2020 Semester 2

Year 12 Physics Examination

Suggested Marking Guide

Question 1 **(4 marks)**

A triangular piece of wire is paced in a uniform magnetic field as shown below. A current (I) flows through the triangular piece of wire as shown.

Complete the following table by labelling the statements as true (T) or false (F).

Statement	**Description**	**Marks**
The triangle rotates about axis WX	T	1
There is zero net force on the triangle	T	1
PR provides more torque than RQ	F	1
P is moving out of the page	T	1
Total		**4**

Question 2 **(4 marks)**

Experiments on the photoelectric effect show that:

- the kinetic energy of photoelectrons released depends upon the frequency of the incident light and not on its intensity
- light below a certain threshold frequency cannot release photoelectrons

How do these conclusions support a particle theory but not a wave theory of light?

Description	**Marks**
Wave theory would suggest that if sufficient light energy is absorbed, then eventually electrons would be emitted.	1
This is not observed	1
If light is considered to be a stream particles (photons) with energy proportional to the frequency	1
Then only photons with sufficient energy (above the threshold f) will cause electrons to be released.	1
Total	**4**

See next page

Question 3 **(4 marks)**

A student pushes a bar magnet into ring A and then into ring B. State what she would observe in each part of the experiment and explain the observations, using relevant Physics.

Description	**Marks**
Pushing the magnet into A will produce no effect.	1
Pushing the magnet into B will cause ring B to move away from the magnet.	1
In ring B, a current is induced as it experiences a change in field (Faraday's law) and the direction of the induced current has a field to oppose the change in field (Lenz's law)	1
As ring A is not a complete circuit, no current flows, so no effect observed (although there would still be an induced emf)	1
Total	**4**

Question 4 **(5 marks)**

(a) Explain why the mass of the planet is not relevant when determining the mass of Pollux. (1 mark) **Description**	**Marks**
By using Kepler's Third Law, the mass of the central body in a satellite situation can be calculated. The mass of the satellite is not in this equation. (or a good explanation that the mass of a satellite has no influence on orbit characteristics).	0-1

(b) Calculate the mass of Pollux. (4 marks)

Description	**Marks**
$M = \frac{4\pi^2 r^3}{GT^2}$, i.e. M is proportional to r^3/T^2	1
$M = \frac{(1.64)^3}{(\frac{592}{365})^2} \times M_E$	1
M = 1.68 x 1.99 x 10^{30} kg	1
= 3.34 x 10^{30} kg	1
Total	**4**

See next page

Question 5 **(5 marks)**

(a) Calculate the rest energy of the electron. (2 marks)

Description	Marks
$E = mc^2$ = (9.11x10^{-31})(3.00 x 10^{8})^2	1
= 8.20 x 10^{-14} J	1
Total	**2**

(b) Calculate the relativistic kinetic energy of the electron. (2 marks)

Description	Marks
$KE = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2 = \frac{8.20 \times 10^{-14}}{\sqrt{1-\frac{0.99c^2}{c^2}}} - 8.20 \times 10^{-14}$	1
= 5.81 x 10^{-13} - 8.20 x 10^{-14} = 4.99 x 10^{-13} J	1
Total	**2**

(c) If this question was about a positron, instead of an electron, in what way would your answer for (b) differ? (1 mark)

Description	Marks
No difference (antimatter has positive mass)	1

Question 6 **(4 marks)**

(a) Name the other two forces acting on the helicopter. (2 marks)

Description	Marks
B = drag (air resistance)	1
C = weight (mg)	1
Total	**2**

See next page

(b) The force vectors are shown in a triangle in Figure 2. State and explain how Figure 2 shows that the helicopter is flying at a constant velocity. (2 marks)

Description	Marks
The vector triangle sums to zero	1
Therefore, no acceleration (constant velocity)	1
Total	**2**

Question 7 **(7 marks)**

(a) Mark on the diagram the direction of the electric field lines. (1 mark)

Description	Marks
Field lines are down. ↓	1

(b) The conducting plates are 5.00 cm apart and have a potential difference of 255 V between them. Calculate the force on the electron due to the electric field. (3 marks)

Description	Marks
$F = Eq = (V/d)(q)$	1
$= (255/0.05)(1.6 \times 10^{-19}) = 8.16 \times 10^{-16}$ N	1
Total	**2**

(c) State the direction of this force on the electron and explain why it does not affect the horizontal velocity of the electron. (3 marks)

Description	Marks
The force is directly up, parallel to the field lines	1
As the force is vertical, it has no component in the horizontal direction and cannot affect horizontal velocity.	0-2
Total	**3**

Question 8 **(6 marks)**

(a) For objects *A* and *B*, show the direction of the net force at the positions shown with arrows.

