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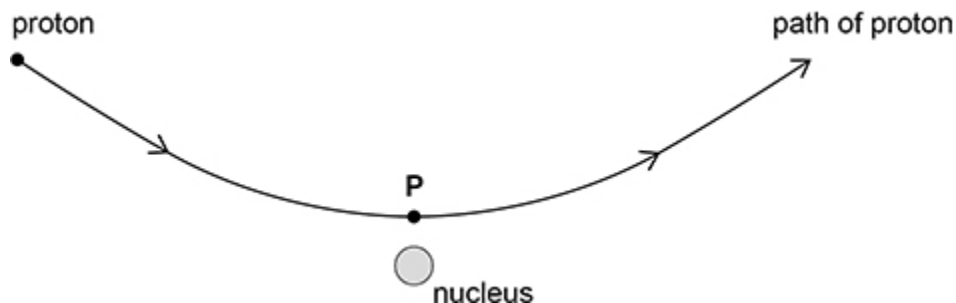* The diagram shows the path of a proton being deflected by the nucleus of an atom. Point **P is the position of the proton when it is closest to the nucleus.

proton   path of proton

P

nucleus

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.

C   Its potential energy is at a maximum.

D   Its acceleration is at a maximum.

(Total 1 mark)

2. The diagram shows an area of 0.10 m² 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.

gamma
source

2.0 m
                                    not to scale
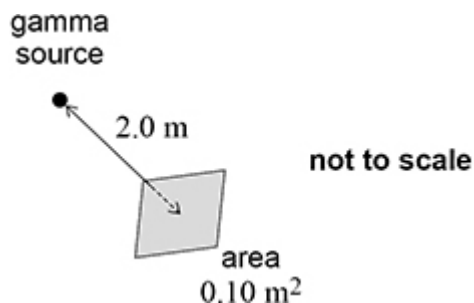
area
0.10 m²

The source emits 5000 gamma photons per second.

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 $64N$

(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)

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.
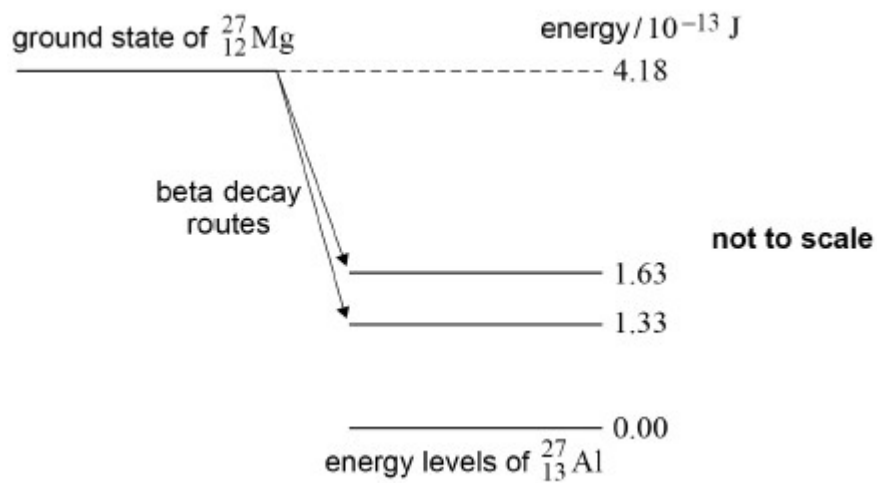
What is the maximum power output of the reactor?

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?

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} ⬭

(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   ⬭

(Total 1 mark)

9. The table shows the masses of three particles.

Particle	Mass / u
proton	1.00728
neutron	1.00867
nucleus of lithium $^{7}_{3}\text{Li}$	7.01436

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

A   4.99841 u

B   0.04216 u

C   0.04147 u

D   0.04077 u

(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)

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 $t_{\frac{1}{2}}$
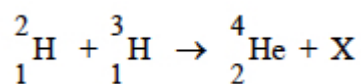
The rate of decay is proportional to

A $\quad N$ ☐

B $\quad t$ ☐

C $\quad \dfrac{1}{t}$ ☐

D $\quad t_{\frac{1}{2}}$ ☐

(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 ☐

(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	○

(Total 1 mark)

