Higher Particles

Past Paper Answers

Contents

Higher Particles Answers

Nuclear Reactions

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20ai)	$x = 222$ $y = 86$	(1) (1)
20aii)	Lost mass is converted into energy.	(1)
20aiii)	total mass before = 3.75428×10^{-25} (kg) total mass after = 3.75419×10^{-25} (kg) lost mass = 9×10^{-30} (kg) $E = mc^2$ $E = 9 \times 10^{-30} \times (3 \times 10^8)^2$ $E = 8.1 \times 10^{-13}$ J *An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only round your final answers! Not your working!*	(1) (1) (1) (1)
20b)	$E_k = ½mv^2$ $E_k = ½ \times 6.64832 \times 10^{-27} \times (1.5 \times 10^7)^2$ $E_k = 7.47936 \times 10^{-13}$ J $E_w = QV$ $E_w = 3.2 \times 10^{-19} \times 25 \times 10^3$ $E_w = 8 \times 10^{-15}$ J Final $E_k = 7.56 \times 10^{-13}$ J	(1) both eq. (1) both sub. (1) initial E_k and E_w ans. (1) final ans.
21ai)	Induced as a neutron is added.	(1) (1)
21aii)	total mass before = 3.9842×10^{-25} (kg) total mass after = 3.9825×10^{-25} (kg) lost mass = 1.7×10^{-28} (kg) $E = mc^2$ $E = 1.7 \times 10^{-28} \times (3 \times 10^8)^2$ $E = 1.53 \times 10^{-11}$ J	(1) (1) (1) (1)

	An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only round your final answers! Not your working!	
21b)	P = E/t 900 x 10^6 = E/20 E = 1.8 x 10^{10} J No. of reactions = Total energy/energy of one reaction No. of reactions = 1.8 x 10^{10}/1.53 x 10^{-11} No. of reactions = 1.18 x 10^{21} (reactions)	(1) (1) (1) (1)
22a)	alpha	(1)
22b)	total mass before = 398.626 x 10^{-27} (kg) total mass after = 398.615 x 10^{-27} (kg) lost mass = 1.1 x 10^{-29} (kg) E = mc^2 E = 1.1 x 10^{-29} x $(3 \times 10^8)^2$ E = 9.9 x 10^{-13} J *An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only round your final answers! Not your working!*	 (1) (1) (1) (1)
23ai)	The number of protons in the nucleus is 92.	(1)
23aii)	The number of protons and neutrons in the nucleus is 235.	(1)
23b)	total mass before = 391.848 x 10^{-27} (kg) total mass after = 391.476 x 10^{-27} (kg) lost mass = 3.72 x 10^{-28} (kg) E = mc^2 E = 3.72 x 10^{-28} x $(3 \times 10^8)^2$ E = 3.35 x 10^{-11} J *An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only round your final answers! Not your working!*	 (1) (1) (1) (1)
24a)	***r*** = 95 ***s*** = 7	(1) (1)
24b)	Lost mass is converted into energy.	(1)

24c)	total mass before = 391.848×10^{-27} (kg) total mass after = 391.478×10^{-27} (kg) lost mass = 3.7×10^{-28} (kg) $E = mc^2$ $E = 3.7 \times 10^{-28} \times (3 \times 10^8)^2$ $E = 3.33 \times 10^{-11}$ J *An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only round your final answers! Not your working!*	 (1) (1) (1) (1)
25a)	(241 - 95 =) <u>146</u>	(1)
25bi)	***s*** = 237 ***r*** = 93	 (1) for both
25bii)	***T*** = Neptunium (*or* Np)	(1)
25c)	V = IR 5 = I x 16 I = 0.3125 A lost volts = Ir lost volts = 0.3125 x 2 lost volts = 0.625 V V across resistor = 9 - 5 - 0.625 V across resistor = 3.375 V *Or another method to reach the same final answer*	(1) both eq. (1) both sub. (1) I and lost volts ans. (1) final ans.
26ai)	(Nuclear) fusion *"fussion" gets 0 marks. Fission and fusion **must** be accurately spelt.*	(1)
26aii)	total mass before = 8.347×10^{-27} (kg) total mass after = 8.317×10^{-27} (kg) lost mass = 3×10^{-29} (kg) $E = mc^2$ $E = 3 \times 10^{-29} \times (3 \times 10^8)^2$ $E = 2.7 \times 10^{-12}$ J *An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only round your final answers! Not your working!*	 (1) (1) (1) (1)

