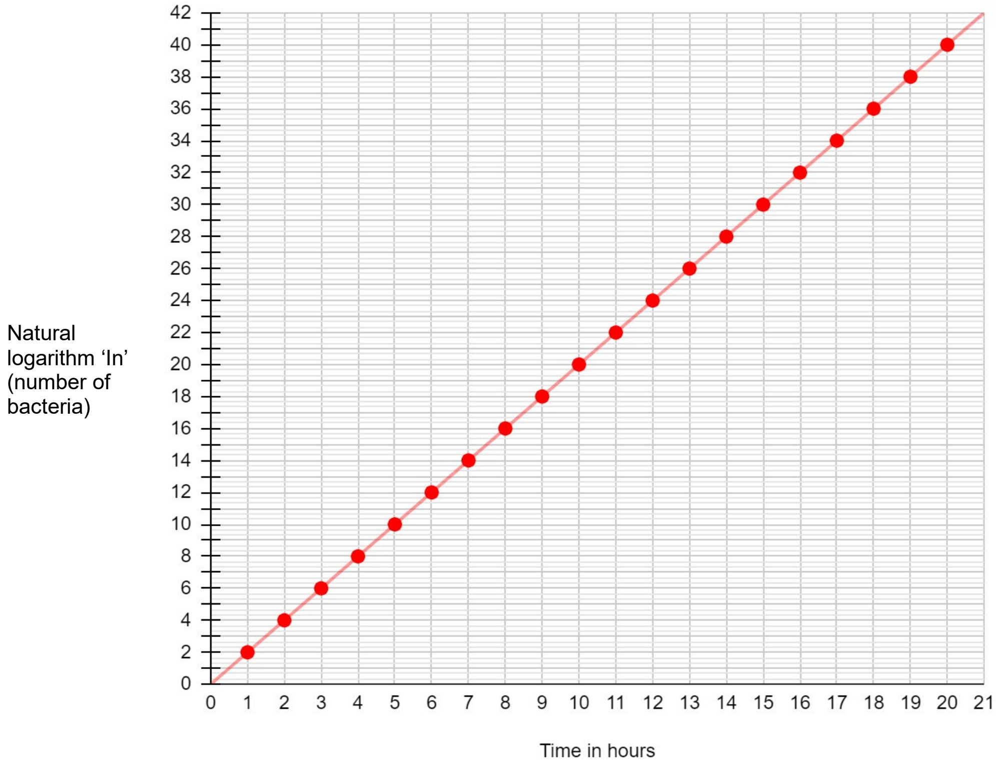
a Calculate the gradient of the line.

b Deduce the equation of the line in the format

$N = e^{A\,t}$

where A is a constant that represents the growth factor and t is the time in seconds.

c Using the equation obtained in part **b** to calculate the natural logarithm of the number of bacteria at the 2-day mark (i.e. 48 hours from $t = 0$ s). Hence calculate the number of bacteria after 2 days.



Growth of bacteria over time

2 Free-fall distance, h, for an object falling from rest is related to the acceleration due to gravity, g, by the simple relationship:

$h = \frac{1}{2}gt^2$

a Complete Table 1.

g on the Earth is 9.81 m s^{-2}, on Mars is 3.72 m s^{-2} and on Jupiter is 24.5 m s^{-2}.

Table 1: free-fall distances on Earth, Mars and Jupiter

Time t (s)	Free-fall height h (m)		
	on Earth	on Mars	on Jupiter
2.00			
4.00			
6.00			
8.00			
10.0			
12.0			
14.0			
16.0			
18.0			
20.0			

b Using the data in Table 1, plot, on a single graph, curves for the free-fall distance against time for all three planets.

c Derive the equation shown below and then copy and complete Table 2.

