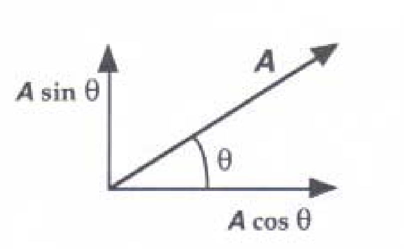
HIGHER PHYSICS EXAM – 2004
WORKED SOLUTIONS

Q1. To calculate the work done in moving the box a horizontal distance of 10m, the force acting in the horizontal direction must be found.

Any vector, **A** can be replaced by two other vectors acting at the same point that are at right angles to each other.



Given that the force applied along the rope is 100N, the horizontal force is calculated to be:

$$\begin{aligned} F_H &= F\cos\theta \\ &= 100 \times \cos(40^\circ) \\ F_H &= 76.6N \end{aligned}$$

The work done is defined by the following expression:

$$W = F \times d$$

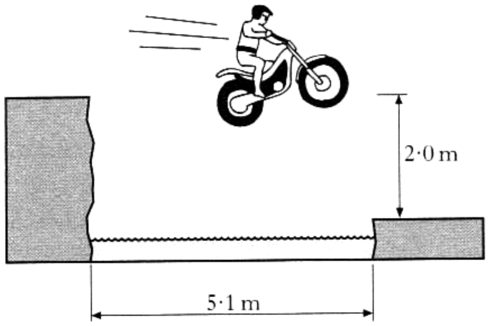
The work done is calculated to be:

$$W = ? \qquad F = 76.6N \qquad d = 10m$$

$$\begin{aligned} W &= Fd \\ &= 76.6 \times 10 \\ W &= 766J \end{aligned}$$

The correct answer is: **C**

Q2. The diagram shown below, illustrates a projectile problem. That is a problem where an object is moving horizontally as well as vertically at the same time.



You should start all projectile problems by noting all the information you are given in the question in respect of the horizontal and vertically directions.

VERTICAL	**HORIZONTAL**
$s = 2.0m$	
$v = 0ms^{-1}$	$s = 5.1m$
$a = -9.8ms^{-2}$	

The initial vertical speed is given by:

$$v^2 = u^2 + 2as$$
$$u^2 = v^2 - 2as$$
$$u^2 = -2as$$
$$u^2 = -2(-9.8)(2)$$
$$u = \sqrt{39.2}$$
$$u = 6.26ms^{-1}$$

Given the initial vertical speed, the time taken for the bike to complete the jump is calculated to be:

$$v = u + at$$
$$at = -u$$
$$t = \frac{-u}{a}$$
$$t = \frac{-6.26}{-9.8}$$
$$t = 0.64s$$

The time taken for the vertical and horizontal are always equal.

As you now know the distance travelled and the time taken, the minimum speed can be calculated using:

$$v = \frac{d}{t}$$

The speed is calculated to be:

$$v = \frac{d}{t}$$
$$= \frac{5.1}{0.64}$$
$$v = 7.97ms^{-1}$$
$$v = 8ms^{-1}$$

The correct answer is: **D**

Q3. There are not enough values given to calculate which of the quantities are conserved or not, so you must have the required knowledge.

In all collisions, the total momentum is conserved.

When two vehicles strike each other and stick together, there is less kinetic energy after the collision than there is before, so kinetic energy is not conserved.

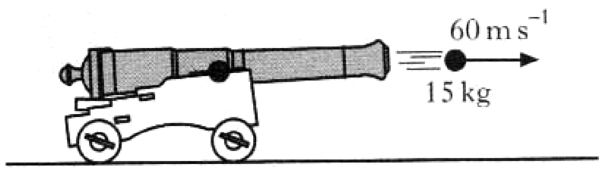
The total energy within any system is always conserved.