26bi)	$E_2 - E_1 = hf$ $-1.360 \times 10^{-19} - (-5.424 \times 10^{-19}) = 6.63 \times 10^{-34} \times f$ $f = 6.129... \times 10^{14}$ (Hz) $v = f\lambda$ $3 \times 10^{8} = 6.129... \times 10^{14} \times \lambda$ $\lambda = 4.89 \times 10^{-7}$ m *Must put energies in the correct way. Getting a negative frequency and scoring out the negative is* <u>*not*</u> *okay.*	(1) both eq. (1), (1) sub. (1) final ans.
26bii)	Blue *or* Blue-green	(1)
27ai)	**X** = Lithium (*or* Li)	(1)
27aii)	$E = mc^2$ $2.97 \times 10^{-12} = m \times (3 \times 10^{8})^2$ $m = 3.3 \times 10^{-29}$ kg **X** $+ 3.342 \times 10^{-27} = (2 \times 6.642 \times 10^{-27}) + 1.675 \times 10^{-27} + 3.3 \times 10^{-29}$ **X** $= 1.165 \times 10^{-26}$ kg	(1) (1) (1) (1)
28a)	Lost mass is converted into energy.	(1)
28bi)	**X** = Scandium (*or* Sc)	(1)
28bii)	the (anti)neutrino	(1)
29a)	Lost mass is converted into heat.	(1)
29b)	total mass before = 8.3519×10^{-27} (kg) total mass after = 8.3214×10^{-27} (kg) lost mass = 3.05×10^{-29} (kg) $E = mc^2$ $E = 3.05 \times 10^{-29} \times (3 \times 10^{8})^2$ $E = 2.745 \times 10^{-12}$ J *An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only round your final answers! Not your working!*	 (1) (1) (1) (1)

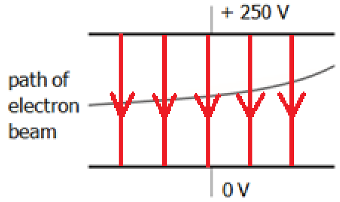
29c)	Plasma would cool down if it came too close to the sides (and reaction would stop). *or* Plasma would melt the sides of the reactor. *or* High temperature plasma could damage/destroy the container.	(1)
29d)	Up the page	(1)
30a)	Two small nuclei combine (*or* fuse *or* join) to form a larger nucleus. *Must be the terms nuclei/nucleus **not** atoms. It's <u>nuclear</u> fusion.*	(1)
30bi)	Lost mass is converted into energy.	(1)
30bii)	total mass before = 8.352×10^{-27} (kg) total mass after = 8.319×10^{-27} (kg) lost mass = 3.3×10^{-29} (kg) $E = mc^2$ $E = 3.3 \times 10^{-29} \times (3 \times 10^8)^2$ $E = 2.97 \times 10^{-12}$ J *An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only round your final answers! Not your working!*	 (1) (1) (1) (1)
31a)	(Nuclear) fusion *"fussion" gets 0 marks. Fission and fusion **must** be accurately spelt.*	(1)
31b)	total mass before = 6.6872×10^{-27} (kg) total mass after = 6.6831×10^{-27} (kg) lost mass = 4.1×10^{-30} (kg) $E = mc^2$ $E = 4.1 \times 10^{-30} \times (3 \times 10^8)^2$ $E = 3.69 \times 10^{-13}$ J *An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only round your final answers! Not your working!*	(1) (1) (1) (1)
	No. of reaction = Total energy/energy of one reaction No. of reactions = $4.1 \times 10^{26}/3.69 \times 10^{-13}$ No. of reactions = 1.11×10^{39} (reactions)	 (1) (1)

