Question			Answer	Max mark	Additional guidance
6.	(a)	(i)	$W = QV$ **(1)** $W = 1 \cdot 60 \times 10^{-19} \times 1600$ **(1)** $W = 2 \cdot 6 \times 10^{-16}$ J	**2**	**"SHOW" question**
		(ii)	$E_K = \frac{1}{2}mv^2$ **(1)** $2 \cdot 6 \times 10^{-16} = \frac{1}{2} \times 9 \cdot 11 \times 10^{-31} \times v^2$ **(1)** $v = 2 \cdot 4 \times 10^7$ m s^{-1} **(1)**	**3**	Accept: 2, 2·39, 2·389
	(b)		Screen will be brighter/increase glow. **(1)** Electrons will gain more energy/move faster. **OR** Increase in number of electrons <u>per second</u>. **(1)**	**2**	Look for correct statement of effect first – if incorrect or missing then 0 marks. Accept: Circle of brightness on fluorescent screen is reduced. (1) Greater force of attraction on the electrons due to the cross. (1) **OR** Cross on screen is sharper. (1) Greater force of attraction on the electrons due to the cross. (1) 'increase in current' alone is insufficient for the justification. Any correct statement followed by wrong physics, 0 marks. Any correct statement followed by no justification, 0 marks.

Question			Answer	Max mark	Additional guidance
6.	(c)		Demonstrates no understanding 0 marks Demonstrates limited understanding 1 mark Demonstrates reasonable understanding 2 marks Demonstrates good understanding 3 marks This is an open-ended question. **1 mark**: The student has demonstrated a limited understanding of the physics involved. The student has made some statement(s) which is/are relevant to the situation, showing that at least a little of the physics within the problem is understood. **2 marks**: The student has demonstrated a reasonable understanding of the physics involved. The student makes some statement(s) which is/are relevant to the situation, showing that the problem is understood. **3 marks**: The maximum available mark would be awarded to a student who has demonstrated a good understanding of the physics involved. The student shows a good comprehension of the physics of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one.	**3**	

Q6(a)(i)

Maximum Mark: 2

RESPONSE 1

$\cancel{= 1600 \times 1.6}$ $= 1600 \times 1.6 \times 10^{-19}$

$= 2.56 \times 10^{-16}$

$= 2.6 \times 10^{-16}$

$\Rightarrow$ as required.

RESPONSE 2

$W = QV$

$= 1.6 \times 10^{-19} \times (1.6 \times 10^{3})$

$= 2.6 \times 10^{-16}$ J

Q6(a)(ii)

Maximum Mark: 3

RESPONSE 1

$\cancel{E = \frac{1}{2}mv^2}$

$\cancel{2.6\times10^{-16} = 0.5\times9.11\times10^{-31}}v^2$

$\cancel{v = 2.39\times10^{7}\,ms^{-1}}$

$E = \frac{1}{2}mv^2$

$2.6\times10^{-16} = 0.5\times9.11\times10^{-31}v^2$

$v = 2.39\times10^{7}$

RESPONSE 2

$P = mv \quad E_w = E_k = \frac{1}{2}mv^2$

$V = \frac{P}{m}$

$= \frac{2.6\times10^{-16}}{9.11\times10^{-31}}$

$=$

$\frac{1}{2}mv^2 = E_w$

$v^2 = \frac{E_w}{\frac{1}{2}m}$

$= \frac{2.6\times10^{-16}}{0.5\times9.11\times10^{-31}}$

$v^2 = 5.7080\times10^{14}$

$= 5.71\times10^{14}$

$V = \sqrt{5.71\times10^{14}}$

$= 2.38914468.67$

$= 2.4\times10^{7}\,ms^{-1}$

RESPONSE 3

$E_w = E_k$

$2.6\times10^{-16} = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2.6\times10^{-16}}{\frac{1}{2}\times(9.11\times10^{-31})}}$

$= 2.39\times10^{7}\,ms^{-1}$

Q6(b)

Maximum Mark: 2

RESPONSE 1

The electrons will be less spread out upon arrival at the screen because they will be travelling faster and have less time to spreadout.

RESPONSE 2

The screen will flucresce more frequently. Increasing the voltage increases the current as $I = \frac{V}{R}$ ∴ ~~more~~ the flow of electrons is stronger and more electrons will be able to get through in the same time frame.

RESPONSE 3

The screen glows more brightly. As a higher number of electrons hit the screen as the voltage is greater.

RESPONSE 4

As the voltage has increased the amount of energy will increase making the screen brighter.