Description	Marks
Arrow directly down at point A.	1
Arrow directly down at point B.	1
Total	**2**

(2 marks)

(b) Calculate the vertical force, *F*, that the mechanical arm is exerting on object *B* at the position shown. (4 marks)

Description	Marks
$F = mv^2/r = ((35)(20)^2/25$	0-3
= 560 N	1
Total	**4**

Question 9 **(3 marks)**

According to Einstein's Theory of Special Relativity, the speed of an object cannot be greater than or equal to the speed of light. However, its kinetic energy can be increased without limit. Explain the apparent contradiction that the speed of an object is limited whereas its kinetic energy is not limited.

Description	Marks
Relativistic kinetic energy is given by: $KE = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2$	1
Although v can never equal (or exceed) c, as v approaches c, the value for KE approaches infinity.	1
Therefore, although velocity is limited, KE can increase without limit.	1
Total	**3**

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Question 10 **(8 marks)**

(a) Explain the origin of the dark lines shown in the absorption spectrum. (2 marks)

Description	Marks
The lines on the atomic spectrum relate to electron transitions between energy levels.	1
If the electron absorbs a photon and rises an energy level an absorption line is observed on the spectrum.	1
Total	**2**

(b) Explain what is meant by a *red shift*. (2 marks)

Description	Marks
Red shift is when the observed wavelength of the light is stretched, so the light is seen as 'shifted' towards the red part of the spectrum.	0-2
Total	**2**

(c) Explain what causes *red shift* and why observed *red shift* of distance galaxies provides evidence of the Big Bang Theory. (2 marks)

Description	Marks
Red shift occurs due to the Doppler effect, which explains why wavelengths of light stretch when the wave source is moving away from the observer.	1
The universe is expanding due to evidence of light being more red shifted for distant galaxies. If the universe is expanding, then logically it was once very compact – evidence of the big bang theory.	1
Total	**2**

(d) Our closest galaxy is the Andromeda Galaxy (pictured). The hydrogen spectrum of Andromeda is observed to have a *blue shift*. Explain this observation and why this observation does not necessarily dispute the Big Bang Theory. (2 marks)

Description	Marks
The observed blue shift suggests that Andromeda is moving towards us.	1
This is because of its proximity and the force of gravity between the two galaxies is forcing them together. This does not contest the big bang theory.	1
Total	**2**

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Question 11 **(7 marks)**

(a) Describe the dimensions of the window according to Eloise. (4 marks)

Description	Marks
$L = L_0\sqrt{1-\frac{v^2}{c^2}}$ $L = 2.00\sqrt{1-\frac{(0.95c)^2}{c^2}}$	1
L = 2.00/0.312	1
Width = 0.625 m	1
Height is unchanged as not in direction of relative motion.	1
Total	**4**

(b) At the moment Odyssey is next to Endeavour, Eloise fires a rocket forwards at a velocity of 0.3 c, relative to Odyssey. Calculate the velocity of the rocket according to Hamish, who is onboard Endeavor. (3 marks)

Description	Marks
$u = \frac{v+u'}{1+\frac{v\,u'}{c^2}}$ *u = (0.95 c + 0.3 c)/(1 +(0.95 x 0.3))*	1
= (1.25 c)/1.285	1
= 0.973 c	1
Total	**3**

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Question 12 **(13 marks)**

(a) Show that the time it took the cannonball to strike the ship was approximately 3.7 s. (2 marks)

Description	**Marks**
In y dir'n: s = 67.0 m, a = 9.8 m s^{-2}, u = 0 $s = ut + ½ at^2$ $67 = 4.9t^2$	1
T = 3.70 s (3.6977)	1
Total	**2**

(b) Show that the initial velocity of the cannonball was approximately 40 m s^{-1}. (2 marks)

Description	**Marks**
In x dir'n: s = 151 m, a = 0, t = 3.70 s v = s/t = 151/3.7	1
= 40.8 m s^{-1}	1
Total	**2**

