St. Clare's Girls' School

Final Examination 2021-2022 Answers

S5 Physics

SECTION A

1.	A	11.	A	21.	A	31.	D
2.	B	12.	C	22.	C	32.	B
3.	D	13.	D	23.	A	33.	C
4.	D	14.	C	24.	D		
5.	B	15.	B	25.	D		
6.	A	16.	B	26.	C		
7.	C	17.	C	27.	B		
8.	D	18.	D	28.	C		
9.	A	19.	A	29	B		
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ST. CLARE'S GIRLS' SCHOOL

FINAL EXAMINATION

2021-2022

PHYSICS

SECTION B : Question-Answer Book

Answers

Exam No.	

Level	**: S5**
Date	**: 21 July 2022**
Time	**: 8:10 a.m. - 10:40 a.m. (2 hours 30 minutes)**
Total Mark	**: 84**

INSTRUCTIONS FOR SECTION B

1. Write your Examination Number in the space provided.

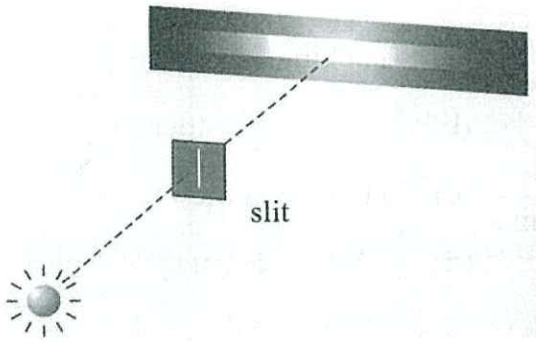
2. Answer **ALL** questions.

3. Write your answers in the spaces provided in this Question-Answer Book.

4. The diagrams in this section are NOT necessarily drawn to scale.

Answer **ALL** questions. Write your answers in the spaces provided.

1.



When a beam of monochromatic light of wavelength 650 nm passes through a narrow vertical slit, a bright fringe is formed on a screen as shown above. The fringe is about the same height as the slit, but it is much wider than the slit.

(a) Name the effect that occurs to the light horizontally. (1 mark)

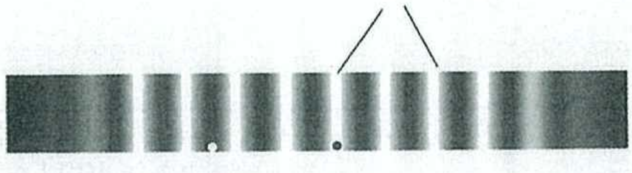
Diffraction 1A

(b) Explain why the above effect is insignificant vertically. (2 marks)

The effect of diffraction depends on the relative size of the wavelength and the slit. 1A

As the height of the slit is much larger than the wavelength, the vertical diffraction is insignificant. 1A

(c) A double-slit is now placed between the narrow slit and the screen. The slits on the double-slit are 0.2 mm apart and the double-slit is 2.5 m away from the screen. The following figure shows the new pattern on the screen.



Find the separation between P and Q. (3 marks)

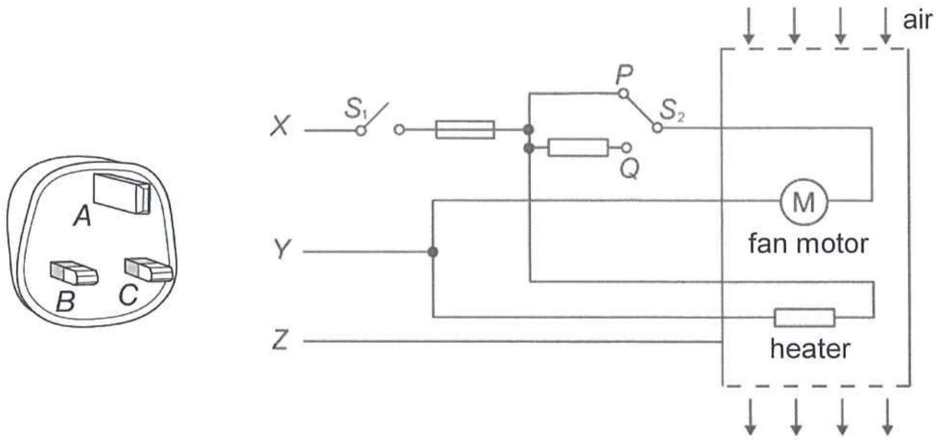
fringe separation $\Delta y = \frac{\lambda D}{a}$

