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Answers

Practice-for-exam questions

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Atomic force microscopy

1 Don't forget to change ng to kg

Substituting the values given into: $f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \rightarrow f_0 = \frac{1}{2\pi}\sqrt{\frac{2.5\ \mathrm{N\ m^{-1}}}{0.5\times10^{-12}\ \mathrm{kg}}} = 336\ \mathrm{kHz}$

de Broglie waves

1 Using equation 8: $\lambda_{dB} = \frac{h}{\sqrt{2meV}}$ substituting for the values given:

$$\lambda_{dB} = \frac{6.626\times10^{-34}\ \mathrm{Js}}{\sqrt{2\times9.1\times10^{-31}\ \mathrm{kg}\times1.6\times10^{-19}\ \mathrm{C}\times200\ \mathrm{V}}} = 8.7\times10^{-11}\mathrm{m}$$

2 **a** Because the graphite consists of many crystals at random angles, the 'slits' are all in random directions and the effect is like rotating an optical diffraction grating in front of a light source, like a laser. In this case, the diffraction dots become circles around the central image. With the graphite, there is no need to rotate it as the diffraction slits, i.e. the layers of atoms, are already in all possible orientations.

b If there was not a vacuum, the electrons would be scattered or absorbed by the particles in the air before reaching the graphite and the fluorescent screen and so would never reach the screen.

c Use equation 9: $d\sin\theta = n\lambda \Rightarrow \theta = \sin^{-1}\left(\frac{n\lambda}{d}\right)$

from question 2, $\lambda_{dB} = 8.7\times10^{-11}$ m

$d_1 = 0.123\times10^{-9}\ \mathrm{m} \Rightarrow \theta = \sin^{-1}\left(\frac{8.7\times10^{-11}\ \mathrm{m}}{0.123\times10^{-9}\mathrm{m}}\right) = 45°$

$d_2 = 0.213\times10^{-9}\ \mathrm{m} \Rightarrow \theta = \sin^{-1}\left(\frac{8.7\times10^{-11}\ \mathrm{m}}{0.213\times10^{-9}\mathrm{m}}\right) = 24°$

d The smallest ring will be for $\theta = 24°$.

Therefore $\frac{\mathrm{radius}}{12\ \mathrm{cm}} = \tan 24° \rightarrow \mathrm{radius} = 12\tan 24° = 5.3\ \mathrm{cm}$

The larger ring will be for θ = 45°.

Therefore $\frac{\text{radius}}{12\text{ cm}} = \tan 45° \rightarrow \text{radius} = 12\tan 45° = 12\text{ cm}$

Phasors

1 As shown in Figure 2 of the article, three equal phasors at 120° to each other have a resultant of zero. This is confirmed by Table 1 where the summary of the three phasor model shows that for three equal phasors at 120° to each other there is a resultant phasor amplitude of zero and a normalised intensity of zero.

This means that the return currents from each of the three phases have equal amplitudes, provided the loads are equal, but are at 120° phase difference to each other and so always add to zero meaning that the return current is zero and the neutral wire carries no current (and is often not even present).

Physics online: magnetism

and

At a glance: magnetic materials

1 **a** Using Faraday's Law from https://tinyurl.com/s-cool-Faraday

$$\varepsilon = NA\frac{\Delta B}{\Delta t}$$

$\varepsilon = 3800 \times 10 \times 10^{-4}\text{m}^2 \times \frac{1.7\text{ T}}{0.02\text{ s}} = 323\ V$ (which is about the peak value of a mains 230 V supply)

b If the generator turns faster, the rate of change of flux in the coil is greater and therefore the peak emf is greater.

c Neodymium magnets are the strongest shown in the figure, so they generate a strong magnetic field, B. The emf generated using the equation in part (a) is larger when the magnetic field is larger, given the same rate of rotation of the coil, number of turns and cross-sectional area.

Calculating information from graphs

1 Each square of the graph grid represents an area 0.1 N × 2.0 mm = 0.1 N × 2.0 × 10^{-3} m = 2.0 × 10^{-4} J

Using a simple counting rule, count more than half a square as 1 and less than half a square as 0, the number of squares below the line is about 13.

Therefore, the work done is about 13 × 2.0 × 10^{-4} J = 2.6 × 10^{-3} J

2 **a** The area will be stress × strain

$$= \frac{\text{Force}}{\text{cross−sectional area}} \times \frac{\text{extension}}{\text{original length}}$$

$$= \frac{\text{Force} \times \text{extension}}{\text{cross−sectional area} \times \text{original length}} = \frac{\text{Work done}}{\text{Volume}} \quad (\text{J}\, m^{-3})$$

b The area enclosed by the two curves represents the work done per unit volume that is not recovered when the load is removed. This is called hysteresis and represents an elastic store of energy that is transferred to the surroundings as an internal or thermal store of energy. It is why, if you repeatedly stretch and release a rubber band, and then hold it near your cheek, you can feel that the band has become warm.

As can be seen from the calculation in Question 1, the amount of energy transferred to thermal energy is usually quite small for one extension and release of a rubber band.

Neutron stars

and

Exam talkback: escape velocity

1 **a** Use the equation given for escape velocity (Equation 6 in 'Neutron Stars', p. 23 or in Box 1 of 'Exam talkback: escape Velocity', p. 32).

$\frac{1}{2}mv^2 = \frac{GMm}{r}$ where *m* is the mass of the rocket and cancels out.

Rearrange to make *v* the subject and substitute values:

$$v = \sqrt{\frac{2GM}{r}} = \sqrt{\frac{2 \times 6.672 \times 10^{-11} \text{N m}^2 \text{ kg}^{-2} \times 5.974 \times 10^{24} \text{ kg}}{6.378 \times 10^6 \text{ m}}} = 11180 \text{ m s}^{-1} \approx 11 \text{ km s}^{-1}$$

b Because the Earth has an atmosphere, the air resistance on any projectile fired up through the atmosphere of the Earth would cause a significant additional force in addition to the gravitational force exerted by the Earth on the rocket and in a direction directly opposite to the direction of travel.

2 **a** $\rho = \frac{M}{V} \rightarrow V = \frac{M}{\rho} = \frac{5.974\times10^{24}\ \text{kg}}{2.3\times10^{17}\ \text{kg m}^{-3}} = 2.6 \times 10^{7}\ \text{m}^3$

The volume of a sphere is $V = \frac{4}{3}\pi r^3 \rightarrow \text{radius} = \sqrt[3]{\frac{3V}{4\pi}} = \sqrt[3]{\frac{3\times2.6\times10^{7} m^3}{4\pi}} = 184\ \text{m}$

b Substituting for ω in the equation for the angular momentum:

$$L = \frac{0.4\times M\times r^2\times 2\pi}{T} = \frac{0.8\times\pi\times M\times r^2}{T}$$

Substituting the figures into the expression:

$$L = \frac{0.8\times\pi\times5.974\times10^{24}\ \text{kg}\times(6.378\times10^{6}\ \text{m})^2}{24\times60\times60\ \text{s}} = 7.1\times10^{33}\text{kg m}^2\text{s}^{-1}$$

c The compressed Earth will have the same angular momentum since, like linear momentum, angular momentum is conserved.

$$L = \frac{0.8\times\pi\times M\times r^2}{T} \rightarrow T = \frac{0.8\times\pi\times M\times r^2}{L}$$

$$T = \frac{0.8\times\pi\times5.974\times10^{24}\text{kg}\times(184\ \text{m})^2}{7.1\times10^{33}\ \text{kg m}^2\ \text{s}^{-1}} = 7.2\times10^{-5}\ \text{s} = 72\ \mu\text{s}$$