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Answers

Practice-for-exam questions

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Sustainable building

1 From Box 1: energy stored, $Q = mc\Delta\theta$

A pillar of volume V has mass $m = \rho V$ and $mc = \rho Vc$

The temperature rise, $\Delta\theta$, for a given amount of energy absorbed, Q, is $\Delta\theta = Q/V\rho c$.

Material	**Density** ρ/ kg m^{-3}	**Specific heat capacity** c/ J kg^{-1}K^{-1}	ρc/J K^{-1} m^{-3}
Concrete	2300	1000	2.3×10^6
Granite rock	2700	774	2.1×10^6
Oak wood	720	2380	1.7×10^6

For the same dimensions (same volume), the granite pillars would have a greater mass than the concrete ones, as granite is about one-sixth more dense than concrete. However the specific heat capacity of granite is only about ¾ that of concrete, so for a given amount of energy absorbed from sunlight, granite pillars would have a larger temperature rise than concrete.

The oak pillars would have a much smaller mass than the concrete ones, as the density of oak is only about $^1/_3$ that of concrete. Oak has a higher specific heat capacity than concrete or granite, but the much lower mass means that the temperature of the oak pillars would rise more than either concrete or granite for a given amount of energy absorbed.

With either granite or oak pillars, the temperature inside the building would be higher during the day, than it would be with concrete — the granite or oak pillars would be less good at keeping the building cool on hot sunny days. And on cooler days or at night, the warm granite or oak pillars would more rapidly reach the temperature of the surrounding cold air — they would be less good at keeping the building warm.

2 As well as a thermal function the columns probably also have structural function within the building and their structural properties should be considered, including the Young modulus and strength under tension and compression.

As this is intended to be a sustainable building the resourcing of each of the materials should also be considered:

- **Granite:** a natural, but limited, material. Quarrying has a local environmental impact when the rock is removed. Not a sustainable resource.

- **Oak:** a renewable material. Oak trees are slow-growin. During their lifetime they remove carbon dioxide from the atmosphere, which would not be released if they were used as a building material (rather than burned).
- **Concrete:** a man-made material, which uses limestone and a considerable amount of energy to produce. Not a sustainable resource.

What use are theories?

1 Elements with high atomic numbers have more protons in the nucleus and therefore the nucleus has a higher electric charge *Q.* Their outer electrons are also at a greater distance, *r*, from the nucleus.

When an electron (charge –*e*) is at a distance *r* from a positive charge Q, the electrostatic potential energy, *E*, is

$E = - Qe/4\pi\varepsilon_0 r$

When the outermost electron in an atom with a high atomic number moves to an inner shell, the change in potential energy is large, because *Q* is large and the distance the electron moves between an outer shell into an inner shell will be greater.

The electromagnetic radiation emitted is determined by the change in electrical potential energy, so a bigger change in energy will result in higher energy radiation. X-rays have higher frequency and therefore higher photon energies than ultraviolet radiation.

2 An electron in an outer shell is attracted to the nucleus because the electron and nucleus are oppositely charged. However, there will also be a repelling force from each of the other electrons in the atom. These other electrons are distributed around the atom, so while there is a resultant attractive force on the outer electron towards the centre of the atom, it will be less than that calculated by simply considering the force between two opposite charges (electron and nucleus) separated by a distance *r*.

Rutherford's nuclear atom revisited

1 $^{218}_{84}\mathrm{Po} \rightarrow {}^{214}_{82}\mathrm{Pb} + {}^{4}_{2}\alpha \rightarrow {}^{214}_{83}\mathrm{Po} + {}^{0}_{-1}\beta + \bar{\nu}_e \rightarrow {}^{214}_{83}\mathrm{Bi} + {}^{4}_{2}\alpha$

2 $1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$

Equation 2 in the article gives a (non-relativistic) expression for v:

$v = \sqrt{(2E_k/M)}$

so

$v = \sqrt{(2 \times 6.0 \times 10^6 \times 1.60 \times 10^{-19}\ \mathrm{J}/6.9 \times 10^{-27}\ \mathrm{kg})}$

$= 1.7 \times 10^7\ \mathrm{m\ s^{-1}}$

Relativistic effects become noticeable when v is greater than about 5% (which is $^1/_{20}$) of the speed of light:

$c/20 = 3.00 \times 10^8\ \mathrm{m\ s^{-1}}/20 = 1.50 \times 10^7\ \mathrm{m\ s^{-1}}$

The calculated alpha speed is slightly greater than this value, so if Rutherford had used alpha particles from the decay of polonium-218, there would have been some relativistic effects, though these would not have been very large as the alpha speed is not much above 5% of *c*.

Frisbee physics

1 Kinetic energy per unit volume is given by

$^1/_2 m v^2/V = {}^1/_2 v^2 \,(m/V)$

where V is volume.

Also

$m/V = \rho$

so

$^1/_2 v^2 \,(m/V) = {}^1/_2 \rho v^2$

2 The lift force F_L must be equal to the weight of the Frisbee:

$F_L = mg$

This lift is produced by a pressure difference p acting over the Frisbee's surface area A:

$A = \pi r^2$

$p = mg/A$

$= mg/\pi r^2$

$= 0.175 \text{ kg} \times 9.81 \text{ N kg} / \pi \,(0.27 \text{ m})^2$

$= 7.49 \text{ N m}^{-2}$

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