$= \frac{650 \times 10^{-9} \times 2.5}{0.2 \times 10^{-3}} = 8.125 \times 10^{-3}$ m 1M

$PQ = 2.5 \Delta y = 2.5 \times 8.125 \times 10^{-3}$ 1M

$= 0.0203$ m 1A

2. The figure below shows the structure of a hand-dryer, which produces hot air for drying wet hands.



(a) Which pins (A, B and C) should wires X, Y and Z of the hand-dryer be connected to? (2 marks)

wire X = B
wire Y = C } 1A
wire Z = A 1A

(b) Explain why switch S_1 of the hand-dryer is placed in wire X. (1 mark)

No part of the hand-dryer is still 'live' when the switch S_1 is off (open) 1A

(c) The hand-dryer operates at 220 V and its heater has a resistance of 50 Ω.

(i) Calculate the current passing through the heater. (2 marks)

$V = IR$

$I = \frac{220}{50}$ 1M

$= 4.4$ A 1A

(ii) Find the power of the heater. (2 marks)

$P = \frac{V^2}{R}$

$= \frac{(220)^2}{50}$ 1M

$= 968$ W 1A

(iii) When switch S_2 is at P, the power of the fan motor is 200 W. If 1 kW h of electrical energy costs \$1.1, calculate the cost of using the hand-dryer for 5 hours. (2 marks)

Energy consumed = (0.968 + 0.2) × 5 1M

= 5.84 kWh

∴ Cost = 5.84 × 1.1

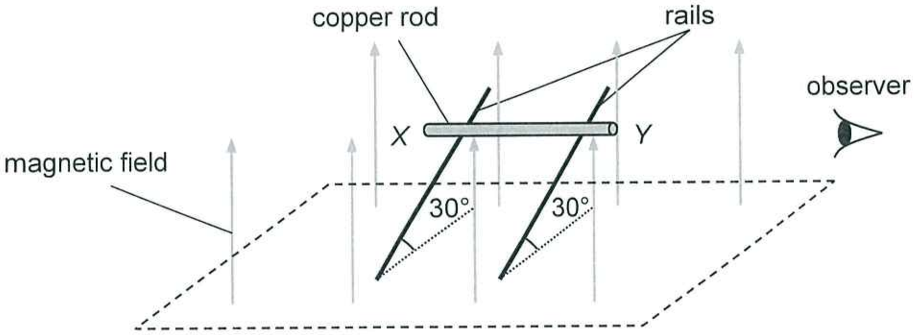
= \$ 6.424 1A

(d) Explain briefly what will happen when switch S_2 is at Q? (2 marks)

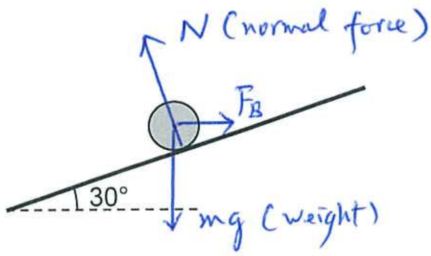
When S_2 is at Q, a resistor is connected in series with the fan motor. The voltage across the fan motor decreases and the power the fan motor decreases. 1A

As a result, the fan blows at a lower speed. 1A

3. In the following figure, a copper rod XY of mass 35g is placed on a pair of smooth parallel metal rails making an angle of 30° to the horizontal plane. The rod is perpendicular to the rails, which are 20 cm apart. An upward magnetic field of magnitude 100 mT is applied on the set-up. A current flows through the copper rod and the rails and the rod remains stationary on the rails.



(a) Draw all the forces acting on the rod as seen from the observer in the diagram below. (3 marks)



F_B = magnetic force 3A

(b) State the direction of current in the rod. (1 mark)

From Y to X. 1A

(c) Find the current in the rod. (4 marks)