Particle Accelerators (MC done)

1. E	2. D	3. E	4. D	5. B	6. C
7. E	8. D	9. A	10. C	11. A	12. D

13a)	200 kJ of work done per coulomb of charge moving between P and Q	(1)
13b)	Protons have a positive charge so are attracted to the negative tube/plate. *or* Protons have a positive charge and experience a force in an electric field. *Must identify the type of charge the proton has.*	(1)
13ci)	$E_W = QV$ $E_W = 1.6 \times 10^{-19} \times 200 \times 10^3$ $E_W = 3.2 \times 10^{-14}$ J *Your answers for <u>energy</u> should never be negative in Higher Physics.*	(1) (1) (1)
13cii)	$E_k = ½mv^2$ $3.2 \times 10^{-14} = ½ \times 1.673 \times 10^{-27} \times v^2$ $v = 6.19 \times 10^6$ ms^{-1}	(1) (1) (1)
13d)	No effect as the charge and voltage are constant (so the work done is constant ($E_W = QV$), and as the mass of the proton is constant then the speed must also be constant ($E_k = ½mv^2$)).	(1) (1)
14a)	$E_k = ½mv^2$ $E_k = ½ \times 6.64 \times 10^{-27} \times (2.6 \times 10^6)^2$ $E_k = 2.24... \times 10^{-14}$ J Work done = Energy gained Work done = $3.05 \times 10^{-14} - 2.24... \times 10^{-14}$ Work done = 8.1×10^{-15} J *"Show" question means you've already been given the answer – no mark for this part. Your final answer must be shown and rounded so that it is the number that the question asked for. No marks if not done.*	(1) (1) (1)
14b)	$E_W = QV$ $8.1 \times 10^{-15} = 3.2 \times 10^{-19}$ V V = 25300 V	(1) (1) (1)
14c)	Less than as the voltage is constant but an electron has less charge (1.6×10^{-19} C) meaning the work done is less ($E_W = QV$).	(1) (1)

15ai)	$E_w = QV$ $E_w = 1.6 \times 10^{-19} \times 1.22 \times 10^3$ $E_w = 1.95 \times 10^{-16}$ J *"Show" question means you've already been given the answer – no mark for this part. Answer must be exactly the same as value given for "show" questions. No mark if left as 1.952×10^{-16} J.*	(1) (1)
15aii)	$E_k = ½mv^2$ $1.95 \times 10^{-16} = ½ \times 2.18 \times 10^{-25} \times v^2$ $v = 4.23 \times 10^4$ ms^{-1}	(1) (1) (1)
15b)	Ft = mv - mu 0.07 x 60 = 750 x v - 750 x 0 v = 0.0056 ms^{-1} (Change in speed = 0.0056 - 0 = 0.0056 ms^{-1})	(1) (1) (1)
15c)	The Xenon ion engine as the change in momentum (*or* impulse) is greater (due to their larger mass) meaning the force must be greater. *Could prove by doing an example calculation to justify your statement.*	(1) (1)
16ai)	$E_w = QV$ $E_w = 1.6 \times 10^{-19} \times 55 \times 10^3$ $E_w = 8.8 \times 10^{-15}$ J *"Show" question means you've already been given the answer – no mark for this part.*	(1) (1)
16aii)	$E_k = ½mv^2$ $8.8 \times 10^{-15} = ½ \times 1.673 \times 10^{-27} \times v^2$ $v = 3.24 \times 10^6$ ms^{-1}	(1) (1) (1)
16b)	Into the page.	(1)
16c)	a.c. voltage needs to change direction to change the direction of the force on the proton. The proton needs to be changed direction to keep moving across the gap (left to right then right to left etc.)	(1) (1)
17a)	$E_w = QV$ $E_w = 1.6 \times 10^{-19} \times 2 \times 10^3$ $E_w = 3.2 \times 10^{-16}$ J *The work done is the kinetic energy gained by the electron.*	(1) (1) (1)
17b)	Q = It $Q = 8 \times 10^{-3} \times 60$	(1) (1)