(c) Fully describe the velocity of the cannonball at the moment it strikes the ship's hull. (5 marks)

Description	**Marks**
Final vertical velocity? v = u + at = 0 + (9.80)(3.70) = 36.26 m s^{-1}	0-2
Therefore: $v^2 = 40.8^2 + 36.26^2$ v = 54.6 m s^{-1}	0-2
Angle below horizontal = $\tan^{-1}(36.26/40.8)$ = 41.6^o	1
Total	**5**

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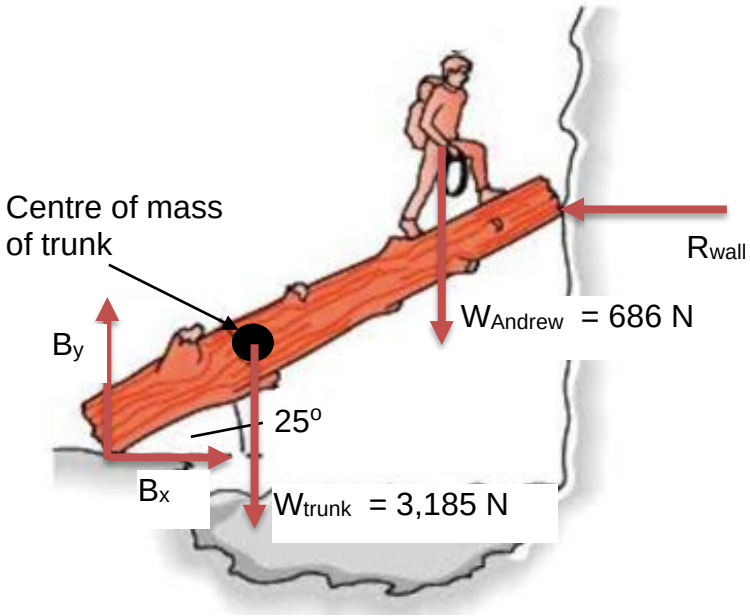
(d) The cannon was then tilted, so that the cannonball was fired at the same velocity, at an angle of 11° above the horizontal. Did the cannon ball still strike the hull of the ship? Support your answer with suitable calculations. (4 marks)

Description	Marks
For y dir'n: u = 40 sin 11° = 7.63 m s^{-1} and a = -9.8m s^{-2}	1
For x dir'n: t for cannonball to travel 151 m? t = s/v = 151/(40 cos 11°) = 3.85 s	1
Vertical displacement at t = 3.85 s? s = ut + ½ a t^2 = (7.63 x 3.85) – 4.9(3.85)^2 = -43.25 m	1
Therefore, cannonball was 67 - 43.25 = 23.7 m above waterline and **missed the hull.**	1
Total	**4**

Question 13 **(10 marks)**

(a) On the diagram above, show as labelled arrows, all forces acting on the trunk. (3 marks)

Description	Marks
	
-1 for each error/missing. Numeric values not required.	0-3
Total	**3**

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(b) Calculate the vertical force exerted by the ground on the trunk at its base and hence the maximum friction that can be provided by the ground to the base of the trunk. (2 marks)

Description	Marks
$\Sigma F_y = 0$ B_y = 3,185 + 686 = 3,870 N	1
Therefore, maximum friction = B_x = 0.8 x 3,870 = 3.10 x 10^3 N	1
Total	**2**

(c) Can Andrew climb all of the way to the end of the trunk without the base slipping? Use suitable calculations to support your answer. (5 marks)

Description	Marks
If Andrew is at end of trunk: Take torques about base: $\Sigma_{cw} = \Sigma_{acw}$ (3185)(2.00)(sin65^o) + (686)(5)(sin65^o) = (R_{wall})(5)(sin25^o)	0-2
R_{wall} = 4,203 N	1
For horizontal equilibrium, B_x must be equal to R_{wall}. B_x = 3,100 < 4,203 therefore the trunk slips.	0-2
Total	**5**

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Question 14 **(16 marks)**

(a) Explain the term *work function*. (2 marks)

Description	Marks
The minimum energy required to remove an electron from the surface of a material.	0-2
Total	**2**

(b) Explain how this current is produced. Use the terms *photon* and *photoelectron* in your explanation. (2 marks)

Description	Marks
Incident photons (from the phototube) are absorbed by atoms in the material (the cathode).	1
This absorbed energy causes photoelectrons to be ejected from the material and travel to the other electrode, producing a current.	1
Total	**2**