$N\cos 30° = mg$ — ① 1A

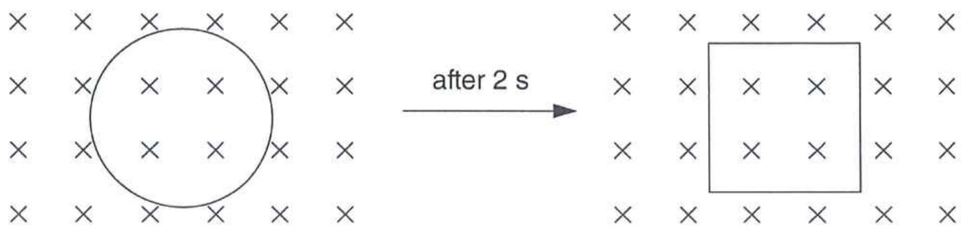
$N\sin 30° = F_B = BIl$ — ② 1A

$\frac{②}{①}$, $\tan 30° = \frac{BIl}{mg}$ 1M

$= \frac{100\times10^{-3} \times I \times 0.2}{0.035 \times 9.81}$

$\therefore I = 9.91\text{ A}$ 1A

4. A wire of length 16 cm is bent into a circular wire frame and placed in a uniform magnetic field of 0.5 T pointing into the page. Its shape is then changed into a square in 2 s.



(a) What is the direction of the induced current in the frame through this period? Explain your answer. (4 marks)

Area of the circle $= \pi r^2 = \pi\left(\frac{0.16}{2\pi}\right)^2 = 2.037\times10^{-3}\text{ m}^2$

Area of the square $= \left(\frac{0.16}{4}\right)^2 = 1.6\times10^{-3}\text{ m}^2$ } 1A

There is a decrease in the area of the frame, 1A

Therefore the magnetic flux through the frame decreases. 1A

By Lenz's Law, the induced current flows clockwisely. 1A

(b) Calculate the average induced e.m.f. in the frame in this period. (3 marks)

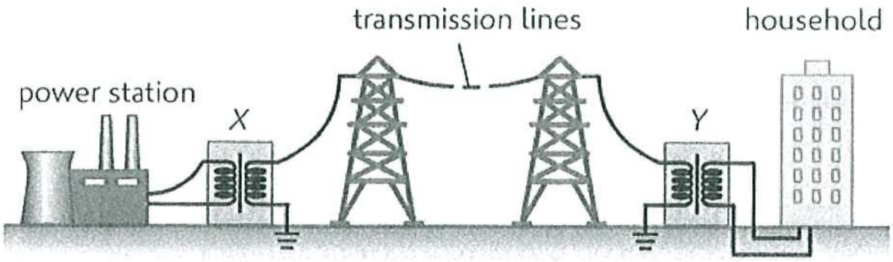
$\varepsilon = \frac{\Delta\Phi}{\Delta t}$ 1M

$= B\frac{\Delta A}{\Delta t}$

$= 0.5 \times \frac{(2.037 - 1.6)\times10^{-3}}{2}$ 1M

$= 1.09\times10^{-4}\text{ V}$ 1A

5. Below shows a simple power transmission system. The electricity generated in the power station is stepped up by transformer X before being fed to the transmission lines.



After passing through the transmission lines, the 50 kV voltage is stepped down to 220 V by transformer Y before it is delivered to the household user. The total current drawn by the house is 50 A. The efficiency of both transformers is 95%.

(a) Why does the power station output an ac voltage ? (1 mark)

AC voltage can be stepped up or down by transformer. 1A

(b) Why should the electrical power be transmitted at high voltage ? (2 marks)

Electrical power transmitted at high voltage will cause the current flowing through the transmission lines to be very small 1A

∴ Power loss at transmission lines is smaller. 1A

(c) The total resistance of the transmission lines is 150 Ω. Find the power dissipated in the transmission lines. (3 marks)

At transformer Y, $P_{out} = P_{in} \times 0.95$

$220 \times 50 = 50 \times 10^3 \times I \times 0.95$ 1M

$I = 0.232$ A (current through the lines)

