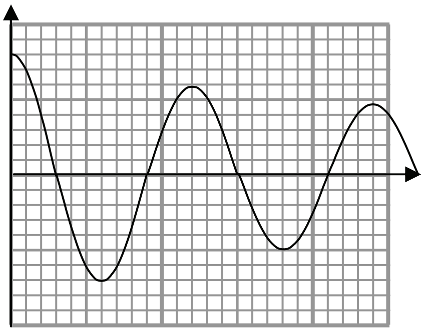
PH4

Question			Marking details	Marks Available
1	*(a)*		$v = \pi \times 0.65 \times 9.3\ \text{s}^{-1}$ [or equiv.]	1
	(b)		$a = r\omega^2$ **or** $a = \frac{v^2}{r}$ (1) $a = 1.1 \times 10^{-3}\ \text{m s}^{-1}$ **or** $n = \frac{r\omega^2}{g}$ **or** $n = \frac{v^2}{r}$ or by impl (1) $n = 1.1 \times 10^2$ [where n = no. of times a is larger than g] (1) (e.c.f. on a)	3
	(c)	(i)	KE $= ½ \times 1.8 \times 19^2$ J $= 325$ J (1)	2
		(ii)	Mass <u>not</u> concentrated on outside edge, so most of the mass is <u>moving more slowly</u>.	1
	(d)		$[\Delta U] = mc\Delta\theta$ [or by impl.] (1) $\Delta\theta = \frac{325\ \text{J (e.c.f.)}}{390\ \text{J kg}^{-1}\text{K}^{-1} \times 0.60\text{kg}}$ [or by impl.] (1) $= 1.4$ K (1)	3
				[10]

Question			Marking details	Marks Available
3	*(a)*	(i)	$pV = nRT$ (1) [or by impl.] $n = 0.020$ mol (1)	2
		(ii)	$T_B = 740$ [± 150] K	1
	(b)		$\Delta T = 435$ K (e.c.f.) **or** $\Delta U = 0.020 \times 20.7 \times (735–300)$ (e.c.f) (1) [or equiv.] $\Delta U = 180$ J (e.c.f. on T_B and n) (1)	2
	(c)		Find 'area' under graph [between A and B] (1) by counting the squares / approximating the curve to straight lines [and using areas of Δs and □s] [or equiv.] (1)	2
	(d)		$Q = \Delta U + W$ [or by impl.] (1) = 180 J – 220 J (e.c.f. on 180 J) (1) ∴ [40 J of] heat flows out of the gas (e.c.f.) (1)	3 **[10]**
4.	*(a)*	(i)	I. [density =] $\frac{Nm}{V}$ II. [mean translational KE =] $\frac{1}{2}m\overline{c^2}$	1 1
		(ii)	$U_{\text{trans}} = N \times \frac{1}{2}m\overline{c^2}$ [or equiv.] (1) Convincing algebra using $pV = \frac{1}{3}Nm\overline{c^2}$ to reach $U_{\text{trans}} = \frac{3}{2}pV$ (1)	2
	(b)	(i)	$p = \frac{1}{3}\rho\overline{c^2}$ (1) [no mark for $pV = \frac{1}{3}Nm\overline{c^2}$ unless N and m are handled correctly] $\overline{c^2} = 2.5 \times 10^5\ \text{m}^2\ \text{s}^{-2}$ [or by impl.] (1) $\sqrt{\overline{c^2}} = 500\ \text{m s}^{-1}$ (1)	3
		(ii)	$U_{\text{trans}}[= \frac{3}{2}pV] = 4.5$ MJ (1) $U_{\text{lorry}} = \frac{1}{2}mv^2$ (1) = 4.0 MJ (1)	3 **[10]**

