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Activity

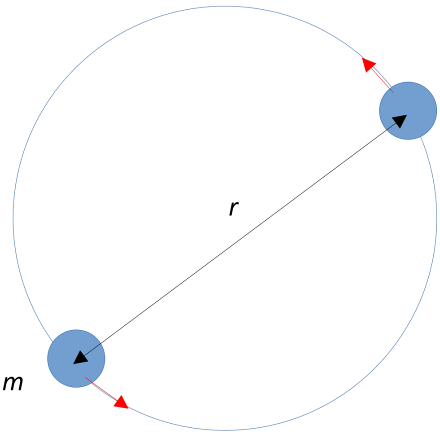
Practice-for-exam questions

Simon Carson

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.

Thinking about motion: orbiting objects (part 2)

Two bodies of equal mass, m, a distance r apart, are orbiting around their common centre of mass:



1 Find an expression for the angular velocity, ω, with which each body rotates. Hence, find an expression for the period of rotation of each body.

2 Write down an expression for the angular momentum of one of the masses, using the equation in Box 1 of the article. Hence, write down an expression for the total angular momentum of the system.

3 Use the expression for the reduced mass, together with your answers from question 1, to write down another expression for the total angular momentum of the system, and show that this is the same as your answer to question 2.

4 The Earth has a mass of 5.97×10^{24} kg and the Moon has a mass of 7.35×10^{22} kg. The distance from the centre of the Earth to the centre of the Moon is 384000 km (approximately, assuming circular orbits). The radius of the Earth is 6380384 km.

Use this data to show that the common centre of mass of the Earth–Moon system is 1709 km below sea level as stated in the article. Calculate the period of rotation of the Earth–Moon system in days.

Mathskit: standard form and SI prefixes

Neils Bohr used his model of the atom to derive an expression for the radius of a hydrogen atom, now known as the Bohr radius. The Bohr radius is given by:

$$a_0 = \frac{4\pi\epsilon_0\hbar^2}{e^2 m_e}$$

where:

$\epsilon_0 = 8.85x10^{-12}\mathrm{C}^2\mathrm{kg}^{-1}\mathrm{m}^{-3}\mathrm{s}^2$ is the permittivity of free space

$\hbar = 1.05x10^{-34}\mathrm{Js}$ is the reduced Planck constant

$e = 1.60x10^{-19}\mathrm{C}$ is the magnitude of the electronic charge

$m_e = 9.11x10^{-31}\mathrm{kg}$ is the electronic mass

1 Calculate the Bohr radius, a_0, using your calculator.

2 Ignore the powers of ten and calculate a value for this expression. Combine the powers of ten without using a calculator and check that your final answer is the same as the answer to question 1.

3 Write the Bohr radius in cm, mm, μm nm, pm and km.

Everyday quantum effects

In the article 'Thinking about motion: orbiting objects (part 2)', the quantised energy levels of the hydrogen atom are given by:

$$E_n = \frac{-1}{n^2} \cdot \frac{m_e e^4}{8h^2\epsilon_0^2}$$

$h = 6.63 \times 10^{-34}$ Js is Planck's constant and the other symbols have the meanings and values given above.

1 Show that this expression can be written as:

$$E_n = \frac{-2.17 \times 10^{-18}}{n^2}\ \mathrm{J}$$

Make sure you clearly show how the units of the constants lead to E_n having the units of joules.

2 Calculate the frequency of electromagnetic radiation emitted when an electron transitions from the n = 4 level to the n = 2 level in hydrogen. Find the corresponding wavelength and state what colour of light this is.

3 Suppose a light source has a power of 10 watts and emits light due to the n = 4 to n = 2 transition in hydrogen. How many photons are emitted per second?

Powerful connections

According to the article, the power transferred by a power line is:

$$P = I_{rms} \times V_{rms}$$

1 In the UK, the peak value of mains voltage is approximately 325 volts. What rms voltage does this correspond to?

2 How much power is transferred by a device operating with a peak current of 15 amps and a peak voltage of 325 volts?

3 If this peak current were carried by the 400 kV transmission line described in the article, how much energy would be dissipated in an hour if the transmission line was 500 km long?

Radiometric age dating of rocks and fossils

1 Alpha decay takes place through quantum tunnelling (see the 'Everyday quantum effects' article for more on this). Use Box 1 of 'Radiometric age dating of rocks and fossils' to fill in the missing numbers in this decay:

$$^{226}_{88}Ra \rightarrow {}^{?}_{?}Rn + {}^{?}_{?}He$$

2 The form of beta decay described in the article occurs through the emission of an electron from the nucleus. In another form of beta decay, a positron, the antiparticle of an electron, is emitted instead. The positron has the same mass as the electron but has the opposite charge. Fill in the missing numbers in this positron emission decay equation. The electron neutrino has no charge and (almost) no mass.

$$^{23}_{12}Mg \rightarrow {}^{?}_{?}Na + {}^{?}_{?}\beta^{+} + {}^{?}_{?}\nu_e$$

3 In Box 2 it is shown that:

$$N(t) = N_0 \times 0.5^{kt}$$

(In the article it is assumed that N_0 = 1.)

Magnesium-23 has a half-life of about 12 seconds and decays as shown in question 2. How much magnesium-23 would remain after 10 minutes, beginning with a 2-gram sample? Calculate your answer using the equation above.

4 Verify your answer to question 3 using the standard equation for radioactive decay, that is:

$$N(t) = N_0 e^{-\lambda t}$$

Show all the steps in your working.

The following question uses ideas from the ***Exam talkback*** *article,* ***Practical skills****.*

5 How could the equation in question 3 be used to plot a straight-line graph from experimental data about the decay of magnesium-23? What data would you gather? What would you plot on the axes of your graph? What would the gradient and the intercept tell you about the decay process?

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