

HSC Physics 9.6 Medical Physics Example Questions

Markers comments, sample answers and marking guidelines

Example Question 1 (2013 HSC Physics exam) Question 33

Sample answer:

Radioactive isotopes are used to show functioning of areas of interest in the body. Radioactive isotopes are attached to pharmaceuticals that roam the body and position themselves in certain areas. Their radioactive decay products are detected with diagnostic imaging tools such as Gamma scan and PET devices.

Radioactive isotopes used for diagnostics are short-lived so that they can decay fast and don't harm the body, yet radiate long enough to be transported and given to the patient. Fluorine-18 and Technetium-99m are such isotopes. T-99m is a gamma emitter and thus suitable for gamma scans. F-18 is a β^+ or positron emitter and thus suitable for PET scans.

The gamma rays emitted by T-99m pass through the body without harming it. The uptake of T-99m is determined by metabolism of the organ and hence different concentration of gamma rays can be detected outside the body by gamma cameras. A computer is used to further process gamma ray locations and concentration.

The F-18 emitted positron combines with a nearby electron, together they annihilate to produce 2 gamma rays which are emitted in opposite direction out of the body. This allows a gamma detector to locate the emission region with high accuracy and hence high-resolution location specific images can be produced for diagnostic purpose.

Marking guidelines Question 33f)

Criteria	Marks
<ul style="list-style-type: none"> Identifies both gamma scans and PET as diagnostic tools using radioactive isotopes Identifies radioactive isotopes for gamma scans and PET from list provided Fully justifies the suitability of the identified radioactive isotopes for use in diagnostic imaging techniques Shows a thorough understanding of both gamma scans and PET and their use as a diagnostic tool with the radioactive isotopes Uses clear and scientifically correct language 	6
<ul style="list-style-type: none"> Identifies both gamma scans and PET as diagnostic tools using radioactive isotopes Identifies radioactive isotopes for gamma scans and PET from list provided Provides a good justification for the suitability of the identified radioactive isotopes for use in diagnostic imaging techniques Shows a good understanding of both gamma scans and PET and their use as a diagnostic tool 	5

<ul style="list-style-type: none"> • Identifies both gamma scans and PET as diagnostic tools using radioactive isotopes • Identifies radioactive isotopes for gamma scans and PET from list provided • Provides some justification for the suitability of the identified radioactive isotopes for use in diagnostic imaging techniques • Shows a sound understanding of either gamma scans or PET and their use as a diagnostic tool 	4
<ul style="list-style-type: none"> • Identifies either gamma scans or PET as diagnostic tools using radioactive isotopes • Identifies a radioactive isotope for either gamma scans or PET from list provided • Gives reason(s) for the suitability of the identified radioactive isotope for use in diagnostic tools • Shows some understanding of either gamma scans or PET and their use as a diagnostic tool 	3
<ul style="list-style-type: none"> • Shows some understanding of diagnostic tool(s) and/or radioactive isotope(s) 	2
<ul style="list-style-type: none"> • Shows a basic understanding of diagnostic tool/radioactive isotope 	1

Example Question 2 (2012 HSC Physics exam) Question 32

Markers' Comments:

c) In better responses, candidates named and clearly described the uses of a radioactive isotope. Some candidates confused Tc-99m as being used for PET or as a positron emitter.

Sample answer:

Answers could include:

To be medically useful, radioactive isotopes must have a half-life that is long enough to allow them to accumulate in the target organ, so that an image can be produced, yet short enough so that the exposure of the person to radioactivity is minimised to reduce harm to the patient. For example Tc-99m that has a half life of 6 hours is used in bone scans.

Radioisotopes must also emit appropriate types of radiation, eg technetium-99m produces gamma radiation. Alpha and beta particles do not penetrate the body and are unsuitable for use as medical radioisotopes. But gamma rays do penetrate the outside the body and can be used for imaging.

Marking guidelines Question 32 c)

Criteria	Marks
<ul style="list-style-type: none"> Clearly describes at least two desirable properties of radioactive isotopes for medical imaging AND Provides a named example of a radioactive isotope with medical application 	3
<ul style="list-style-type: none"> States desirable properties of a radioactive isotope for medical applications OR Names example of a radioactive isotope with medical applications and states one property of the isotope 	2
<ul style="list-style-type: none"> Shows some understanding of the desirable properties of a radioactive isotope for medical applications OR Provides a named example of a radioactive isotope with medical applications 	1

Example Question 3 (2011 HSC Physics exam) Question 32

Sample answer:

Research into radioactive isotopes has identified a number of important properties, including half-life, gamma rays and functioning, that have led to the development of medical technologies such as bone scans and PET scans.

Both of those technologies produce images of body function from gamma rays detected by gamma ray cameras. Radioisotopes, which produce gamma rays, are used because gamma rays can penetrate out of the body without causing ionisation of molecules in cells. The gamma rays are emitted from radioisotopes with an appropriate half-life. The half-life must be long enough for the radioisotope to be metabolised, but not so long that body tissue may be damaged (6–8 hours is ideal).

Bone scans rely on radioisotopes, such as technetium-99m, which emit gamma rays and which allow the production of a scan of the metabolic activity of the region. Hotspots indicate a higher uptake of the isotope and are frequently associated with diseases such as bone tumours and with stress fractures.

An understanding of the production of positrons by certain isotopes (eg fluorine-18) and their matter-antimatter annihilation with electrons to produce a pair of gamma ray photons is the basis of a PET scan. PET scans using F-18 are very important in scanning the brain. FDG contains F-18 and the body treats FDG like glucose. The brain uses a lot of glucose and hence FDG can be used to show the functioning of the brain.

Increased understanding of the properties discussed above has therefore resulted in the development of important technologies that provide information about bodily processes and improve the detection of disease.