	Q = 0.48 C No. of electrons = total charge/charge of one electron No. of electrons = 0.48/1.6 x 10^{-19} No. of electrons = 3 x 10^{18} (electrons)	(1) (1)
17c)	 *Electric field lines <u>always</u> shown going away from positive charge/voltage.*	(1)
18ai)	E_W = QV E_W = 1.6 x 10^{-19} x 2.5 x 10^3 E_W = 4 x 10^{-16} J	
18aii)	So the electron (or particle) always experiences a force in the same direction. *or* So the electron (*or* particle) accelerates in the same direction. *or* To ensure the direction of the electric field is correct when the electron (*or* particle) passes between gaps. *Must make some implication of "same direction".*	 (1)
18bi)	Out of the page.	
18bii)	Magnetic fields are in opposite direction (as electron forced opposite way). Magnetic field in S is stronger than R (as electron is forced/deviated more in S).	(1) (1)
18c)	E_K = ½mv^2 4.16 x 10^{-17} = ½ x 9.11 x 10^{-31} x v^2 v = 9.56 x 10^6 ms^{-1}	(1) (1) (1)
19ai)	E_W = QV E_W = 1.6 x 10^{-19} x 1.6 x 10^3 E_W = 2.6 x 10^{-16} J *"Show" question means you've already been given the answer – no mark for this part. Answer must be exactly the same as value given for "show" questions. No mark if left as 2.56 x 10^{-16} J.*	

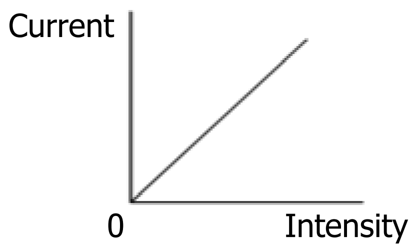
19aii)	$E_k = ½mv^2$ $2.6 \times 10^{-16} = ½ \times 9.11 \times 10^{-31} \times v^2$ $v = 2.39 \times 10^7\ ms^{-1}$	(1) (1) (1)
19b)	Screen will be brighter (*or* increase in glow). Electrons will gain more energy (*or* move faster). *or* Increase in number of electrons <u>per second.</u> *Acceptable:* *Circle of brightness on fluorescent screen is reduced.* *Greater force of attraction on the electrons due to the cross.* *or* *Cross on screen is sharper.* *Greater force of attraction on the electrons due to the cross.*	(1) (1) *or* (1) *(1)* *(1)* *(1)* *(1)*
20.	**Show teacher if possible** *Answer <u>could</u> include correct information on a comparison of the ball being like charged particles in a real particle accelerator, or the motor accelerating the ball being like the electric fields that accelerate charged particles, or the track changing the direction of the ball where magnetic fields change the direction of charged particles. It could also include equations such as $E_W = QV$ and $E_k = ½mv^2$. Also, the collision with the block may break the ball apart if going fast enough in the same way that certain charged particles like hadrons and be broken apart into quarks, which are fundamental particles and cannot be broken down further.*	(3)