∴ power dissipated in transmission lines $= I^2R = (0.232)^2(150)$ 1M

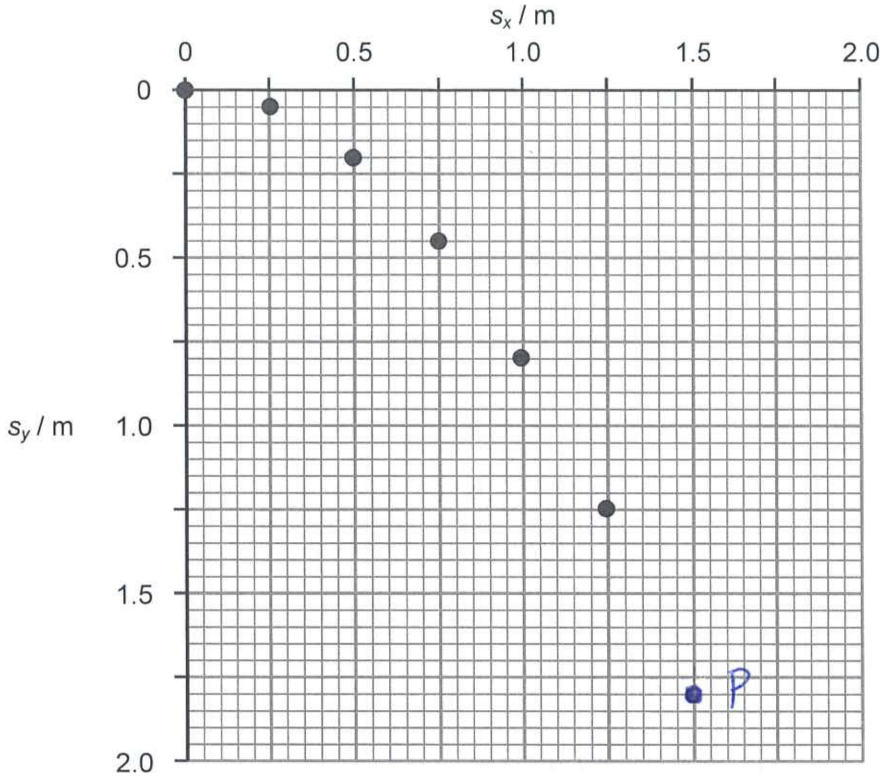
$= 8.074$ W 1A

(d) Find the power output from the power station. (2 marks)

Power output from power station $= \dfrac{\frac{50 \times 220}{0.95} + 8.074}{0.95}$ 1M

$= 12196.86$ W 1A

6. The figure below shows the displacements of a steel ball recorded at 0.1-second intervals. The ball is projected horizontally with initial speed u at a height 1.8 m above the ground. Air resistance is negligible.



1A

(a) Using the data given, calculate the gravitational acceleration. (2 marks)

At $t = 0.5$ s, $S_y = 1.25$ m

'↓' +ve $S_y = u_y t + \frac{1}{2} a_y t^2$

$1.25 = 0 + \frac{1}{2} a_y (0.5)^2$ 1M

$a_y = 10 \text{ ms}^{-2}$ 1A

(b) Find the time taken for the ball to fall to the ground. (1 mark)

$S_y = u_y t + \frac{1}{2} a_y t^2$

$1.8 = 0 + \frac{1}{2}(10) t^2$

$t = 0.6$ s 1A

(c) Calculate the range of the ball. Hence, mark the position of the ball when hitting the ground in the above figure. Label this position *P*. (3 marks)

$u_x = \frac{1.0}{0.4} = 2.5 \text{ m s}^{-1}$ 1M

Range $= u_x \cdot t$

$= (2.5)(0.6)$

$= 1.5 \text{ m}$ 1A

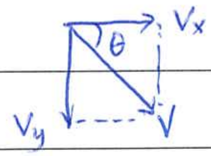
(d) Calculate the magnitude and direction of the velocity of the ball when it hits the ground. (3 marks)

$V_y = u_y + a_y t$

$= 0 + (10)(0.6) = 6 \text{ m s}^{-1}$ 1M

$V = \sqrt{V_x^2 + V_y^2} = \sqrt{(2.5)^2 + (6)^2}$

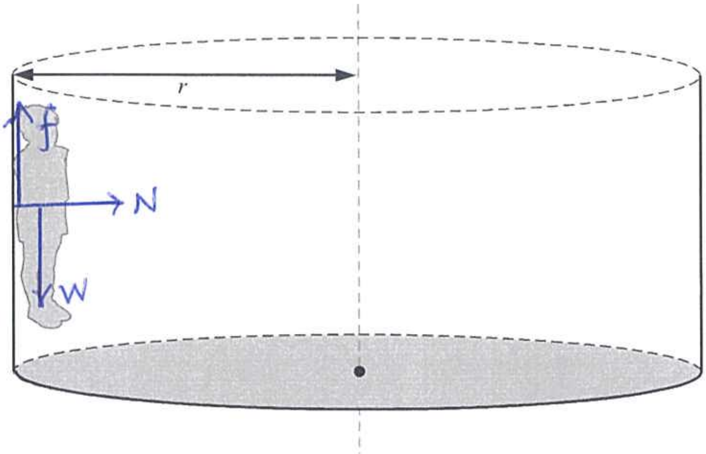
$= 6.5 \text{ m s}^{-1}$ 1A



$\tan\theta = \frac{V_y}{V_x} = \frac{6}{2.5}$

$\therefore \theta = 67.4°$ 1A

7. There is an amusement ride called the Rotor. It consists of a large barrel rotating at about 33 revolutions per minute (rpm). When the barrel attains its full speed, the riders have already been pinned against the wall. Consider the barrel below. A boy of mass 45 kg has already been pinned against the wall.