From the list the correct statements are I and III, giving the answer to be: **D**

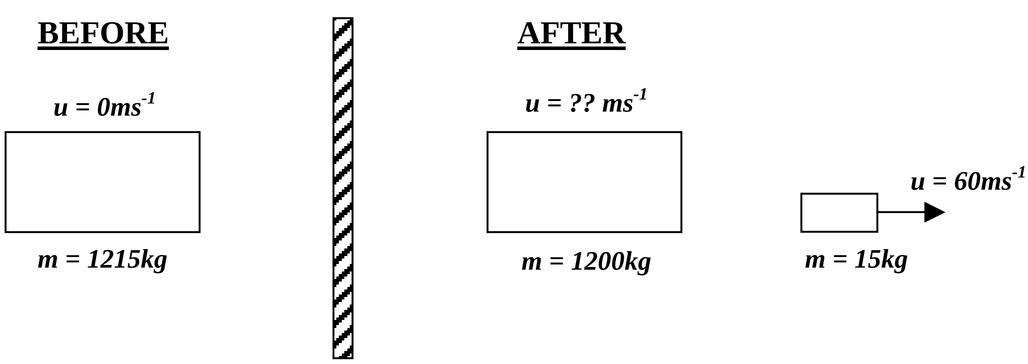
Q4. When a cannonball is fired from a cannon it moves off with velocity.

Since the cannon produces such a great force in the direction of the cannonball, the cannon itself will also move. It will move off in the opposite direction from which the cannon was fired.

As the diagram shows the cannon moving off with a velocity of $60ms^{-1}$ to the right, the cannon must move off with a velocity to the left.



Deal with this problem in two stages. Think of it in terms of before and after.



Since momentum is conserved in any collision or explosion, start by stating:

total momentum before = total momentum after

Using the principle of conservation of momentum, the velocity of the cannon is calculated to be:

$$\begin{aligned} \textit{total momentum before} &= \textit{total momentum after} \\ mv &= mv \\ (1215 \times 0) &= (1200 \times v) + (60 \times 15) \\ 0 &= 1200v + 900 \\ 1200v &= -900 \\ v &= \frac{-900}{1200} \\ v &= -0.75ms^{-1} \end{aligned}$$

As the cannonball travels east, the negative sign indicates that the velocity of the cannon is $0.75ms^{-1}$ to the west.

The answer is therefore: **C**

Q5. This type of question requires you to apply your knowledge of dynamics to a situation you may not have dealt with before.

Consider each statement on it's own.

Since Car X has a crumple zone, the force applied to the car is less than that applied to car Y.
Car Y will hit the wall with a greater force, and from Newton's Third Law, the wall will produce an equal and opposite force.

Car Y will come to rest almost instantly (assuming the wall does not collapse). On the other hand, as the front of Car X will crumple, it will travel for a slightly longer period of time and then come to rest.

Since the two cars are identical and travel at the same speed, their initial momentum is equal. Since both cars come to rest, the change in momentum for both Car X and Car Y will be exactly equal.

The correct answer therefore is: **B**

Q6. The area under a force time graph is equal to the impulse.

The term impulse is defined as:

$$Impulse = Force \times Time\ of\ contact$$

From Newton's Second Law, we can write impulse in terms of change of momentum:

$$F = ma$$

Where the acceleration can be written as: $a = \frac{v-u}{t}$

We can write: $F = m\frac{v-u}{t}$

And this gives: $F = \frac{mv-mu}{t}$

Finally, the impulse then can be written as:

$$Ft = mv - mu$$

In this case, the initial velocity of the golf ball before being struck is zero, which means impulse, can be written in the following form:

$$Ft = mv$$

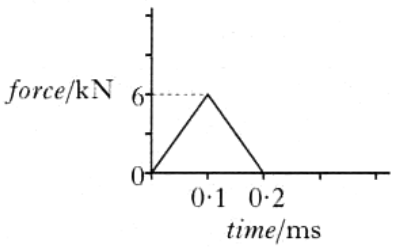
The velocity of the ball can then be found from re-arranging the above expression to give:

$$v = \frac{Ft}{m}$$

The question advises you that the second golf ball is the same size, mass and hit with the same club and moves off with the same velocity as the first ball.