Question			Marking details	Marks Available
7.	*(a)*	(i)	0.08 m	1
		(ii)	1.2 s	1
		(iii)	$T = 2\pi\sqrt{\frac{m}{k}}$ (1) $m = \frac{kT^2}{4\pi^2}$ (1) [transposition at any stage] m = 1.46 kg (1) [or figures correctly inserted into $m = \frac{kT^2}{4\pi^2}$]	3
	(b)	(i)	5.24 (1) rad s^{-1} (1)	2
		(ii)	$x = 0.08\sin\frac{7}{6}\pi$ **or** $0.08\sin 3.67$ **or** 0.08 sin 210° (1) [or equiv. or by impl.] $x = -0.04$ m (1) [$x = 5.1 \times 10^{-3} \rightarrow 1$ (°/rad slip)]	2
		(iii)	Spot on! (e.c.f.) [N.B.'No' (e.c.f.) needs evidence either here or annotation on graph]	1
	(c)		$v_{max} = A\omega$ (1) = 0.42 m s^{-1} (1) [accept: tangent drawn (1); v_{max} = 0.42 [± 0.04] m s^{-1} (1)]	2
	(d)	(i)	kinetic (1) kinetic energy is zero at the extremes of displacement [**or** any other valid reason] (1)	2
		(ii)	$E_0 = \frac{1}{2}kA^2$ **or** $E_0 = \frac{1}{2}mv_{max}^2$ **or** $E_0 = \frac{1}{2}mA^2\omega^2$ (1) E_0 = 0.13 J (1) – e.c.f. on v, A, ω.	2
		(iii)	• E can't be created or destroyed but transferred…. ✓ • PE + KE constant in the system ✓ • Energy transferred between PE and KE in this sytem ✓ } any 2 × (1)	2
	(e)		 damped cosine (1) period doesn't change with t (1) period = 1.2 s [or slightly larger] (1)	2 **[20]**

PH5

Question			Marking details	Marks Available
1	*(a)*		Lungs or throat or mouth (1)[>2 wrong organs →0] α-particles low penetration / high ionisation (1) can be breathed in / through mouth and nose(1) [Not α not strong enough to escape]	3
	(b)	(i)	6.6×10^5 s	2
		(ii)	$A = A_0e^{-\lambda t}$ (1) [accept $N = N_0e^{-\lambda t}$] or $A = A_0 2^{-n}$ $\lambda = \frac{\ln 2}{T_{1/2}}$ (1) [correct logs or n = 1.61] $t = \frac{1}{2}\ln\left(\frac{A}{A_0}\right)$ = 5.3×10^5 s (1)	3
	(c)	(i)	$I/I_0 = e^{-10\times 0.003}$ [= 0.97]	1
		(ii)	γ (1); α or β would not penetrate 3 mm [or equiv.] (1) [or only γ would pass, **not** because γ would pass]	2 **[10]**

Question			Marking details	Marks Available
5	*(a)*	(i)	$F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$ (1) $= \frac{2e^2}{4\pi\varepsilon_0(26\times10^{-12})^2}$ $= 6.8 \times 10^{-7}$ N (1)	2
		(ii)	$F = \frac{GMm}{r^2}$ (1) $= 6.0 \times 10^{-46}$ N (1)	2
		(iii)	Gravitational is far less than the electrostatic force (1) [no e.c.f]	1
	(b)		P.E. = [–] $\frac{Q_1Q_2}{4\pi\varepsilon_0 r}$ (1) = [–]1.8×10^{-17} J (1)	2
	(c)		$\frac{mv^2}{r} = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$ (1) **or** $mr\omega^2 = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$ $\therefore \ \frac{1}{2}mv^2 = \frac{1}{2}\frac{Q_1Q_2}{4\pi\varepsilon_0 r}$ (1) [algebra / manip] **or** $v^2 = 1.9 \times 10^{13}$ m^2 s^{-2} $= 0.9 \times 10^{-17}$ J (1) [“correct” calculation using gravity → 7.8×10^{-57} J → 1 mark]	3 **[10]**