$$\log_{10} h = 2\log_{10} t + \log_{10} g - 0.30$$

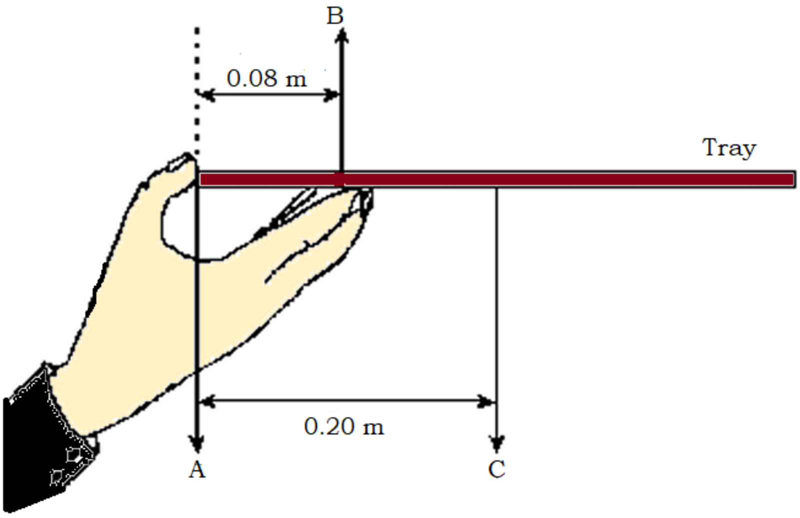
Table 2

log10(t/s)	log10(h/m) on Earth	log10(h/m) on Mars	log10(h/m) on Jupiter

d Using your completed Table 2, plot, on a single set of axes, graphs of log10(h/m) against log10(t/s) for all three planets. What is the slope of each curve?

Moments, torques and electric cars

1 A person holds a tray horizontally in one hand between their fingers and their thumb as shown below. A, B and C are the three forces acting on the tray.



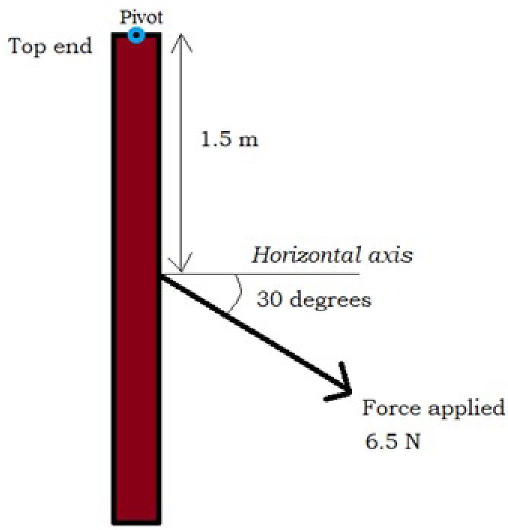
a **i** State two relationships between the forces that must be satisfied if the tray is to remain horizontal and in equilibrium.

ii If the mass of the tray is 0.20 kg, then calculate the magnitude of the force C. Assume acceleration due to gravity to be 9.81 ms^{-2}.

iii Calculate the magnitude of forces A and B.

b The person now places a glass on the tray. State and explain where the glass should be placed on the tray if force A is to have the same value as in part **a**.

2 A rod is fixed to a pivot such that it can rotate about its top end. At a distance of 1.5 m below the top end, 6.5 N is applied at an angle of 30 degrees with respect to the horizontal as shown below. What is the torque acting on the bar?



3 One side of a seesaw carries a 20 kg mass 4.0 m from the fulcrum and a 25 kg mass 2.0 m from the fulcrum. To balance the seesaw, what mass should be placed 9.0 m from the fulcrum on the side opposite the first two masses? Draw a diagram showing the position and direction of the forces at play here.

Domestic 'heat batteries'

1 Consider an electric shower that is capable of completely filling a cylindrical bucket of radius 10 cm and height 40 cm in 3 minutes. Assume the initial temperature of the mains water supply to be 8 °C in winter and 12 °C in summer. It is desired that the electric shower warms the water to 40 °C in the winter and 38 °C in the summer.

Assuming the specific heat capacity of water to be 4.20×10^3 J kg^{-1} $°C^{-1}$, calculate how much electrical power is required to operate the electric shower in the:

a Winter

b Summer

2 **a** What does the term 'specific latent heat' of a substance refer to? Briefly explain.

b 50.0 g of water at 100 °C is heated such that it experiences no temperature change. If the latent heat of vaporisation of water is 2.26×10^6 J kg^{-1}, then how much energy in kJ is needed to boil the water completely away?

c A block of solid gold is at its melting point of 1064 °C. It has a specific latent heat of fusion of 63.0 kJ/kg. If this block is completely melted by suppling 5.20 kJ of thermal energy, what is its mass in grams, assuming that there is no resulting temperature change?