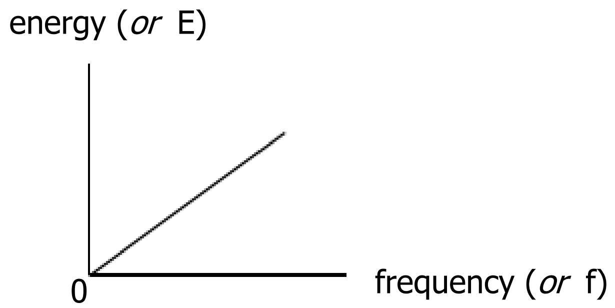
The Photoelectric Effect

1. B 2. D 3. A 4. A 5. A 6. E

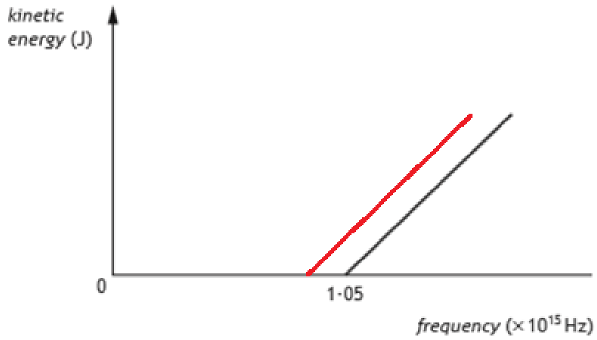
7. D 8. A 9. A 10. D 11. B 12. C

13. C 14. E

15ai)	Photoelectric emission is when electrons are ejected from a metal surface when exposed to electromagnetic radiation.	(1)
15aii)	The threshold frequency.	(1)
15aiii)	More photons are incident on the metal surface (per second) so more electrons are ejected from it <u>per second</u>.	(1) (1)
15bi)	$E = hf$ $E = 6.63 \times 10^{-34} \times 9 \times 10^{14}$ $E = 5.97 \times 10^{-19}$ J	(1) (1) (1)
15bii)	No. of photons = total energy/energy of one photon No. of photons = $40.5 \times 10^{-6}/5.97 \times 10^{-19}$ No. of photons = 6.78×10^{13} (photons)	 (1) (1)
16a)	The threshold frequency.	(1)
16bi)	$E_o = hf_o$ $E_o = 6.63 \times 10^{-34} \times 3.33 \times 10^{14}$ $E_o = 2.21 \times 10^{-19}$ J	(1) (1)
16bii)	$E_k = hf - hf_o$ $E_k = 6.63 \times 10^{-34} \times 5.66 \times 10^{14} - 6.63 \times 10^{-34} \times 3.33 \times 10^{14}$ $E_k = 1.54 \times 10^{-19}$ J	(1) (1) (1)
16biii)	$E_w = QV$ $E_w = 1.6 \times 10^{-19} \times 2 \times 10^4$ $E_w = 3.2 \times 10^{-15}$ J	(1) (1) (1)
17a)		(1)
17bi)	The work function is the <u>minimum energy required to eject electrons</u> from a metal.	(1)
17bii)	$v = f\lambda$ $3 \times 10^8 = f \times 400 \times 10^{-9}$	(1) both eq. (1), (1) sub.

	$f = 7.5 \times 10^{14}$ Hz $E_k = hf - hf_o$ $E_k = 6.63 \times 10^{-34} \times 7.5 \times 10^{14} - 3.11 \times 10^{-19}$ $E_k = 1.86 \times 10^{-19}$ J	(1) final ans.
18a)	$v = f\lambda$ $3 \times 10^8 = f \times 605 \times 10^{-9}$ $f = 4.95... \times 10^{14}$ Hz $E_o = hf_o$ $E_o = 6.63 \times 10^{-34} \times 495... \times 10^{14}$ $E_o = 3.29 \times 10^{-19}$ J	(1) both eq. (1), (1) sub.
18bi)	$E_k = hf - hf_o$ $E_k = 5.12 \times 10^{-19} - 3.29 \times 10^{-19}$ $E_k = 1.83 \times 10^{-19}$ J	 (1)
18bii)	The reading will decrease as less irradiance means less photons incident on the metal (per second) so less electrons ejected per second.	(1) (1)
19a)		(1)
19b)	$E_k = hf - hf_o$ $6 \times 10^{-20} = 6.63 \times 10^{-34} \times 6.1 \times 10^{14} - hf_o$ (work function) work function $= 3.44 \times 10^{-19}$ J *Or another method to reach the same final answer*	(1) (1) (1)
19c)	As each photon still has the same amount of energy (as it still has the same frequency ($E = hf$)).	(1)
20ai)	$E_k = hf - hf_o$ $E_k = 5.23 \times 10^{-19} - 2.56 \times 10^{-19}$ $E_k = 2.67 \times 10^{-19}$ J *Or another method to reach the same final answer*	 (1)
20aii)	$E_k = \frac{1}{2}mv^2$ $2.67 \times 10^{-19} = \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$ $v = 7.66 \times 10^5$ ms^{-1}	(1) (1) (1)