Since the velocity and mass of the second golf ball is the same as the first, you can see from the last expression that the impulse must also equal that of the first strike.

Given the graph below:



The impulse is calculated to be:

$$\begin{aligned} impulse &= area\ under\ \ force\text{-}time\ graph \\ &= 6kN \times 0.2s \times 0.5 \\ impulse &= 0.6 \times 10^{3}\ Ns \end{aligned}$$

By calculating the area under each of the graphs shown, you should find that the impulse from one of the graphs equals the impulse from the first strike.

The correct answer is: **B**

Q7. Consider the molecular arrangement you would normally associate with liquids and gases.

Water at 100°C is still a liquid. Steam at 100°C is a gas.

Molecules in a liquid are quite closely bound together but free to move around.

The molecules in a gas are widely spaced, move in all directions and generally moving at high speed.

The density of a substance is defined as:

$$\rho = \frac{m}{V}$$

Since there are less molecules in a gas per unit volume than in water, there is less mass.

The density of steam therefore, is less than the density of water, although both are at the temperature of 100°C.

Density of steam is less because the molecules move further apart in a gas.

The correct answer from the list given is: **A**

Q8. To calculate the largest percentage uncertainty you should do the following:

Temperature Rise: $\% \, error = \frac{error}{reading} \times 100\% = \frac{1}{10} \times 100\% = 10\%$

Heater Current: $\% \, error = \frac{0.2}{5} \times 100\% = 4\%$

Heater Voltage: $\% \ error = \frac{0.5}{12} \times 100\% = 4.2\%$

Time: $\% \ error = \frac{2}{100} \times 100\% = 2\%$

Mass of Liquid: $\% \ error = \frac{0.005}{1} \times 100\% = 0.5\%$

The answer from the choices is: **A**

Q9. To calculate the new volume of gas, use the general gas equation:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Note the information you are given, then do the calculation:

$P_1 = 2kPa = 2 \times 10^3 \ Pa$
$V_1 = 6m^3$
$T_1 = 300K$
$P_2 = 1kPa = 1 \times 10^3 \ Pa$
$V_2 = ?$
$T_2 = 600K$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$P_1 V_1 T_2 = P_2 V_2 T_1$$

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1}$$

$$V_2 = \frac{(2 \times 10^3) \times 6 \times 600}{(1 \times 10^3) \times 300}$$

$$V_2 = 24m^3$$

The correct answer is: **E**

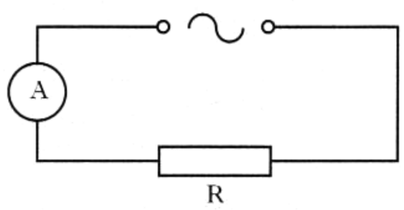
Q10. Your knowledge of electric fields is essential to answer this question. You should know the following:

- A charge will experience a force when it is in an electric field.
- The free electric charges in a conductor move when an electric field is applied to a conductor.
- Work is done in moving charge through an electric field.

All the statements given in the question are true.

The correct answer is: **E**

Q11. Firstly, consider the resistor in series with an ammeter connected to an alternating power supply.



When dealing with an ac power supply, the quoted values of voltage and current are not the peak values, but the root mean square values.

Since the peak voltage across the resistor and the peak current through the resistor are reached at the same instant, the resistance of the resistor can be described by the following expression:

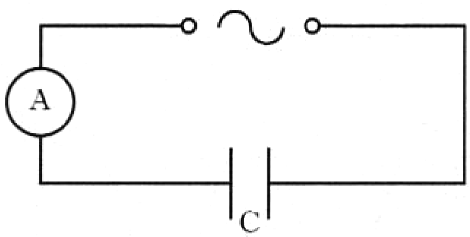
$$R = \frac{V_R}{I_R}$$

Since the ratio $\frac{V_R}{I_R}$ will always remain constant, the value of resistance will be constant.

