A LEVEL PHYSICS

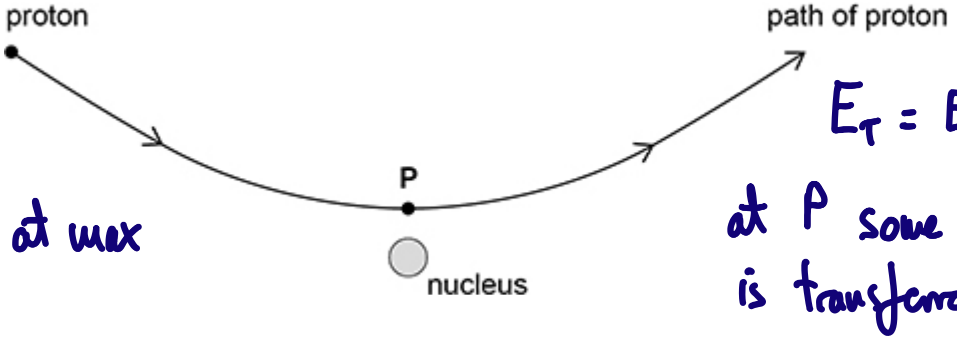
WORKED SOLUTIONS

8. Nuclear Physics MCQ

Worked Solutions by Lewis Matheson from **ALevelPhysicsOnline**.com in collaboration with **PhysicsAndMathsTutor**.com

Physics Online

1. The diagram shows the path of a proton being deflected by the nucleus of an atom.
Point **P** is the position of the proton when it is closest to the nucleus.



$\frac{\Delta p}{\Delta t}$ max

$\therefore a$ at max

$E_T = E_K + E_P$

at P some of its E_K is transferred to E_P

$\therefore E_K$ min & E_P max

What is **not** true about the proton along its path at **P**?

A Its rate of change of momentum is at a minimum. ●

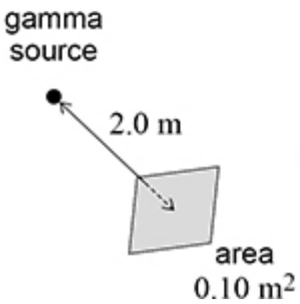
B Its kinetic energy is at a minimum. true ○

C Its potential energy is at a maximum. true ○

D Its acceleration is at a maximum. true ○

(Total 1 mark)

2. The diagram shows an area of 0.10 m^2 normal to a line connecting it to a point source of gamma radiation. The source emits photons uniformly in all directions.
The area and the source are separated by a distance of 2.0 m.



The source emits 5000 gamma photons per second.

$$A_{sphere} = 4\pi r^2$$

$$\frac{A}{A_{sphere}} \times 5000 = \frac{0.10}{4\pi \times 2.0^2} = 9.95 \text{ photons } s^{-1}$$

How many photons pass through the area every second?

A 500 ○

B 250 ○

C 10 ●

D 2.5 ○

(Total 1 mark)

3. **X** and **Y** are two radioactive nuclides. **X** has a half-life of 3.0 minutes and **Y** has a half-life of 9.0 minutes.

Two freshly prepared samples of **X** and **Y** start decaying at the same time. After 18 minutes the number of radioactive nuclei in both samples is the same. The sample of **Y** initially contained N radioactive nuclei.

What was the initial number of radioactive nuclei in the sample of **X**?

A $4N$ ○

B $16N$ ●

C $32N$ ○

D $64N$ ○

$X: 6\ t_{1/2}$ $Y: 2\ t_{1/2}$

$$\frac{N_x}{2^6} = \frac{N_Y}{2^2}$$

$$4N_x = 64N_Y$$

$$N_x = 16N_Y$$

$$N_Y = \frac{N_x}{16}$$

(Total 1 mark)

4. What is the main purpose of a moderator in a thermal nuclear reactor?

A to shield the surroundings from ionising radiations ○

B to decrease the number of fission chain reactions ○

C to decrease neutron speeds ●

D to prevent the core from overheating ○

(Total 1 mark)

Moderators slow down neutrons, increasing the likelihood of a fission reaction.