(c) State the effect on the released photoelectrons of an increase in: (2 marks)

(i) the intensity of the light used _____

(ii) the frequency of the light used _____

Description	Marks
(i) Number of photoelectrons released (per second) increases	1
(ii) Kinetic energy of photoelectrons increases	1
Total	**2**

(d) Light of wavelength 4.2×10^{-7} m is shone onto the metal cathode. Calculate the energy of these photons. (2 marks)

Description	Marks
$E = hc/\lambda$ $= (6.63 \times 10^{-34})(3 \times 10^{8})/ 4.2 \times 10^{-7}$ $= 4.74 \times 10^{-19}$ J	1
$= 2.96$ eV	1
Total	**2**

See next page

(e) The metal is sodium, with a work function of 2.7 eV. Calculate the maximum kinetic energy in eV that a photoelectron could gain from this photon. (1 mark)

Description	Marks
2.96 – 2.7 = 0.26 eV	1
Total	**1**

(f) When the potential difference between the cathode and anode was reversed the current was reduced.

(i) Explain this observation. (2 marks)

Description	Marks
Reversing the polarity would provide a potential difference that opposed the photoelectrons.	1
The work done by the PD reduces the KE. As they are now travelling slower, the current is reduced.	1
Total	**2**

(ii) Calculate the potential difference required (stopping potential) for the current to be reduced to zero. (2 marks)

Description	Marks
KE of photoelectrons = 0.26 eV, therefore the electric field needs to provide 0.26 eV of energy. W = Vq, therefore 0.26 V required.	0-2
Total	**2**

(g) Does the photoelectric effect support a *wave* or particle theory of light. Explain. (3 marks)

Description	Marks
Particle theory	1
Electrons are only dislodged by photons that reach or exceed a threshold frequency. Below that threshold, no electrons are emitted from the metal regardless of the light intensity or the length of time of exposure to the light. This suggests that a beam of light is not a wave propagating through space, but rather a collection of **discrete** wave packets (photons).	0-2
Total	**2**

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Question 15 **(16 marks)**

(a) Explain what is meant by a charge of $+2/3$. (1 mark)

Description	**Marks**
Means +2/3 of the fundamental charge (i.e. +2/3 of 1.6 x 10^{-19} C)	1
Total	**1**

(b) State the predicted mass and charge of the antiquark $\bar{s}$. (2 marks)

Description	**Marks**
Mass = 95 MeV/c^2	1
Charge = + 1/3	1
Total	**2**

(c) Calculate the mass of a down quark in kg. (2 marks)

Description	**Marks**
m = (4.8 x 10^6) (1.6 x 10^{-19})/(3 x 10^8)^2	1
= 8.53 x 10^{-30} kg	1
Total	**2**

(d) (i) Kaons (K) consist of combinations of *either* an up or down quark plus a strange quark. The omega minus consists of three strange quarks.
Complete the following table by ticking the appropriate boxes. (4 marks)

Description	**Marks**
<table><tr><th></th><th>MESON</th><th>BARYON</th><th>NUCLEON</th><th>LEPTON</th></tr><tr><td>NEGATIVE KAON</td><td>✓</td><td></td><td></td><td></td></tr><tr><td>OMEGA MINUS</td><td></td><td>✓</td><td></td><td></td></tr></table>	0-4
Suggest: 4 marks for the two correct ticks, then removing 1 mark for each error.	
Total	**4**

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(ii) Write an equation using standard particle symbols to summarise this event. (2 marks)

Description	Marks
$K^- + p^+ \rightarrow K^+ + K^0 + \Omega^-$	0-2
Total	**2**

(e) The negative kaon has a quark composition of $\bar{u}s$. Deduce the quark structure of the other two kaons involved in this event. (2 marks)

Description	Marks
K^0: $\bar{d}s$ or $d\bar{s}$	1
K^+: $u\bar{s}$	1
Total	**2**

(f) The total mass of the three particles created after this event is larger than the total mass of the two particles before. Discuss the quantities that must be conserved in interactions between particles and explain this increase in mass. (3 marks)

Description	Marks
The following must be conserved: baryon number, lepton number and charge (and spin - not in syllabus)	0-2
Mass can increase as the kinetic energy of the colliding particles is converted to mass.	1
Total	**3**