The ratio is not dependant upon the frequency of the supply.

The current is therefore independent of frequency in an ac circuit.

Secondly, consider the circuit where the capacitor and ammeter are connected in series to an alternating power supply.

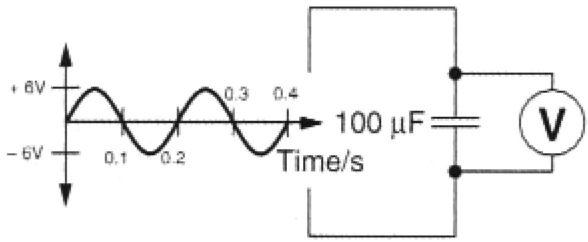


You should be aware that as the frequency of the supply is increased in the above circuit, the current through the capacitor increases.

The current through a capacitor in an AC circuit is directly proportional to the frequency of the supply.

The above is explained by the theory that follows.

Consider the following circuit where a continuously alternating voltage supply is connected across a capacitor.



As there is no resistor in the previous circuit, the voltage across the capacitor follows instantly the voltage set by the power supply.

In this instance, the voltage across the capacitor after 0.05s is 6V.

The charge stored on the $100\mu F$ capacitor is found from:

$$Q = ? \qquad Q = CV$$
$$C = 100\mu F = 100 \times 10^{-6} F \qquad Q = (100 \times 10^{-6})(6)$$
$$V = 6V \qquad Q = 600 \times 10^{-6} C$$

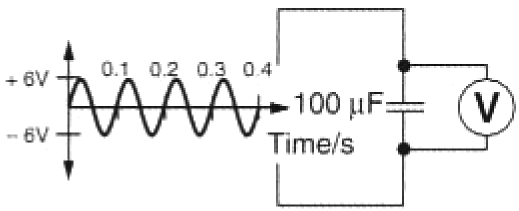
After a further 0.05s the voltage across the capacitor will be 0V and so this means that the capacitor has given up its entire charge of $600 \times 10^{-6} C$.

A current will be detected on an ammeter if connected into the circuit because of this movement of charge.

The current at any instant during the discharge varies, but the average current during the 0.05s can be found from:

$$average\,current = \frac{total\ charge}{time}$$
$$= \frac{600 \times 10^{-6}}{0.05}$$
$$= 0.012A$$
$$= 12mA$$

Now consider an alternating source with the same peak voltage of 6V but the frequency of the source having doubled.



The charge stored is given as before:

$$Q = ? \qquad Q = CV$$
$$C = 100\mu F = 100 \times 10^{-6} F \qquad Q = (100 \times 10^{-6})(6)$$
$$V = 6V \qquad Q = 600 \times 10^{-6} C$$

In this case though, the capacitor will discharge not in 0.05s but rather in half that time, 0.025s.

The current at any instant during the discharge will vary, but the **average current** is calculated to be:

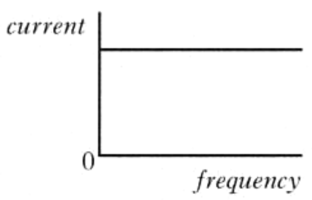
$$\begin{aligned} average\,current &= \frac{total\ charge}{time} \\ &= \frac{600 \times 10^{-6}}{0.025} \\ &= 0.024A \\ &= 24mA \end{aligned}$$

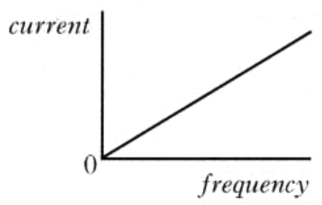
Doubling the **frequency** has **doubled** the **current** in the circuit.

The **same amount of charge** has **left the capacitor** in **half the time**.

The current in the circuit is **directly proportional** to **the frequency of the supply.**

The following two graphs represent the relationships explained previously for a resistor and capacitor connected in series to alternating supplies respectively.