Marking guidelines Question 32 e)

Criteria	Marks
<ul style="list-style-type: none"> • Demonstrates a thorough understanding of the properties of radioactive isotopes • Describes the use of radioactive isotopes in two scanning techniques • Outlines at least two scanning techniques that use radioactive isotopes to produce an image • Correctly uses scientific principles and ideas to support the given statement • Demonstrates coherence and logical progression 	5-6
<ul style="list-style-type: none"> • Demonstrates a sound understanding of the relevant properties of radioactive isotopes <p>AND EITHER</p> <ul style="list-style-type: none"> • Identifies TWO relevant scanning techniques <p>OR</p>	3-4

<ul style="list-style-type: none">• Outlines one relevant scanning technique	
<ul style="list-style-type: none">• Demonstrates a basic understanding of radioactive isotopes• Identifies at least one relevant scanning technique	1-2

Example Question 4 (2010 HSC Physics exam) Question 34

Markers' comments:

Question 34 b) i)

In weaker responses, candidates included general comments about isotopes without addressing an advantage and disadvantage of using an isotope with a six-hour half-life.

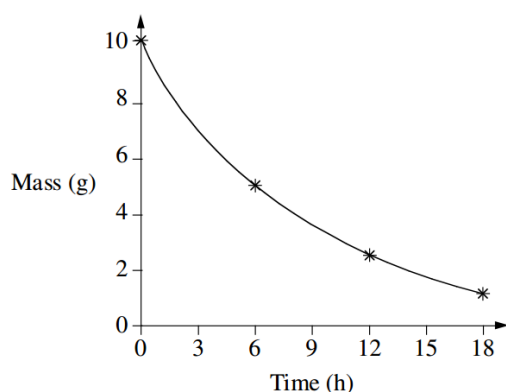
Sample answer:

Question 34 b) i)

The 6-hour half-life is an advantage because the amount of radioactive material present in the patient's body reduces quickly, presenting the patient with less risk than if the half-life were longer.

A disadvantage of the 6-hour half-life is that the isotope cannot be stored for use. It must be made within a few days at most of the procedure being carried out on the patient.

Question 34 b) ii)



Marking guidelines

Question 34 b) i)

Criteria	Marks
• States ONE advantage AND ONE disadvantage	2
• States ONE advantage OR ONE disadvantage	1

Question 34 b) ii)

Criteria	Marks
• Plots points accurately • Draws a smooth curved line showing a half-life of 6 hours	2
• Draws a smooth curved line indicative of an exponential decay, however, points are not correct	1

Example Question 5 (2010 HSC Physics exam) Question 34

Markers' Comments Question 34 e)

In better responses, candidates identified the most appropriate technique, gave a valid reason and validly discounted the other techniques – all while using their knowledge of the techniques and the images they form. They recognised that a small brain tumour will have a high metabolic activity which would allow it to show up on a PET scan.

Some candidates wrote only about PET and CAT scans, not talking about ultrasound at all. In weaker responses, candidates described the technologies but did not make a judgement about which would be the most appropriate.

Sample answer Question 34 e)

The doctor should choose PET. PET uses isotopes that emit gamma radiation from inside the body. The isotope accumulates in areas of high metabolic activity, which is a characteristic of tumours. Therefore the tumour would show up as a bright spot on a PET scan even though it is very small.

CAT uses X-rays which would be effective in penetrating the skull. However CAT scans only show structural information, not function, and have poor ability to distinguish between soft tissues. A small tumour in the brain would be very difficult to see in a CAT scan image.

Ultrasound (US) energy would not be able to image the brain because of the high difference in acoustic impedance between brain tissue and skull bone; very little US energy would pass through into or out of the brain. US images show structure only and do not have the resolution required to observe a 3 mm tumour.

Marking guidelines Question 34 e)

Criteria	Marks
<ul style="list-style-type: none"> Identifies the most appropriate technology to use Justifies their choice in terms of the nature of the technique and its ability to detect function Discounts the other techniques with valid reason(s) Demonstrates coherence and logical progression and includes correct use of scientific principles and ideas 	5-6
<ul style="list-style-type: none"> Identifies most appropriate technology and gives a valid reason Describes the techniques AND/OR their diagnostic uses Communicates some scientific principles and ideas in a clear manner 	3-4
<ul style="list-style-type: none"> Identifies most appropriate technology and gives a reason Outlines the techniques or their diagnostic uses Communicates ideas in a basic form using general scientific terms 	1-2

Example Question 6 (2009 HSC Physics exam) Question 29

(Please note that the PET scan image has been changed)

Markers' Comments Question 29 c) ii)

Better responses linked the image to the positron emitting radioisotopes and a description of the two gamma rays produced.

Sample answer Question 29 c) ii)

A tracer is a particular radioisotope, which is taken up by specific organs. This enables only those organs to be imaged. For a PET scan the tracer is labelled with a positron-emitting radioisotope. When the positron encounters an electron, pair annihilation occurs and 2 gamma rays are produced. The pairs of gamma photons travel in opposite directions and emerge from the body to be detected by gamma cameras. Their relative intensity is also measured. These measurements are then used to determine the position of the decaying radioisotope and hence where it has accumulated.

Marking guidelines Question 29 c) ii)

Criteria	Marks
<ul style="list-style-type: none"> • Relates the use of a tracer to accumulation in the target organs • Provides a description of electron-positron annihilation to produce gamma rays • Provides a description of how gamma rays are detected 	3
<ul style="list-style-type: none"> • Provides TWO of the following: <ul style="list-style-type: none"> – Outlines the role of the tracer – Provides an outline of positron emission and the production of gamma rays – Provides an outline of the detection of the gamma rays 	2
<ul style="list-style-type: none"> • Provides ONE piece of relevant information 	1