5. In the core of a nuclear reactor, the mass of fuel decreases at a rate of 9.0×10^{-6} kg hour^{-1} due to nuclear reactions.

What is the maximum power output of the reactor?

$E = mc^2$ $P = \frac{E}{t}$

$P = \frac{mc^2}{t}$

$P = \frac{9.0 \times 10^{-6} \times (3.0 \times 10^8)^2}{3600} = 2.25 \times 10^8$

A 2.3×10^8 W ●

B 1.4×10^{11} W ○

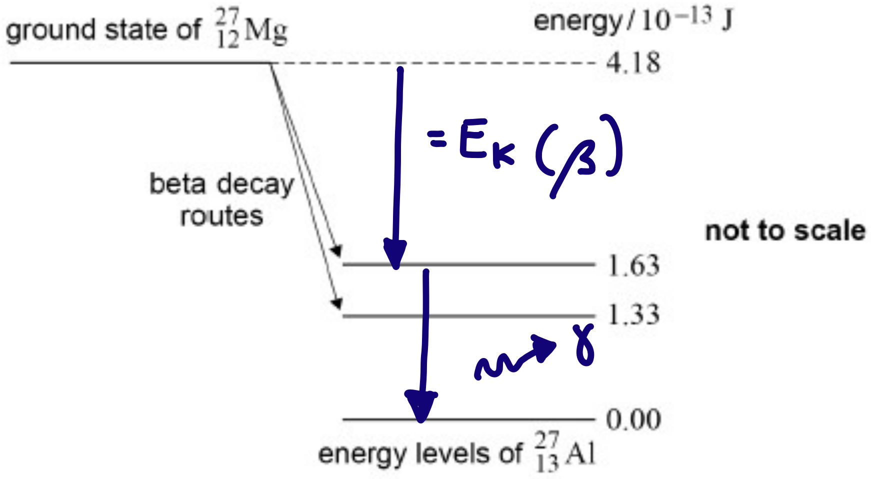
C 8.1×10^{11} W ○

D 2.9×10^{15} W ○

(Total 1 mark)

6. $^{27}_{12}\mathrm{Mg}$ can decay by beta minus emission to one of two possible excited states of $^{27}_{13}\mathrm{Al}$.

Both excited states decay by the emission of a gamma photon directly to the ground state.



The diagram shows the energy levels and two routes for the beta decay.

One route results in the emission of a gamma photon with a higher frequency than the other photon.

What is the maximum possible kinetic energy for the beta particle emitted in this route?

$E = hf$ ∴ Higher frequency

= higher energy

$= 1.63 \times 10^{-13}$ J

$4.18 - 1.63 = 2.55$

A 1.33×10^{-13} J ○

B 1.63×10^{-13} J ○

C 2.55×10^{-13} J ●

D 2.85×10^{-13} J ○

(Total 1 mark)

7. A point source emits gamma radiation. The intensity I of the radiation is measured at different distances d from the source.

Which graph will show a straight line through the origin?

A I plotted against d ○

B I plotted against d^2 ○

C I plotted against d^{-1} ○

D I plotted against d^{-2} ●

$$I = \frac{k}{d^2} = kd^{-2}$$

k = constant

$$I \propto d^{-2}$$

(Total 1 mark)

8. The mass of the fuel in a fission reactor decreases at a rate of 6.0×10^{-6} kg hour^{-1}.

What is the maximum possible power output of the reactor?

A 75 MW ○

B 150 MW ●

C 300 MW ○

D 9000 MW ○

$E = mc^2$ $\quad P = \frac{E}{t}$

$$P = \frac{mc^2}{t}$$

$$P = \frac{6.0\times10^{-6} \times (3.0\times10^{8})^2}{3600} = 1.5\times10^{8}$$

$$= 150\times10^{6}$$

(Total 1 mark)

9. The table shows the masses of three particles.

Particle	**Mass / u**
proton	m_p 1.00728
neutron	m_n 1.00867
nucleus of lithium $^{7}_{3}\mathrm{Li}$	m_{Li} 7.01436

$^{7}_{3}Li$

$3 \times p$

$4 \times n$

What is the mass difference of a $^{7}_{3}\mathrm{Li}$ nucleus?