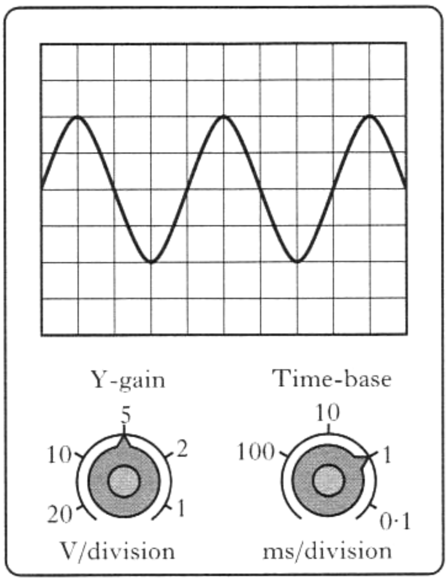


The correct answer is: **B**

Q12. The frequency of a wave is defined as:

The frequency of a signal is the number of waves to pass a particular point is one second.

Given the following oscilloscope trace:



The frequency of a wave can be calculated from the distance between peaks of the signal and the time base setting.

This would give you the period of a wave, and the frequency is found from:

$$f = \frac{1}{T}$$

The answer from the options is: **B**

Q13. The operation of an ideal op-amp is best described by two rules:

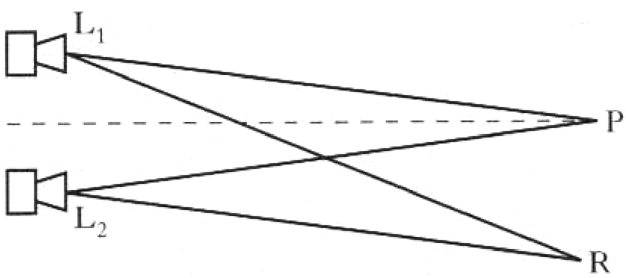
1. The op-amp will keep the inverting and non-inverting inputs at the same voltage.
2. The inverting and non-inverting terminals of an op-amp have an infinite input resistance.

Consider each of the statements in turn:

I - is stated above in rule 2.
II - is stated above in rule 1.
III - is self explanatory, if there is infinite resistance there can be no current.

All of the statements are correct. **E**

Q14. You are told that there is a maximum at P and R as illustrated in the diagram you are given.



Both sources are operated at the same frequency and are in phase with each other.

At this stage you should recall that you are aware of an equation that incorporates path difference, wavelength and maximum number.

path difference = n λ

The **path difference** is given by subtracting the length of L_2R from L_1R.

Point **P** represents the **central maximum** since it occurs the same distance away from both sources. **R** is therefore the 1st **maximum** as you are told this is the next maximum intensity point.

This now allows you to express the **wavelength** as:

$$\begin{aligned} \text{path difference} &= \text{L}_1\text{R - L}_2\text{R} \\ &= 5.6m - 5.3m \\ n &= 1 \\ \lambda &= ? \end{aligned}$$

$$\begin{aligned} \text{path difference} &= \text{n}\ \lambda \\ \lambda &= \frac{\text{path difference}}{\text{n}} \\ \lambda &= \frac{5.6 - 5.3}{1} \\ \lambda &= 5.6 - 5.3 \end{aligned}$$

You should now try and recall an equation that relates wavelength, speed and frequency, which you find is:

$$v = f\lambda$$

The speed of sound is advised to you in the question, the wavelength was found previously so the **final expression** is found by re-arranging the above formula:

$$\begin{aligned} v &= 340ms^{-1} \\ \lambda &= 5.6 - 5.3 \\ f &= ? \end{aligned}$$

$$\begin{aligned} v &= f\lambda \\ f &= \frac{v}{\lambda} \\ f &= \frac{340}{5.6 - 5.3} Hz \end{aligned}$$

C

Q15. In replacing the clean zinc plate by a different metal that has a lower work function, there is less energy required to eject a photoelectron.