$W = QV$

$= 1.6 \times 10^{-19} \times 2.2 \times 10^{3}$

$= 3.52 \times 10^{-16}\,J$

Q 6(c) **Maximum Mark: 3**

RESPONSE 1

The model is good as it shows the circular motion taken by a particle in the LHC, but the plastic block doesn't show the same level of collision that happens between particles as in the LHC, particles are accelerated towards eachother but in this case the plastic block is stationary meaning that it's not the same effect as in the LHC

RESPONSE 2

- The ball represents the particle. When the ball hits the block, energy is released. In the hadron collider the same process happens with a particle hitting into an object. The object causes the particle to break down. Energy is released in this process also.

RESPONSE 3

The motor speeding up the ball is realistic as in the large hadron collider the particles are sped up by a changing electric field. The second ball which is used to collide with the first ball is also realistic as particles are ~~to~~ moved through tubes in the opposite direction towards a target where a magnetic field will influence their direction so they will collide with one another.

RESPONSE 4

model	CERN
ball turned mechanically due to contact with track	particles turned using magnetic fields
ball accelerated at one point on loop of the motor	particles accelerated at one point when they reach the electric field
ball accelarated by motor	prticles accelerated by electric field
Collision caused by block being pushed onto track	Collision caused by prticles going in opposite direction.

RESPONSE 5

In the model, the ball is only accelerated at one point in the circle. In the large hadron colle particles can be accelerated at more than one pla Cyclotrons ~~Synchrotrons~~ are used to accelerate the particles before they enter the LHC Synchotron. In th model the plastic block is stationary when the ~~ba~~ collides with it whereas in the large hadron colli the particles are accelerated inopposite directio around the accelerator. This makes the particles collide with much more energy than if ~~they~~ are was stationary before impact. In the model friction is used to keep the ball on the track. In the large hadron collider an alternating electric field is used to accelerate the particles through drift tubes. Electromagnets are used to focus the beam of particles ~~into the middle~~ so that the ~~[illegible]~~ can turn ~~[illegible]~~ along the circlar path.

RESPONSE 6

~~An~~ A large hadron collider such as the one at CERN, does not use motors to fire a "ball" around a track. It uses magnetic fields to fire particles at ~~a~~ great speeds. In CERN, they also don't push a block onto the path of the particle, The particle is guided to an end point when a controlled collision can take place

RESPONSE 7

The track in this model represents a magnetic field. This magnetic field keeps the particle stay in circular motion moving at high speeds. The ball represents the particle in ~~a~~ a real particle accelerator. When the block is released and obstructs the ball, they will both collide.

In a particle accelerator, this collision ~~creates~~ releases incredible amounts of energy which can be collected and readings can be determined for further scientific analysis.

RESPONSE 8

In some particle accelerators (circular accelerators), ~~[illegible]~~ particles are accelerated in a large circle to build up speed. This is similar to what is shown in the model. The particles are accelerated using magnets (for this reason, neutrons cannot be used) and electromagnets are used to ~~[illegible]~~ keep the particles in a concentrated stream. The particles then hit a target and scientists study the data to see what has been ~~[illegible]~~ created. It was in this manner that many fundamental particles were discovered, such as the quarks that make up protons, ~~and~~ (and neutrons, though these cannot be used in a particle accelerator.

RESPONSE 9

Although this model is similar to a real particle accelerator, it is not the same.
In a real particle accelerator the particle does not sit on a track as the ball does, eletric fields are used so it does not touch any thing. This makes the model less good as the ball can be slowed down by friction.
Also in a real particle accelerator the particle is constantly being pushed around by electric fields however this model is only being pushed around

at a certain point of the track making it less like a real particle accelerator.
Also in a real particle accelerator 2 particles collide with each other therefore 2 of the same thing collide however in this model it is not 2 of the same thing as it is a ball and a block.
This model would be more like a real particle accelerator if 2 balls ~~wer~~ are used the collide with each other.

Response 10

The ball acts as a ~~[illegible]~~ negatively charged particle. The plastic block acts as a magnetic field. Both of these are negatively charged (like charges repell). Therefore, when the ball hits the plastic block, this simulates two 'like' charges repelling. This causes greater collisions between particles of the same charge. As a result, this generates ~~[illegible]~~ more kinetic energy.

Response 11

This is a good model, because it has all the basics, it has a circular ~~[illegible]~~ track so that it can be accelerated ~~for~~ as much as you want, unlike a linear accelerator where it can only accelerate until the end of the track. The motor accelerates the ball like the electric fields in the particle accelerator and the block will cause a collision

Response 12

At CERN an AC current is used to attract and repel the particle accordingly to ensure the maximum attraction /repulsion is acting on the ball to ensure maximum speeds are reached. In CERN there are many forces being exerted on particles, here it is only the force from the battery motor. The speed ~~[illegible]~~ generated would be far greater at CERN.