A 4.99841 u ○

B 0.04216 u ●

C 0.04147 u ○

D 0.04077 u ○

$m_{Li} - 3m_p - 4m_n$

$7.01436 - (3 \times 1.00728) - (4 \times 1.00867)$

$= 0.04216$

(Total 1 mark)

10. When a small radioactive source is placed in a cloud chamber, straight tracks about 4 cm long are observed. The same source is placed 10 cm from a Geiger tube and a count rate is detected. When a sheet of aluminium 5 mm thick is placed between the source and the Geiger tube the count rate falls to the background count rate.

Which types of radiation are emitted by the source?

A α, β and ~~γ~~ ○

B β and ~~γ~~ ○

C α and ~~γ~~ ○

D α and β ●

(Total 1 mark)

Straight tracks in cloud chamber ∴ must be α

Detected 10 cm ∴ could be β or γ

Stopped by thin Aluminium ∴ must be β

11. The number of parent nuclei in a sample of a radioactive element is N at time t. The radioactive element has a half-life $t_{\frac{1}{2}}$

The rate of decay is proportional to

A N ●

B t ○

C $\frac{1}{t}$ ○

D $t_{\frac{1}{2}}$ ○

$A = \lambda N$

$A \propto N$

(Total 1 mark)

12. A deuterium nucleus and a tritium nucleus fuse together to form a helium nucleus and a particle **X**. The equation for this process is:

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + \mathrm{X}$$

What is **X**?

A electron ○

B neutron ●

C positron ○

D proton ○

mass no. $2 + 3 = 4 + 1$

proton no. $1 + 1 = 2 + 0$

$^{1}_{0}n$

(Total 1 mark)

13. What effect are the control rods intended to have on the average kinetic energy and number of fission neutrons in a thermal nuclear reactor?

	Average kinetic energy of fission neutrons	Number of fission neutrons	
A	unchanged	~~unchanged~~	○
B	~~reduced~~	~~unchanged~~	○
C	unchanged	reduced	●
D	~~increased~~	reduced	○

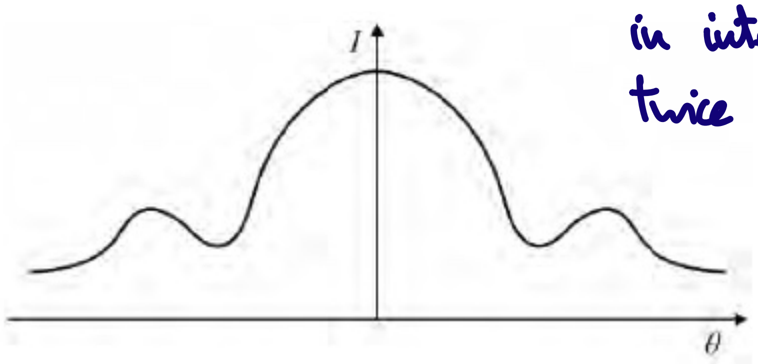
Control rods absorb neutrons - but don't slow them down

(Total 1 mark)

14. Which graph shows how intensity I varies with angle θ when electrons are diffracted by a nucleus?

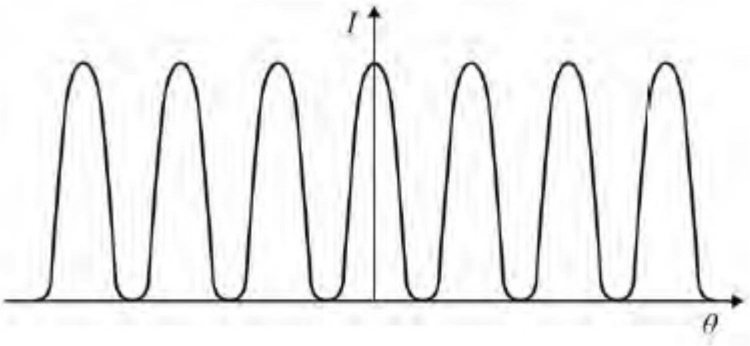
Each maxima decreases in intensity. Central maxima twice as wide.