This "extra" energy is given to the photoelectron as kinetic energy.

Think of this in terms of a word equation:

energy of incident photon	=	work function	+	kinetic energy of electron

Therefore, we can conclude that the maximum kinetic energy of the photoelectron is greater.

If the maximum kinetic energy of the photoelectron increases, this will affect the speed of the photoelectrons.

Consider the equation:

$$E_K = \frac{1}{2}mv^2$$

- Mass of photoelectron is constant
- Kinetic energy has increased

To ensure the above equation is satisfied:

- Speed of photoelectrons must increase.

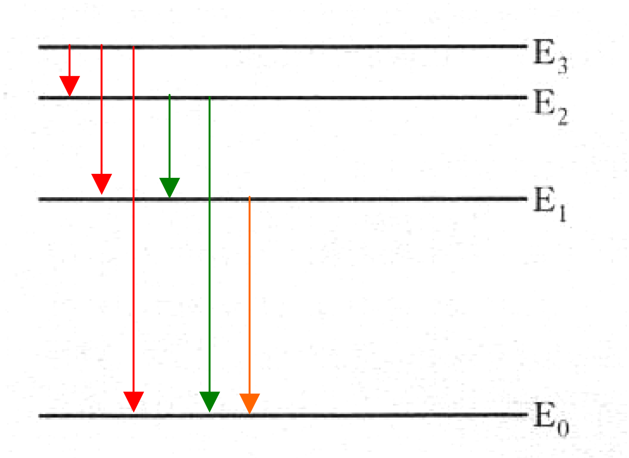
Nothing discussed above suggests that the rate at which the photoelectrons are ejected should increase.

The rate at which photoelectrons are ejected is proportional to the intensity of the radiation.

Statements, I and II are true. **D**

Q16. Simple type of question, which requires almost no knowledge of physics at all.

Approach this type of question with some sort of sequence in mind, or you will miss one or two of the transition lines that are possible.



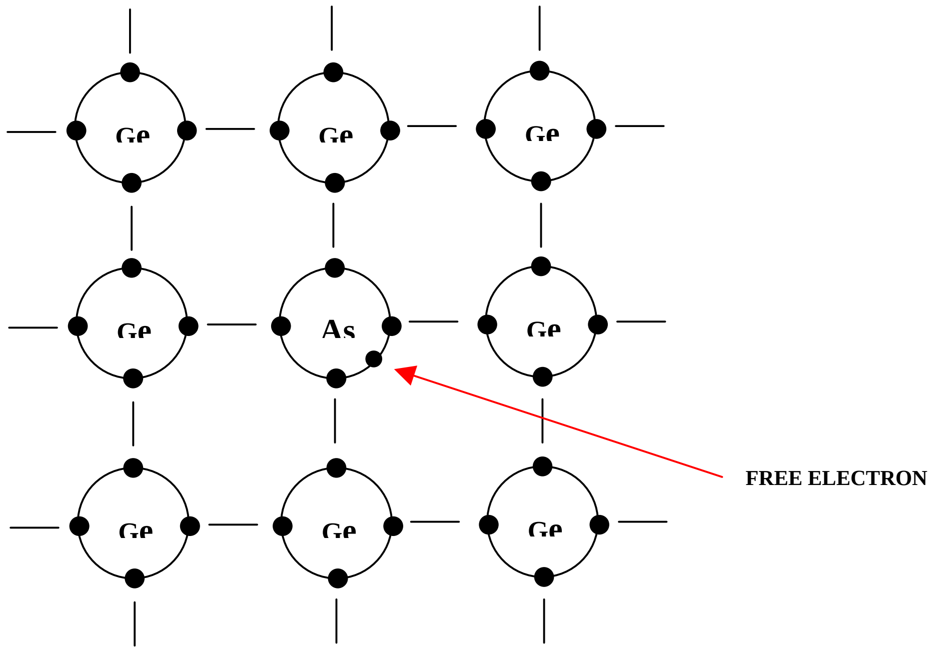
- I have considered the energy level E_3 and drawn each of the possible emission lines that can occur from this level.
- Secondly, I have considered level E_2 and drawn the possible emission lines from here.
- Finally, energy level E_1 has only one possible emission.

