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Activity

Practice 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. Some of the questions require additional data: students should either make reasonable estimates of quantities, or look up values using a data book or websites. Suggested outline answers to questions are provided in a separate document.

Proton therapy

1 Explain why X-rays and gamma rays can potentially cause more damage to living cells than other electromagnetic radiation

2 Figure 3 in the article shows the spiral path of a proton, which is accelerated in a magnetic field. Explain why a proton moving at a steady speed at right angles to a magnetic field follows a circular path, and why the proton's increasing speed causes it to move in a spiral.

The swinging ponytail

You may have observed that a mass suspended from a spring that is oscillating vertically also begins to swing from side to side. This occurs when the natural frequency of the vertical oscillation is twice the pendulum frequency. The following questions are about this example of a parametric oscillator.

1 What are the parameters that determine the natural frequencies of these two separate modes of oscillation?

2 Suggest and explain which parameter is changing to cause the observed complex motion of the mass-and-spring system.

Mathskit: Angles, units and approximations

These questions apply the ideas discussed in *Mathskit* to the remnant of Tycho's supernova pictured on p. 34.

1 Estimate the angle (in radians) subtended at the Earth by Tycho's supernova remnant, which has an angular width 4.3 arcmin.

2 Estimate the distance in kpc across the supernova, which is at a distance of about 3 kpc.

3 Explain why your calculation of distance, based on arc length, can nevertheless be used as an estimate of the observed straight line distance.

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Supernova cosmology

Box 4 Relativistic red shift

Try for yourself

The relativistic equation relating redshift z to recession velocity v is

$$z = \sqrt{\frac{1+\frac{v}{c}}{1-\frac{v}{c}}} - 1 \qquad \text{(Equation 4.1)}$$

1 Show that Equation 4.1 can be rearranged to give

$$v = \left[\frac{(z+1)^2-1}{(z+1)^2+1}\right] c \qquad (4.2)$$

Adding 1 to both sides and squaring

$$(z+1)^2 = \frac{1+\frac{v}{c}}{1-\frac{v}{c}} \qquad (4.3)$$

Multiplying the right-hand side by c (top and bottom) gives

$$(z+1)^2 = \frac{c+v}{c-v} \qquad (4.4)$$

and therefore,

$$(c-v)(z+1)^2 = c+v \quad (4.5)$$

and

$$c(z+1)^2 - v(z+1)^2 = c+v \quad (4.6)$$

leading to

$$v + v(z+1)^2 = c(z+1)^2 - c \quad (4.7)$$

and finally,

$$v = \left[\frac{(z+1)^2-1}{(z+1)^2+1}\right] c \quad (4.8)$$

2 Show that, when $v << c$, Equation 4.1 approximates to the non-relativisitic equation:

$z = v/c$ (Equation 2)

First, slightly rewrite Equation 4.3

$(z + 1)^2 = (1 + v/c)(1 – v/c)^{-1}$ (4.8)

We now need to use the binomial approximation — the useful result that, when $x << 1$

$(1 + x)^a \approx 1 + ax$ (4.9)

(See *Mathskit*, PHYSICS REVIEW, February 2013, pp. 23–25)

When $v << c$, $v/c << 1$, so we can rewrite Equation 4.8:

$(1 + z)^2 \approx (1 + v/c)(1 + v/c)$ (4.10)

$(1 + z)^2 \approx (1 + v/c)^2$

so

$z \approx v/c$

Electricity supply

1 The author uses three examples to show how the average power consumption per person varies between countries. Use these examples to suggest two reasons why these variations occur.

2 Explain why there has been a move from using fossil fuels in thermal power stations to more renewable energy sources in the last 12 years.

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