A



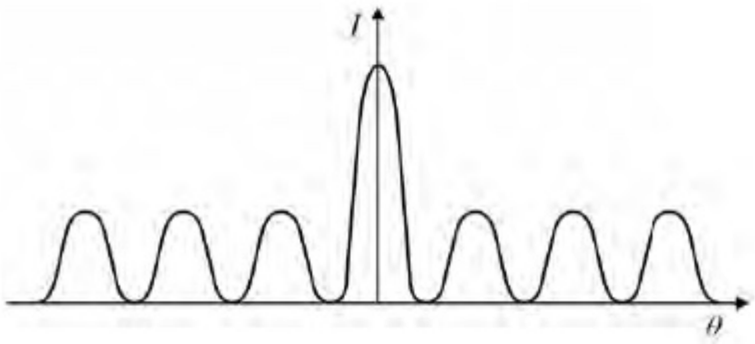
●

B



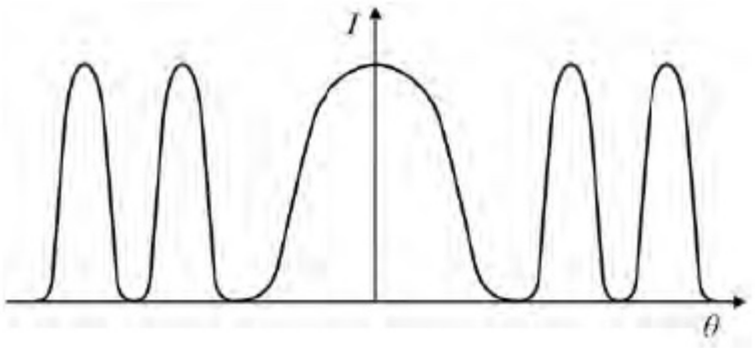
○

C



○

D



○

(Total 1 mark)

15. The radius of a uranium $^{238}_{92}\text{U}$ nucleus is 7.75 × 10^{-15} m

What is the radius of a $^{12}_{6}\text{C}$ nucleus?

A 1.10×10^{-18} m ○

B 3.91×10^{-16} m ○

C 2.86×10^{-15} m ●

D 3.12×10^{-15} m ○

$r \propto A^{1/3}$

$$\frac{r_c}{r_u} = \sqrt[3]{\frac{A_c}{A_u}}$$

(Total 1 mark)

$$r_c = r_u \sqrt[3]{\frac{A_c}{A_u}} = 7.75 \times 10^{-15} \times \sqrt[3]{\frac{12}{238}}$$

$$= 2.86 \times 10^{-15} \text{ m}$$

16. During a single fission event of uranium-235 in a nuclear reactor the total mass lost is 0.23 u. The reactor is 25% efficient.

How many events per second are required to generate 900 MW of power?

A 1.1×10^{14} ○

B 6.6×10^{18} ○

C 1.1×10^{20} ●

D 4.4×10^{20} ○

$$E = mc^2$$
$$= 0.23 \times 1.661 \times 10^{-27} \times 9.0 \times 10^{6}$$
$$= 3.437 \times 10^{-11}\ J$$

$$\frac{900 \times 10^6}{3.437 \times 10^{-11} \times 0.25} = 1.05 \times 10^{20}$$

(Total 1 mark)

17. Which of the following substances can be used as a moderator in a nuclear reactor?

A Boron ○

B Concrete ○

C Uranium-238 ○

D Water ●

Light elements that do not absorb neutrons are used as moderators.

(Total 1 mark)

18. The Rutherford scattering experiment led to

A the discovery of the electron. ○

B the quark model of hadrons. ○

C the discovery of the nucleus. ●

D evidence for wave-particle duality. ○

(Total 1 mark)

The electron had already been discovered. This experiment showed there was a dense positive region, the nucleus.

19. A Geiger counter is placed near a radioactive source and different materials are placed between the source and the Geiger counter.

The results of the tests are shown in the table.