Response 13

This model of a particle accelerator has no magnetic fields ore electric fields.
The hadron collider has magnetic fields so the partiles move in a circular path and the electric fields accelerate the particles so the move fast enough. They accelerate due to the unbalanced force from the electric field.
Hadron has 'dees' and the polarity is constantly changed so the

6. (c) (continued)

particles can cross the dees in both directions.

This model uses a motor to accelerate the ball.
A real one uses an electric field to accelerate the particle.

This model uses a circular track to create a curved path for the ball.
A real one use ~~an~~ magnetic field to create a circular path.

This model uses a plastic block to collide with the ball.
A real one uses other particles to collide with particles.

Response 14

This model represents a ~~par~~ synchrotron like the LHC, which uses both electric and magnetic fields to accelerate particles around a ring.
In the LHC, sources of potential difference located around the ring increase the particles energy by generating electric fields, according to $E_w = QV$. This causes them to accelerate. In the model, the battery-operated motors fulfill this role as they accelerate the ball. In the LHC, magnetic fields are used to

control the particles' direction and ensure they follow the correct path around the ring. The fields deflect the particles in a direction perpendicular to both the field direction and the particles' velocity. It is called a synchrotron because the magnetic field strength must synchronise with the particle's increasing speed to ensure correct deflection.
There is no direct comparison to be made in the model with this, as it is kept going in the right direction by the normal force caused by the constant contact with the plastic track.
Another difference between the two situations is that in the model, the collision is between a moving and stationary object, whereas in the LHC, two streams of particles are accelerated in opposite directions before being made to collide at very high energy, effectively doubling the energy of the collision. This would be impossible in the model unless another ~~[illegible]~~ circular track was added so another ball could go in the other direction before they collided at a crossing between the tracks

Q6(a)(ii)	**3**	
Response 1	**2**	The candidate has selected an appropriate relationship, substituted correctly but has not included the correct unit in the final answer.
Response 2	**2**	The candidate has selected an appropriate relationship, substituted correctly but has made an incorrect statement, $\sqrt{5{\cdot}71 \times 10^{14}} = 2{\cdot}3891448{\cdot}62$, and so the mark for the final answer is not awarded.
Response 3	**3**	The candidate has selected an appropriate relationship, substituted correctly and has given an acceptable final answer.
Q6(b)	**2**	
Response 1	**0**	The candidate has not suggested an observed change. The mark for justification cannot be accessed.
Response 2	**0**	The candidate's suggested observed change is incorrect. Again, the mark for justification cannot be accessed.
Response 3	**1**	The candidate's suggested observed change is acceptable, but their justification does not imply an increase in the *rate* of electrons hitting the screen.
Response 4	**1**	Again, the candidate's suggested observed change is acceptable, but their justification does not imply an increase in the energy *of the electrons* hitting the screen.

the physics involved.

Q6 (c)	3	1 – limited 2 – reasonable 3 – good
Response 1	**1**	The candidate's response demonstrates a limited understanding of the physics involved, comparing the shape of the tracks, and the nature of the collisions.
Response 2	**1**	Again, the candidate's response demonstrates a limited understanding of the physics involved, comparing the nature of the collisions.
Response 3	**2**	The candidate has made a number of points, comparing how acceleration is achieved, and the possibility of the model being refined to collisions between two balls. Overall, it was felt that the understanding of the physics demonstrated was reasonable rather than limited.
Response 4	**2**	The candidate has compared various aspects, including the travel medium, means of acceleration and the collisions, demonstrating a reasonable understanding of the physics involved.
Response 5	**3**	The candidate shows good knowledge of the working of a particle accelerator, and contrasts and compares a number of aspects with the model, showing a good understanding of the physics involved.
Response 6	**0**	Although showing a little knowledge, the candidate's response does not demonstrate even a limited understanding of the physics involved.
Response 7	**1**	The candidate is aware that the track is modelling the magnetic field in a particle accelerator, showing a limited understanding of the physics involved.
Response 8	**1**	The candidate's response mainly concentrates on the working of a particle accelerator and does not comment in great detail on the model, demonstrating a limited understanding of the physics involved.
Response 9	**2**	The candidate's response compares the model with a particle accelerator, highlighting similarities and differences, showing a reasonable understanding of the physics involved.
Response 10	**0**	The candidate's response does not demonstrate even a limited understanding of the physics involved.

Question /Response	Mark	Commentary
Response 11	**1**	The candidate’s comparison of the model with a particle accelerator is very basic and shows just a limited understanding of the physics involved.
Response 12	**0**	The candidate’s response does not demonstrate even a limited understanding of the physics involved.
Response 13	**2**	The candidate has compared a number of aspects of the model with a particle accelerator, and demonstrates a very reasonable understanding of the physics involved.
Response 14	**3**	As the previous response, the candidate has compared a number of aspects of the model with a particle accelerator, and demonstrates a very good understanding of the physics involved.