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Answers

Practice-for-exam questions

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Electric vehicles

1

Wheel diameter = 63.6 cm = 0.636 m

Wheel circumference = $\pi \times 0.636$ m

Maximum rotation rate = 1.3×10^3 rpm

1 hour = 60 minutes

Distance travelled in 1 minute = 1.3×10^3 rotations $\times \pi \times 0.636$ m

= 2.60×10^3 m

= 2.6 km

Distance travelled in 1 hour = 2.6 km $\times$ 60 = 156 km

2 The battery has to be carried in the vehicle as it travels (which needs energy). The heavier the battery, for the same energy stored, the shorter the range the vehicle can travel between charging. A Li-ion battery is lighter than a lead-acid battery, so if both batteries store the same amount of energy a vehicle with a Li-ion battery will have a longer range.

Golf buggies and scooters are used for relatively short journeys and can be recharged after each journey. A car needs a much longer range to be useful.

Building the pyramids

1 a

Volume of a pyramid = 1/3 $\times$ area of base $\times$ height

$V = Ah/3$

mass = density $\times$ volume

$m = \rho V$

weight = mass $\times$ gravitational field strength

$W = mg$

$= \rho Vg$

$= \rho Ahg/3$

Stress = load/area

$\sigma = W/A$

Shard:

$V = 2500\ \text{m}^2 \times 310\ \text{m}/3$

$= 2.6 \times 10\ \text{m}^3$

If the Shard were made of solid limestone

$W = 2600\ \text{kg m}^{-3} \times 2.6 \times 10^5\ \text{m}^3 \times 9.8\ \text{N kg}^{-1}$

$= 6.6 \times 10^9\ \text{N}$

$\sigma = 6.6 \text{ x } 10^9\ \text{N}/2500\ \text{m}^2$

$= 2.6 \times 10^6\ \text{Pa}$

Notice that we have first multiplied by area *A*, then divided by it so its value does not affect the final answer. Doing some algebra first can streamline the calculations:

$\sigma = W/A$

$= \rho Ahg/3A$

$= \rho hg/3$

$= 2600\ \text{kg m}^{-3} \times 310\ \text{m} \times 9.8\ \text{N kg}^{-1}/3$

$= 2.6 \times 10^6\ \text{Pa}$

b Although steel is denser than limestone, both concrete and glass are less dense than limestone, and a large fraction of the volume of the Shard is air-filled space. So the average density of the Shard is likely to be less than the density of limestone, and the loading on the ground is likely to be less than calculated in (a).

2 The building that is being removed will have loaded the ground when it was built, compressing it. When it is removed the ground may 'spring back' — possibly affecting other structures in the surrounding area.

The new building is much taller and will be heavier and will increase the load again, causing further movement.

Brownian motion revisited

1

$$v^2 = \frac{3kT}{m}$$

so

$T = mv^2/3k$

On a warm summer day, $T \approx 300\text{K}$

If the molecular speed *v* is 10 times greater, 1 mm s^{-1} rather than 0.1 mm s^{-1}, v^2 will be multiplied by 10^2 (= 100).

Therefore, the temperature *T* will also be 100 times greater, so $T \approx 30\,000$ K.

2 A particle jiggles because the impacts due to molecules hitting it from different directions are unequal, so the particle experiences an unbalanced force that fluctuates in size and changes direction. The larger the particle, the more collisions there will be from each direction, so these fluctuations will even out and there will not be a noticeable difference in the force from different directions.

Metallic glasses

1 **a** A low temperature coefficient of resistivity means that there is little change in resistance with temperature. In a circuit that undergoes large changes in temperature it would be a disadvantage for the resistance to change.

b A thermistor has a high temperature coefficient of resistivity. The property can be used to monitor changes in temperature, or in thermostats that control circuits in response to changes in temperature.

2 The area under the line represents the energy per unit volume stored in material as it is stretched.

Area under straight part of graph = stress × strain/2

$= \sigma\varepsilon/2$

stress = applied force/cross-section area of sample

$\sigma = F/A$

strain = extension/original length of sample

$\varepsilon = x/L$

work done in stretching sample = average force × extension

$W = Fx/2$

volume of sample = length × area

$V = LA$

So area under graph = $(F/A) \times (x/L)/2$

$= (Fx/2)/(AL)$

$= W/V$

= work done/volume of sample