Material	**Count rate of Geiger counter / s^{-1}**
None	1000
Paper	1000
Aluminium foil	250
Thick steel	50

What is the radiation emitted by the source?

A ~~α~~ only ○

B ~~α~~ and γ ○

C ~~α~~ and β ○

D β and γ ●

All passes through paper

$\therefore$ not α

Reduced by aluminium

$\therefore \beta$

Gets through steel

$\therefore \gamma$

(Total 1 mark)

20. Nobelium-259 has a half-life of 3500 s.

What is the decay constant of nobelium-259?

A $8.7 \times 10^{-5}\ s^{-1}$ ○

B $2.0 \times 10^{-4}\ s^{-1}$ ●

C $1.7 \times 10^{-2}\ s^{-1}$ ○

D $1.2 \times 10^{-2}\ s^{-1}$ ○

$$t_{1/2} = \frac{\ln 2}{\lambda}$$

$$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{3500} = 1.98 \times 10^{-4}\ s^{-1}$$

(Total 1 mark)

21. A pure sample of nuclide **X** containing N nuclei has an activity A. The half-life of **X** is 6000 years.

A pure sample of nuclide **Y** containing $3N$ nuclei has an activity $6A$.

What is the half-life of nuclide **Y**?

A 1000 years ○

B 3000 years ●

C 12 000 years ○

D 18 000 years ○

$$A = \lambda N \qquad \lambda = \frac{\ln 2}{t_{1/2}}$$

$$A \propto \frac{N}{t_{1/2}}$$

$$\frac{A_X}{A_Y} = \frac{t_{1/2\,Y}}{t_{1/2\,X}} \cdot \frac{N_X}{N_Y}$$

$$t_{1/2}Y = t_{1/2}X \cdot \frac{A_X}{A_Y} \cdot \frac{N_Y}{N_X}$$

$$= 6000 \times \frac{1}{6} \times 3 = 3000$$

(Total 1 mark)

22. Cobalt-60 has a half-life of 5.27 years.

What is the total activity of 1.0 g of cobalt-60?

A 4.2×10^{13} Bq ●

B 2.2×10^{14} Bq ○

C 2.5×10^{15} Bq ○

D 1.3×10^{21} Bq ○

$$A = \lambda N = \frac{\ln 2}{t_{1/2}} N$$

$$N = \text{no. moles} \times N_A$$

$$\text{no. moles} = \frac{\text{mass}}{\text{molar mass}}$$

$$A = \frac{\ln 2 \times \frac{1}{60} \times 6.02\times10^{23}}{5.27 \times 365 \times 24 \times 3600} = 4.18\times10^{13}$$

(Total 1 mark)

23. The radius of a nucleus of the iron nuclide ${}^{56}_{27}\text{Fe}$ is 4.35×10^{-15} m.

What is the radius of a nucleus of the uranium nuclide ${}^{238}_{92}\text{U}$?

A 2.69×10^{-15} m ○

B 2.89×10^{-15} m ○

C 6.55×10^{-15} m ○

D 7.05×10^{-15} m ●

$$r \propto A^{1/3}$$

$$\frac{r_u}{r_{Fe}} = \sqrt[3]{\frac{A_u}{A_{Fe}}}$$

$$r_u = r_{Fe}\sqrt[3]{\frac{A_u}{A_{Fe}}} = 4.35\times10^{-15} \times \sqrt[3]{\frac{238}{56}} = 7.05\times10^{-15}\ \text{m}$$

(Total 1 mark)

24. Uranium-236 undergoes nuclear fission to produce barium-144, krypton-89 and three free neutrons.

What is the energy released in this process?

U-236 → Ba-144 + Kr-89 + 3n

$(236 \times 7.5) - (144 \times 8.3) - (89 \times 8.6)$

$= -190.6$ MeV

Nuclide	Binding energy per nucleon / MeV
$^{236}_{92}U$	7.5
$^{144}_{56}Ba$	8.3
$^{89}_{36}Kr$	8.6

A 84 MeV ○

B 106 MeV ○

C 191 MeV ●

D 3730 MeV ○

(Total 1 mark)