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

A

○

B

○

C ⬭

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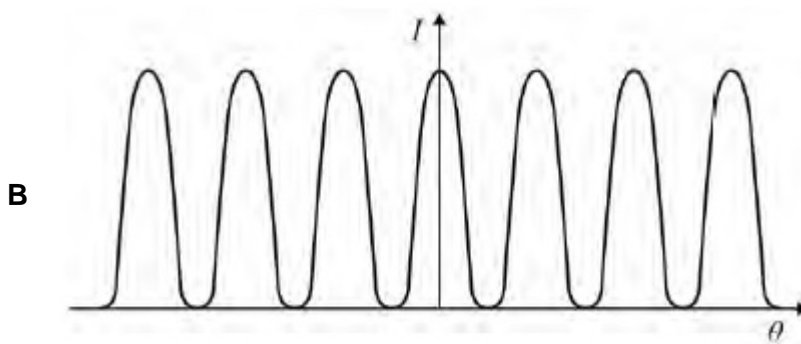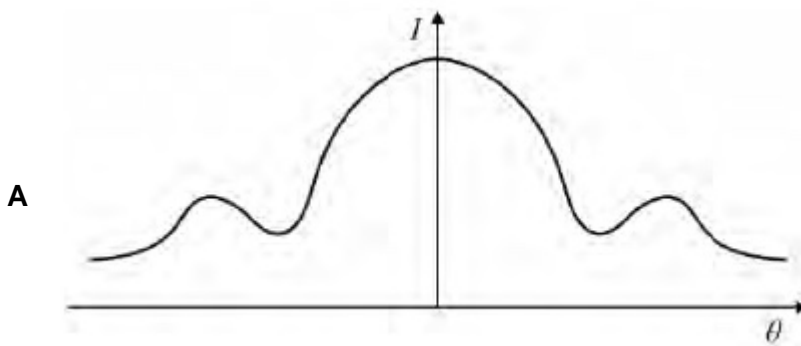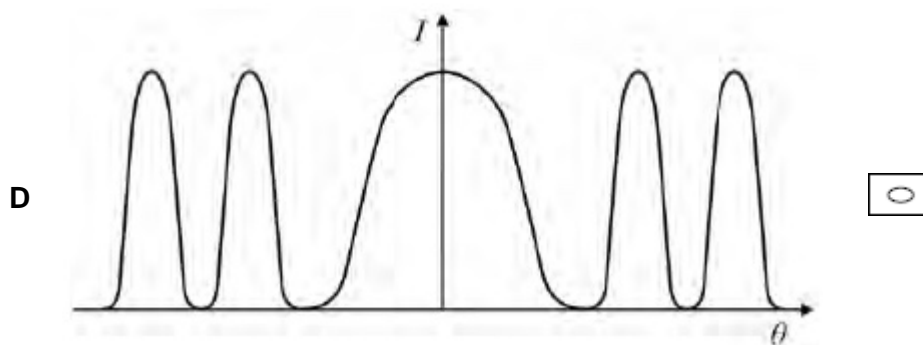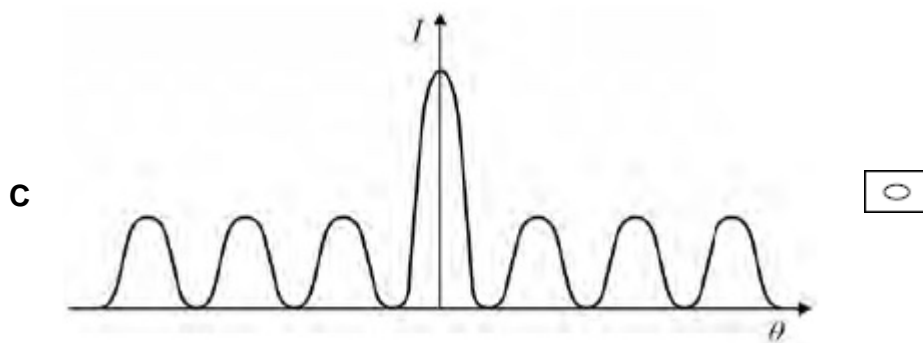
15. The radius of a uranium $^{238}_{92}\text{U}$ nucleus is 7.75×10^{-15} m

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   ⬭

(Total 1 mark)

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}

(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

(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)

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

(Total 1 mark)

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

What is the decay constant of nobelium-259?

A 8.7×10^{-5} s^{-1}

B 2.0×10^{-4} s^{-1}

C 1.7×10^{-2} s^{-1}

D 1.2×10^{-2} 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

(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

(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

(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?

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)