There are 6 possible emission lines that can be produced.

D

Q17. When a material is doped to produce n-type semi-conducting material, the impurities added have more electrons than required, to bond with surrounding atoms leaving "free" electrons.

This is shown below:



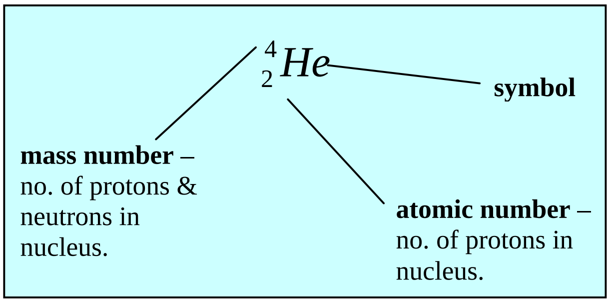
A voltage connected across such n-type semiconductor material, causes the "free" electron to flow towards the positive terminal of the supply.

As there is more than one "free" electron, the flow of electrons allows a flow of charge.

A

The majority charge carriers are therefore electrons.

Q18. During alpha decay, a particle that is essentially a helium nucleus is released.



The number of neutrons is found by:

$$\text{number of neutrons} = \text{mass number} - \text{atomic number}$$

The number of protons is 2, and the number of neutrons is 2.

In a stable nucleus, the number of protons and neutrons are equal.

Statement I – incorrect.

During beta decay, particles known as high-energy electrons are emitted.

This can be represented by $^{0}_{-1}e$.

Statement II – correct.

During gamma decay, there is no change to the isotope.

Gamma radiation is a member of the electromagnetic spectrum. It consists of particles known as photons. Photons are emitted when an unstable nucleus rearranges to become stable.

Statement III – correct.

D

Q19. A lot of information is given, so start by writing down what information you are given in the question and what you're asked to find:

$$t = 150 \text{ hours}$$
$$t_{TOTAL} = 150 \times 7 = 750 \text{ hours}$$
$$Q = 3$$
$$\dot{D} = 10 \mu\, Gy\, h^{-1}$$
$$H = ?$$

Using the equation for dose equivalent:

$$H = DQ$$

You can state that a form of this equation can include the rates for dose equivalent and absorbed dose:

$$\dot{H} = \dot{D} Q$$

The dose equivalent rate therefore is calculated to be:

$$\dot{H} = \dot{D} Q$$
$$\dot{H} = (10 \times 10^{-6}) \times 3$$
$$\dot{H} = 30 \times 10^{-6}\, Gy\, h^{-1}$$

To find the dose equivalent from the dose equivalent rate:

$$\dot{H} = \frac{H}{t}$$

The dose equivalent is found to be:

$$H = \dot{H}\, t_{TOTAL}$$
$$H = (30 \times 10^{-6}) \times 750$$
$$H = 2.25 \times 10^{-2}\, Sv$$

B

Q20. Given a "corrected count rate of 1000 counts per second" at a distance of 400mm from the source, this simply means that the rate has been corrected for background radiation.

The half value thickness of an absorber is how thick the absorber must be half the detected intensity.

As we started with a rate of 1000 counts per second and after inserting the metal plate have a rate of 125 counts, we know that the metal sheet inserted must be greater than 20mm.

If the metal plate had been 20mm, the counts detected would half and give a rate of 500 counts per second.

You should do the following to correctly calculate the new count rate:

$$1000 \xrightarrow{20\text{mm}} 500 \xrightarrow{20\text{mm}} 250 \xrightarrow{20\text{mm}} 125$$

Shown above, the detected count rate has halved three times. Each time the detected rate falls by half, this indicates a thickness of 20mm.

C

So the thickness of the metal sheet is 60mm.