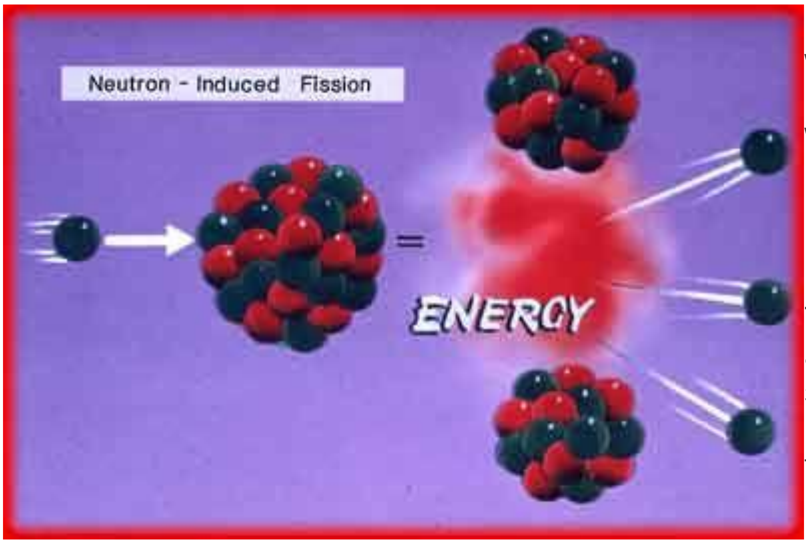
Question			Marking details	Marks Available
6.	*(a)*	(i)	$A = 4$ **and** $Z = 2$	1
		(ii)	α or Helium nucleus	1
	(b)	(i)	Attempt at finding mass difference (1) $\Delta m = \pm 0.0001$ u (1) [i.e. no sign penalty] × 931 (1) [accept use of $E = mc^2$] Energy release = -0.093 MeV [1.5×10^{-14} J] (1) [NB – sign required]	4
		(ii)	Δm only accurate to 1 sf [accept: any reference to combining uncertainties (each being around 0.0001 u etc.]	1
	(c)	(i)	PE $= \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$ (1) $= \frac{6e \times 6e}{4\pi \times 8.9 \times 10^{-12} \times 10 \times 10^{-15}}$ (1) [= 8.2×10^{-13} J]	2
		(ii)	[8×10^{-13} J or 8.2×10^{-13} J] ÷ e (1)→ 5 MeV or 5.2 MeV (1)	2
	(d)		$\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ (1) [**or** $p = \frac{1}{3}\rho\overline{c^2}$ and $pV = nRT$; **or** $\frac{1}{2}M\overline{c^2} = \frac{3}{2}nRT$] Re-arrange, i.e. $T = \frac{2}{3}\frac{\text{KE}}{k}$ (1) $T = 3.9 \times 10^8$ K (or °C) (1) ((**unit**))	3
	(e)	(i)	$\frac{1}{2}mv^2$ (1) $= \frac{GMm}{r}$ (1) [**or** KE = PE (1 mark)] $v^2 = \frac{2GM}{r}$ (1) $v = 2.2 \times 10^5$ m s^{-1} (1) $v^2 = \frac{GM}{r}$; $v = 1.5 \times 10^5$ m s^{-1} → 1 mark	4
		(ii)	Some carbon escapes (1) [or clear impl, e.g “most C not escape”] Source of carbon for planets / rest of Universe etc. (1)	2
				[20]

SECTION B

Inside the sun, fusion reactions take place at very high temperatures and enormous gravitational pressures

The foundation of nuclear energy is harnessing the power of atoms. Both fission and fusion are nuclear processes by which atoms are altered to create energy, but what is the difference between the two? Simply put, fission is the division of one atom into two, and fusion is the combination of two lighter atoms into a larger one. They are opposing processes, and therefore very different.

The word fission means "a splitting or breaking up into parts" (Merriam-Webster Online, www.m-w.com). Nuclear fission releases heat energy by splitting atoms. The surprising discovery that it was possible to make a nucleus divide was based on Albert Einstein's prediction that mass could be changed into energy. In 1939, scientist began experiments, and one year later Enrico Fermi built the first nuclear reactor.