20b)	No effect as the energy of each photon is still the same (as the frequency is still the same ($E = hf$)).	(1) (1)
21ai)	$v = f\lambda$ $3 \times 10^{8} = f \times 525 \times 10^{-9}$ $f = 5.71... \times 10^{14}$ Hz $E = hf$ $E = 6.63 \times 10^{-34} \times 5.71... \times 10^{14}$ $E = 3.79 \times 10^{-19}$ J *"Show" question means you've already been given the answer – no mark for this part. Your final answer must be shown and rounded so that it is the number that the question asked for. No marks if not done.*	(1) both eq. (1), (1) sub.
21aii)	$E_k = hf - hf_o$ $E_k = 3.79 \times 10^{-19} - 2.24 \times 10^{-19}$ $E_k = 1.55 \times 10^{-19}$ J	 (1)
21bi)	Photons with a frequency below f_o do not have the energy required to eject electrons. *Your answer must be in terms of photon energy.*	 (1)
21bii)	$E_o = hf_o$ $2.24 \times 10^{-19} = 6.63 \times 10^{-34} \times f_o$ $f_o = 3.38 \times 10^{14}$ Hz	(1) (1) (1)
22ai)	$E_k = hf - hf_o$ $E_k = 6.63 \times 10^{-34} \times 6.74 \times 10^{14} - 3.78 \times 10^{-19}$ $E_k = 6.89 \times 10^{-20}$ J	(1) (1) (1)
22aii)	$E_k = ½mv^2$ $6.89 \times 10^{-20} = ½ \times 9.11 \times 10^{-31} \times v^2$ $v = 3.89 \times 10^{5}$ ms^{-1}	(1) (1) (1)
22b)	No effect as the energy of each photon is still the same (and the work function of the metal is still the same, so the kinetic energy of each photoelectron is unchanged therefore the maximum velocity of each photoelectron is unchanged)	(1) (1)
23a)	Frequency of the UV/photons/light is not high enough. *or* Frequency of the UV/photons/light is less than the threshold. *or*	(1)

	Energy of the <u>photons</u> (*not UV or light*) is not high enough. *or* Energy of the <u>photons</u> is less than work function. *or* May not be a "clean plate".	
23bi)	6.94×10^{-19} J of energy is the <u>minimum</u> energy required for electrons to be ejected.	1
23bii)	No effect as the energy of each photon is unchanged.	(1) (1)
23c)	 *same gradient* *lower starting frequency* *If your line starts at the origin (zero) then no marks.*	(1) (1)
23d)	Each photon contains a discrete amount of energy *or* Each photon ejects one electron.	(1)

The Standard Model

1. B	2. C	3. B	4. E	5. C	6. D
7. A	8. D	9. D	10. E	11. A	12. E
13. B	14. A				

15ai)	Number at **X** <u>much</u> larger than number at **Y**. *Need to indicate significantly more at **X**.*	(1)
15aii)	Small nucleus compared to size of the atom. *or* Most of an atom is empty space. *or* Mass of the atom is concentrated in the nucleus. *or* Nucleus has a positive charge. *or* Atoms have a nucleus.	(1) *any one*
15bi)	Induced because a neutron is added. *No attempt to justify means 0 marks, even if you said induced.* *"**must** justify your answer".*	(1) (1)
15bii)	**r** = 55 **s** = 95	(1) (1)
15biii)	***T*** = Rubidium (*or* Rb)	(1)
15biv)	total mass before = 391.894×10^{-27} (kg) total mass after = 391.554×10^{-27} (kg) lost mass = 3.4×10^{-28} (kg) $E = mc^2$ $E = 3.4 \times 10^{-28} \times (3 \times 10^8)^2$ $E = 3.06 \times 10^{-11}$ J *An arithmetic error when calculating lost mass can be carried forward, i.e. you still get the last three marks if you calculate lost mass wrong. If your masses are rounded then you only get one mark for the equation. Only*	 (1) (1) (1) (1)