f = friction
W = weight
N = normal force

2A

(a) Sketch a free-body diagram of the boy in the above figure. (2 marks)

(b) The centripetal acceleration is about 1.5*g*, i.e. 15 m s^{-2}. Find *r*. (3 marks)

angular speed $\omega = \frac{33 \times 2\pi}{60} = 1.1\pi$ rad s^{-1} 1M

By $a = r\omega^2$

$15 = r(1.1\pi)^2$ 1M

$r = 1.256$ m 1A

(c) What is the linear speed of the boy? (1 mark)

linear speed $v = r\omega = 1.256 \times (1.1\pi)$

$= 4.34$ ms^{-1} 1A

(d) Find the resultant force acting on the boy by the wall. (3 marks)

$f = W = mg = 45 \times 10 = 450$ N 1M

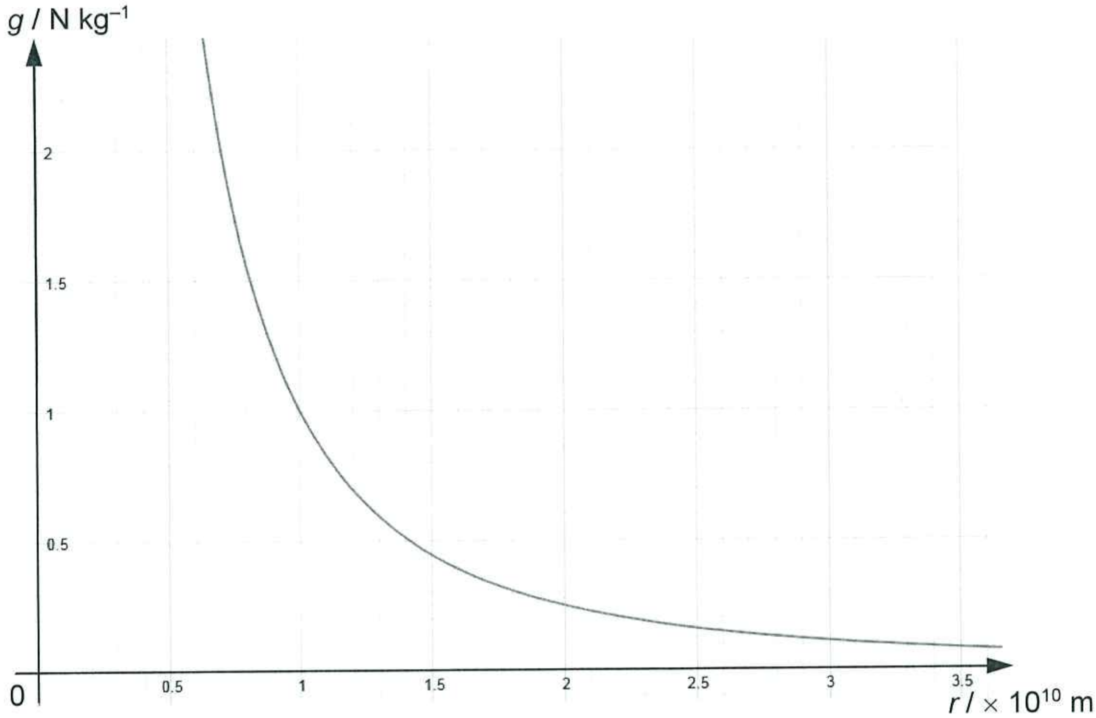
$N = mr\omega^2 = ma = 45 \times 15 = 675$ N 1M

∴ Resultant force $= \sqrt{f^2 + N^2}$

$= \sqrt{450^2 + 675^2}$

$= 811.25$ N 1A

8. The figure below shows how the gravitational field strength g of a star changes with the distance r from its centre. Take the universal gravitational constant G as 6.67×10^{-11} N m^2 kg^{-2}.