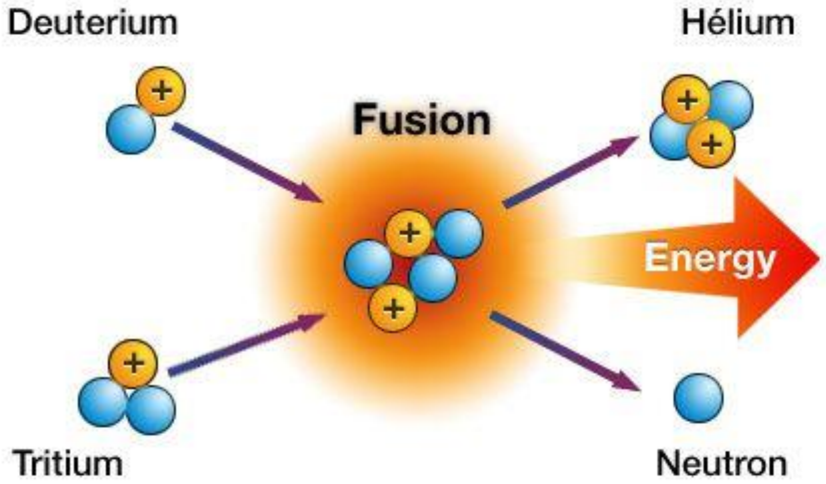


Nuclear fission takes place when a large, somewhat unstable isotope (atoms with the same number of protons but different number of neutrons) is bombarded by high-speed particles, usually neutrons. These neutrons are accelerated and then slammed into the unstable isotope, causing it to fission, or break into smaller particles. During the process, a neutron is accelerated and strikes the target nucleus, which in the majority of nuclear power reactors today is Uranium-235. This splits the target nucleus and breaks it down into two smaller isotopes (the fission products which are Barium-139 with a binding energy per nucleon of 8.5MeV and Kryton-94 with a binding energy per nucleon of 8.7MeV), three high-speed neutrons, and a large amount of energy.

This resulting energy is then used to heat water in nuclear reactors and ultimately produces electricity. The high-speed neutrons that are ejected become projectiles that initiate other fission reactions, or chain reactions.

The word fusion means "a merging of separate elements into a unified whole". Nuclear fusion refers to the "union of atomic nuclei to form heavier nuclei resulting in the release of enormous amounts of energy". Fusion takes place when two low-mass isotopes, typically isotopes of hydrogen, unite under conditions of extreme pressure and temperature.

Fusion is what powers the sun. Atoms of Tritium and Deuterium (isotopes of hydrogen, Hydrogen-3 (binding energy 2.8MeV per nucleon) and Hydrogen-2 (binding energy 1.1MeV per nucleon), respectively) unite under extreme pressure and temperature to produce a neutron and a helium isotope (He-4 with a binding energy per nucleon of 7MeV). Along with this, an enormous amount of energy is released, which is several times the amount produced from fission.



Scientists continue to work on controlling nuclear fusion in an effort to make a fusion reactor to produce electricity. Some scientists believe there are opportunities with such a power source since fusion creates less radioactive material than fission and has a nearly unlimited fuel supply. However, progress is slow due to challenges with understanding how to control the reaction in a contained space.

Both fission and fusion are nuclear reactions that produce energy, but the applications are not the same. Fission is the splitting of a heavy, unstable nucleus into two lighter nuclei, and fusion is the process where two light nuclei combine together releasing vast amounts of energy. Fission is used in nuclear power reactors since it can be controlled, while fusion is not utilized to produce power since the reaction is not easily controlled and is expensive to create the needed conditions for a fusion reaction. Research continues into ways to better harness the power of fusion, but research is in experimental stages. While different, the two processes have an important role in the past, present and future of energy creation.

Question – use your knowledge of the binding energy vs nucleon number to compare the difference in the energy given off, **per reaction** (fusion vs fission). Perform some calculations to find the energy released when hydrogen isotopes fuse to form helium, then do the same for the fission of uranium. Explain your workings and do not rely entirely on calculations for your answer. [10 MARKS]

Answer: Using stats from the article, H2 + H3 → He4

H2 has BE per nucleon 1.1MeV. H3 (2.8MeV) and He4 (7MeV)

1.1x2+2.8x3 → 7x4   leads to a BE change of 17.4MeV or 17.4/5 = 3.48MeV per nucleon (because there were 5 nucleons before the reaction took place) (3)

Fission:

U(7.7MeV), Ba(8.5MeV) and Kr(8.7MeV)

7.7x235 → 8.5x139 + 8.7x94   gives a BE change of 189.9MeV

Or 189.8/235 = 1.41MeV per nucleon (because there were 135 nucleons before the reaction) (3)

Fusion to fission 3.48:1.41

Fusion releases 2.47 times as much energy as fission. (1)

Draw the BE curve (with axes labelled and units) to show the difference reflected in the slope of the curve before and after Iron. (4)