BMAT 2010 Solutions

Q3

Over 12 minutes the sample slowly decays to 16 mg of uranium-234. This implies there were 16 mg of protactinium-234 before the β-emission. Looking at the table, after 1.2 minutes there is 8 mg of uranium implying there is 8 mg of protactinium; its mass has halved. Again, looking at 2.4 minutes there is 12 mg of uranium and therefore 4 mg of protactinium. It takes 1.2 minutes for the mass of the protactinium to half and therefore, this is its half-life, Option **A**.

Q4

Immediately we need to think about what we've been given in the question. The values p and q represent the fraction of water filled for the larger and smaller container respectively. So initially p=1 and q=0. Now we pour half of the larger container into the smaller so p, by definition, will be equal to 0.5. This also indicates that q $>$ 0.5 as its smaller than container p but contains the same amount of water. Our answer is therefore Option **C**.

Q6

Lets just follow the mass through each equation. So, 12g of carbon is used in stage 2, which results in 56 g of carbon monoxide being produced This is calculated by adding the masses $2 \times (12 + 16) = 56$. In stage 3, for every molecule of carbon-monoxide reacted, a molecule of carbon-dioxide is produced.

Therefore the amount of carbon-dioxide is calculated by adding another oxygen particle to the CO produced in stage 2, so $2 \times (12 + 16 + 16) = 88$. Therefore our answer is Option **C**.

Q7

This is testing your ability to read the values of frequency and amplitude from a graph. Remember that the definition of amplitude is the height of the wave from the average position to a peak and the frequency is the number of waves per second.

So, lets calculate the amplitude. The average of this wave, halfway between two peaks, is 13 metres. We have a maximal point at 16 m, so 16-13 = 3 m for the amplitude.

The time taken for a full wave to pass is from 0 hours to 12 hours, so our wavelength is 12 h or 12×3600 s. The frequency is the number of full wavelengths per second, so just take the reciprocal, which results in $1/(12 \times 3600)$.

We have our results, which correspond to Option **A**.

Q8

This question is just asking what the probability of getting a particular results is. To see this imagine we make a first move from position A to position B. We want to return to position A on the first move, which is only allowed by the opposite direction and same distance, so no matter what our original move is, its possible to reverse it.

Since we have a $\frac{1}{4}$ probability of getting a particular distance, and the same for a particular direction, the probability is just the product between them

$$\frac{1}{4} \times \frac{1}{4} = \frac{1}{16},$$

which is Option **C**.

Q11

Remember what happens with β and α emission.

In α-decay a He nucleus is emitted resulting in a loss of 2 to the atomic number and 4 to the mass number. Since we've had 3 of these emitted we need to subtract 12 from the mass number and 6 from the atomic number. So we currently sit at

$$^{207}_{80}\mathrm{X}.$$

In β-decay a neutron transforms to a proton, emitting an electron. This means no change to the mass number as neutrons and protons are the same mass, but results in 1 being added to the atomic number. We have two of these decays so we add 2 to the atomic number, resulting in,

$$^{207}_{82}\mathrm{X}.$$

Our solution is therefore Option **C**.

Q12

Q15

When switch P is open and switch Q is closed, almost no current will flow through any bulbs except bulb Y. This is because the majority of the current will short circuit through switch Q.

Now we open switch Q and close switch P. A large amount of current can now short circuit through switch P, so we can view it as a series circuit with just bulbs X and Y. Since bulb X initially had very little current flowing through it, it will be brighter, and since bulb Y is now in a series circuit and is not the only bulb, it will be dimmer than initially.

The solution is therefore Option **B**.

Q17

Since X carries the condition, their parents U and V must both be carriers. Therefore U is 100% a carrier.

If P and Q are both carriers of a recessive allele, the probability of the rest of their children carrying the allele is 50%, as none of their children carry the condition, so will only have one copy of the recessive allele. The only combinations of alleles allowed are RD and DD, for a dominant allele D and recessive R. This means S and T have a 50% chance of being carriers.

The solution is Option **E**.

Q19

Take each graph in turn.

P

This is a velocity-time graph, so to calculate the acceleration, we calculate the gradient. Remember, dy/dx for a straight line, which is $10/24\text{m/s}^2$, which does not equal 2.4.

Q

It's difficult to see the exact point where the guiding points meet the y-axis but approximately 58 m/s is not a bad guess. Taking dy/dx again, as it's a velocity-time graph, results in

$$\frac{58 - 10}{20} = 2.4.$$

Therefore Q is accelerating at 2.4m/s^2.

R

This is a distance time graph, but it has a constant gradient. So taking a differential twice would just equal 0. So this isn't accelerating.

S

This is the same as R.

Since only Q is accelerating at 2.4 m/s^2, the solution is Option **B**.

Q20

Equate the equations for the surface area and the volume and rearrange to get in terms of h.

$$\begin{aligned} \pi r^2 h &= \pi(2rh + 2r^2) \\ r^2 h &= 2rh + 2r^2 \\ h(r-2) &= 2r \\ h &= \frac{2r}{r-2} \end{aligned}$$

This gives us our solution, which is Option **A**.

Q23

For this we use the equations for gravitational potential energy, $E_p = mgh$, and kinetic energy, $E_k = \frac{1}{2}mv^2$.

5kg of water passing through each second will reach a height of 5m. This means that our gravitational potential energy is $5 \times 5 \times 10 = 250$ J. Immediately, we know that this will be the power of the pump, as every second the water is being given 250 J of energy.

Upon leaving the pump, the water will have 250 J of kinetic energy, and rearranging the equation for kinetic energy

$$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{500}{5}} = 10,$$

so it leaves at 10 m/s. Our solution is therefore Option **G**.

Q24

For this we'll need to calculate the area of the second square as a fraction of the first.

To do this, look at the parts of the original square not covered up by the second square. We effectively have 4 triangles in each corner of length 1/3 and 2/3 in relation to the original square, with their hypotenuse being the length of a side of the second square. So, using pythagoras' theorem, $a^2 + b^2 = c^2$, we can calculate this length,

$$c^2 = \frac{1}{3}^2 + \frac{2}{3}^2 = \frac{5}{9}.$$

This is conveniently the area of the second square as a fraction of the original. If we want to calculate the area of the fourth square following this process, we just apply 5/9 two more times.

$$1 \times \frac{5}{9} \times \frac{5}{9} \times \frac{5}{9} = \frac{125}{729}$$

Therefore our answer is Option **C**.

Q27

For this you'll need the equation for work done $E = F \times d$.

For this, the car is working against both friction and gravity, so the work done to oppose friction will be 50×500, which is 25 kJ.

It will have also done work to oppose gravity, which we can work out using gravitational potential energy gained, $E_p = mgh$. This is $800 \times 10 \times 2.5 = 20$kJ as it gains 1 metre up for every 20 metres across.

Summing these up gives us the total work done by the engine of 45 kJ, so the solution is Option **D**.