(a) Considering g at $r = 10^{10}$ m, estimate the mass of the star. (3 marks)

From the graph, $g = 1$ N kg^{-1} at $r = 10^{10}$ m

By $g = \frac{GM}{r^2}$ 1M

$1 = \frac{(6.67 \times 10^{-11}) M}{(10^{10})^2}$ 1M

$\therefore M = 1.50 \times 10^{30}$ kg 1A

(b) A planet of mass 2.4×10^{23} kg orbits the star in a circular orbit of radius 3.1×10^{10} m.

(i) Find the gravitational force acting on the planet. (2 marks)

At $r = 3.1 \times 10^{10}$ m, $g = 0.1$ N kg^{-1}

Gravitational force $= mg = (2.4 \times 10^{23})(0.1)$ 1M

$= 2.4 \times 10^{22}$ N 1A

(ii) Find the orbital period (in seconds) of the planet. (3 marks)

$a = r\omega^2$ 1M

$g = r\left(\frac{2\pi}{T}\right)^2$ 1M

$0.1 = 3.1 \times 10^{10} \times \frac{4\pi^2}{T^2}$

$\therefore T = 3.50 \times 10^{6}$ s 1A

9. A scientist investigates the properties of a new radioisotope.

(a) He measures the count rate of a sample of the radioisotope in a vacuum chamber. The results are shown as follows:

Time t / min	0	1	2	3	4	5	6
Count rate / counts per min	900	417	225	150	113	92	102
Corrected count rate / counts per min	800	317	125				

1A

The background count rate is 100 counts per minute on average.

(i) Why is the count rate at $t = 5$ min even lower than the average background count rate? (2 marks)

The count rate due to the source is nearly zero at $t = 5$ min, so the count rate recorded is due to background radiation. 1A

Also, radioactivity is random in nature, so the background count rate can be higher or lower than the average value. 1A

(ii) Write down the corrected count rates for $t = 0$ to 2 min in the table. (1 mark)

(iii) Estimate the decay constant and half-life of the radioisotope. (4 marks)

By $A = A_0 e^{-kt}$

decay constant $k = -\frac{1}{t} \times \ln\left(\frac{A}{A_0}\right)$

$= -\frac{1}{60} \times \ln\left(\frac{317}{800}\right)$ 1M

$= 0.01543\ s^{-1}$ 1A

$t_{\frac{1}{2}} = \frac{\ln 2}{k}$ 1M

$= \frac{\ln 2}{0.01543}$

$= 44.9\ s$ 1A

(b) The scientist proposes that the radioisotope only emits β radiation. Describe an experiment to verify this. (3 marks)

Place the sample close to the detector (GM tube). 1A

Insert a piece of paper between the sample and the GM tube. If there is no significant drop in the count rate, the radioisotope does not emit α - radiation. 1A

Replace the paper with 5mm - thick aluminium sheet. If the count rate drops to the background count rate, the radioisotope emits β - radiation but not γ - radiation. 1A

10. (a) In a nuclear fusion process, a $^{2}_{1}H$ nucleus and a $^{3}_{1}H$ nucleus fuse together to give a $^{4}_{2}He$ nucleus and a particle *X*.

(i) What is *X*? (1 mark)

Neutron 1A

(ii) Write down an equation to describe the above fusion process. (1 mark)

$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$ 1A

(iii) Particle *X* plays an important role in a fission reactor. Explain briefly what the role is. (2 marks)

Neutrons bombard with fuel nuclei to trigger fission. 1A

The neutrons emitted during fission bombard with other fuel nuclei to maintain a chain reaction. 1A

(b) $^{220}_{86}$Rn undergoes α decay to become $^{216}_{84}$Po.

Given: mass of α particle = 4.001 506 u

mass of $^{216}_{84}$Po = 216.001 915 u

mass of $^{220}_{86}$Rn = 220.011 394 u

1 u = 1.661×10^{-27} kg = 931 MeV and $c = 3.00 \times 10^{8}$ m s^{-1}

Find the energy released in the above decay

(i) in joules. (3 marks)

Energy released $= \Delta m c^2$

$= (220.011394 - 216.001915 - 4.001506)(1.661 \times 10^{-27})(3 \times 10^{8})^2$ 2M

$= 1.19 \times 10^{-12}$ J 1A

(ii) in MeV. (1 mark)

Energy released

$= (220.011394 - 216.001915 - 4.001506)(931)$

$= 7.423$ MeV 1A

End of paper