	round your final answers! Not your working!	
16a)	They cannot be broken down (into something smaller).	(1)
16b)	-1/3 (*negative one third*)	(1)
16c)	1 up quark and 2 down quarks	(1)
16di)	Down the page	(1)
16dii)	They have no charge so won't be affected by electric/magnetic fields.	(1) (1)
17ai)	Meson as mesons are made of a quark-antiquark pair.	(1) (1)
17aii)	+1/3 (*positive two thirds*)	(1)
17aiii)	An anti-up and a down quark.	(1)
17aiv)	$t' = \frac{t}{\sqrt{1 - (\frac{v}{c})^2}}$ $t' = \frac{2.6 \times 10^{-8}}{\sqrt{1 - (\frac{0.9c}{c})^2}}$ $t' = 5.96 \times 10^{-8}$ s *If* <u>*both*</u> *"c" values changed to* 3×10^8 ms^{-1} *then this is fine for substitution too.*	(1) (1) sub. (1)
17bi)	electric field	(1)
17bii)	magnetic field	(1)
18a)	The photon	(1)
18bi)	Energy of 126 GeV = $126 \times 10^9 \times 1.6 \times 10^{-19}$ Energy = 2×10^{-8} J $E = mc^2$ $2 \times 10^{-8} = m \times (3 \times 10^8)^2$ $m = 2.2 \times 10^{-25}$ kg	 (1) (1) (1)
18bii)	$2.2 \times 10^{-25}/1.673 \times 10^{-27} = 132$ Higgs boson is <u>2</u> orders of magnitude <u>bigger</u>. *If not shown working but still correct answer then still two marks given.*	(1) (1)
19a)	They are made up of smaller particles (*or* quarks).	(1)

19bi)	Baryons are hadrons made of 3 quarks. Mesons/some hadrons are made of a quark-anitquark pair so are not baryons.	(1) (1)
19bii)	-1/3 (*negative one third*)	(1)
19ci)	strong nuclear force	(1)
19cii)	The gluon	(1)
19d)	$t' = \frac{t}{\sqrt{1 - (\frac{v}{c})^2}}$ $t' = \frac{1.5 \times 10^{-10}}{\sqrt{1 - (\frac{0.9c}{c})^2}}$ $t' = 3.4 \times 10^{-10}$ s *If both "c" values changed to 3×10^8 ms^{-1} then this is fine for substitution too.*	(1) (1) (1)
20ai)	They cannot be broken down (into something smaller).	(1)
20aii)	Fermions	
20b)	$+\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e + \frac{2}{3}e - \frac{2}{3}e$ $+1e$ **or** $1e$ **or** e	(1) (1)
20ci)	Meson	
20cii)	$t' = \frac{t}{\sqrt{1 - (\frac{v}{c})^2}}$ $t' = \frac{8 \times 10^{-21}}{\sqrt{1 - (\frac{0.91c}{c})^2}}$ $t' = 1.93 \times 10^{-20}$ s *If both "c" values changed to 3×10^8 ms^{-1} then this is fine for substitution too.*	
20di)	Energy of 4450 MeV = $4450 \times 10^6 \times 1.6 \times 10^{-19}$ Energy = 7.12×10^{-10} J *Fine if you've not given the units as the question asked for it "in joules".*	(1) ans.

20dii)	$E = mc^2$ $7.12 \times 10^{-10} = m \times (3 \times 10^8)^2$ $m = 7.91 \times 10^{-27}$ kg	(1) (1) (1)