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Activity

Practice-for-exam questions

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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.

Cepheid variable stars

1 Alpha Centauri A (also known as Rigil Kentaurus) is part of a triple star system located closer to the solar system than any other known star system. Its radius is estimated to be approximately 1.22 times that of the Sun with a surface temperature just 10.0 K higher than the Sun.

The Sun has a radius of 6.96×10^8 m and a mean surface temperature of 5780 K.

Given these data, determine:

a The stellar luminosity of Alpha Centauri A in terms of Sun's luminosity. Luminosity of the Sun = 3.85×10^{26} W

b The apparent brightness of Alpha Centauri A in units of *solar constant*. Alpha Centauri A's distance from the Earth is estimated to be 4.34 light-years (or 1.33 parsecs).

c The distance modulus of Alpha Centauri A.

2 The light curve of a typical Cepheid variable star is shown in Figure 1 below.

a Using this light curve, determine the star's pulsation period 'P' and its mean apparent magnitude 'm'.

b Refer to Figure 3.2 of the article to determine the mean absolute magnitude 'M' for the star and, using this information in conjunction with values from part **a**, determine the star's astronomical distance 'd'.

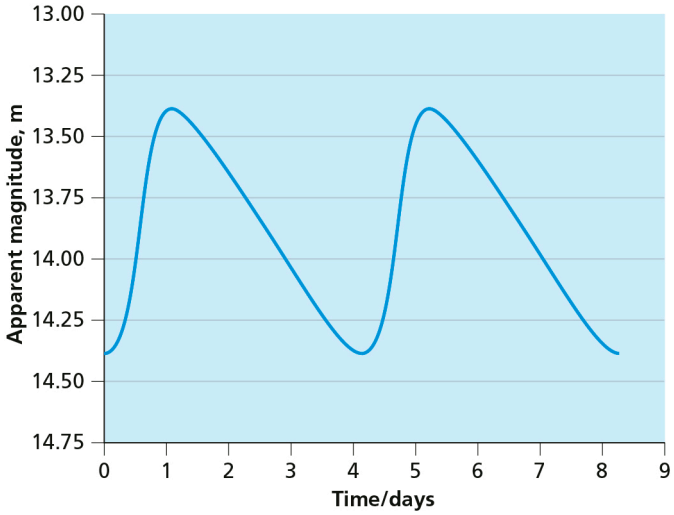

Figure 1 The light curve of a typical Cepheid variable star

Source: https://sci.esa.int/documents/34439/36575/1567254558082-4-exercise2-high.pdf

Cryo-electron microscopy

1 As a Cryo-TEM microscopist, you can control (as the article explains) the wavelength λ of the electron beam (by controlling the accelerating voltage).

a Show that V is related to the wavelength λ by the equation $\lambda = \frac{1.23}{\sqrt{V}}$ nm

b Calculate the accelerating voltage needed for an electron wavelength of 0.020 nm

c Determine the velocity of the electrons at the same wavelength specified in part **b**.

Mass of an electron is 9.11 x 10^{-31} kg, charge on an electron is 1.60 x 10^{-19} C and Planck constant is 6.63 x 10^{-34} Js.

2 A proton and an electron are each accelerated from rest through the same potential difference.

a Show that the de Broglie wavelength of the electron is about 40 times the de Broglie wavelength of the proton.

Mass of an electron is 9.11 x 10^{-31} kg and mass of a proton is 1.67 x 10^{-27} kg.

b If the de Broglie wavelength of the electron is known to be 1.23 nm, then show that the kinetic energy of the proton is approximately 1eV.

1eV = 1.60 x 10^{-19} J

3 *This question goes beyond the A-level specification and introduces quantitative ideas about resolution, and about a new quantity, numerical aperture. To learn more about this, you can find more details and helpful animations here:*

www.olympus-lifescience.com/en/microscope-resource/primer/anatomy/numaperture/

The resolution 'r' based on the Rayleigh criteria when applied to TEM can be written as

$$r = \frac{0.610\,\lambda}{NA}$$

where NA is the numerical aperture of the TEM system.

a Derive a theoretical relationship between the Rayleigh resolution 'r' and the accelerating voltage 'V'.

b With a numerical aperture (NA) of 10^{-2} (typical for TEM), and using the relationship derived in part **a** of question **1**, determine the theoretical resolution at an applied voltage of 3782.25 Volts.

Electrical wires do not transfer energy

1 **a** Calculate the number of atoms contained in 1.00 m^3 of gold. Molar mass of gold is 197 g/mol. Density of gold is 19320 kg/m^3 and the Avogadro's number is 6.02 x 10^{23}.

b Calculate the velocity of electric current through a gold wire with a circular cross-section of 2.00 mm.

c Quantitively compare this value against the speed of electric current in copper (see Box 1 of article).

2 Based on your reading of the article, explain what is meant by the terms 'individual electron velocity', 'electron drift velocity' and 'signal velocity'.

Physics online: upthrust

1 An object with a density P_{object} when placed in a liquid with a density of P_{liquid} will sink in the case where $P_{liquid} < P_{object}$, otherwise it floats partly or wholly submerged.

A wooden block with original volume 32.00 cm^3, had a hole with a volume of 2.00 cm^3 drilled into it. This hole was then filled with lead.

P_{lead} = 11.0 g cm^{-3}, P_{water} = 1.00 g cm^{-3}, P_{wood} = 0.500 g cm^{-3}

Hint: consider this equation when answering the questions that follow:

(P_{wood} × $Volume_{block\ without\ lead}$) + ($P_{lead}$ × $Volume_{lead}$) = mass of block

a Calculate the total mass of the wooden block containing the lead.

b Calculate the new density of the wooden block containing the lead.

c Will this block sink or float when placed in water? Explain your answer.

d Consider the situation when the original wooden block (32.00 cm^3 of pure wood) is drilled with a hole of a certain volume, which is then completely filled-in with lead such that it results

in a state where the block is just about to sink in water. What would the volume of this hole need to be?

2 **a** An ice cube of density 0.90 g cm^{-3} floats in freshwater of density 1.00 g cm^{-3}. What percentage volume of the ice cube will be submerged?

b If the same ice cube is floating in sea water of density 1.30 g cm^3, what percentage volume of the ice cube will be submerged?

c A sphere of iron and another of wood of the same radius are placed on the surface of water. Explain which of the two will sink and provide a reason for your answer.

d If each side of this ice cube is 40.0 cm long, calculate the upthrust experienced on the ice cube when submerged in freshwater. Assume acceleration due to gravity as 9.81 N/kg.

e What would be the upthrust on the same ice cube when submerged in seawater?