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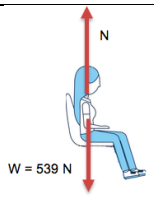
Question 16 **(12 marks)**

(a) Calculate the speed of the rollercoaster at C. (2 marks)

Description	Marks
$KE_{original} + PE_{lost} = KE_{final}$ $(½)(1530)(0.25^2) + (1530)(9.8)(5) = ½ (1530)v^2$	1
$V = 9.90 \text{ m s}^{-1}$	1
Total	**2**

(b) The figure below shows Gemma, who has a mass of 55.0 kg sitting in the rollercoaster at point C. Show all vertical forces acting on Gemma as labelled arrows on the diagram. (2 marks)

Description	Marks
Labelled arrow up: Normal reaction force	1
Labelled arrow down: Weight (539 N)	1
 **Total**	**2**

(c) Gemma usually experience her weight (*mg*) when sitting in a chair. By what multiple of this weight does Gemma "feel" heavier or lighter at point C? (e.g. if she *feels* 80% of her usual weight, the multiple is 0.8). (3 marks)

Description	Marks
$N - W = mv^2/r$ $N = 55(9.9)^2/5 + 539$ =	1
= 1620 N	1
Therefore *feels* 1620/539 = 3.00 times **heavier**	1
Total	**3**

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(d) Would Gemma need her seatbelt at point D to prevent her from lifting off her seat? Support your answer with an appropriate calculation. (3 marks)

Description	Marks
$KE_D = ½ (55)(9.9^2) – (55)(9.8)(1)$ $= 2,156$ J $\therefore ½ (55)(v^2) = 2,156$ $v = 8.85$ m s^{-1}	1
$W – N = mv^2/r$ $N = (55)(9.8) - (55)(8.85^2)/5$ $= -322$ N	1
Seatbelt needed if N <0 (i.e. down). **YES** seatbelt required.	1
Total	**3**

(e) Calculate the average force of friction provided by the water, between points E and F, for the rollercoaster to come to rest before reaching point F. (2 marks)

Description	Marks
Work done by friction = KE $KE = ½ (1530)(0.25^2) + (1530)(9.8)(10)$ $= 1.50 \times 10^5$ J	1
$F \times 12 = 1.50 \times 10^5$ $F = 12,500$ N	1
Total	**2**

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Question 17 **(15 marks)**

(a) Using the graph, estimate the time of day at which the array begins to generate energy. (2 marks)

Description	Marks
Smooth curve through points	1
08:00	1
Total	**2**

(b) State the value the power produced by the array at 12:00. (2 marks)

Description	Marks
6.0 kW	1
± 0.4 kW	1
Total	**2**

(c) State the percentage uncertainty of the power produced by the array at 12:00. (2 marks)

Description	Marks
(0.4/6.0) x 100	1
= 6.7% (~7%)	1
Total	**2**

(d) The average power consumed by the house between 8:00 and 12:00 is 2.00 kW. Calculate the excess energy supplied by the array to the electricity grid in this time. Give your answer in MJ. Note: uncertainties are not required in this part of the question. (4 marks)

Description	Marks
Total energy used by house = 4 x 2 = 8 kWh = (8/1000) x 3600 = 28.8 MJ	1
estimate of total area ~ 14 kW = 50.4 MJ	0-2
Excess energy = 50.4 – 28.8 = 21.6 MJ	1
Total	**4**

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(e) Using the graph, determine the relationship between P^2 and t. (3 marks)

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Description	Marks
Intercept = 8.7	1
Slope = -8.7/210 = - 0.041	1
$\therefore P^2 = -0.041t + 8.7$	1
Total	**3**

(f) Using your relationship from part (e), estimate the power output of the array, 50 minutes before the above data was collected. (2 marks)

Description	Marks
i.e. t = - 50 minutes $P^2 = -0.041(-50) + 8.7$	1
P = 10.8 W	1
Total	**2**

Question 18 **(12 marks)**

(a) Is the electric motor designed to operate on an AC or a DC source? Explain. (2 marks)

Description	Marks
DC	1
Split ring commutator present	1
Total	**2**

(b) Show with arrows, the direction of the magnetic field surrounding the coil ABCD. (2 marks)

Description	Marks
Field is left to right	1
Straight arrows shown parallel to pane of ABCD	1
Total	**2**

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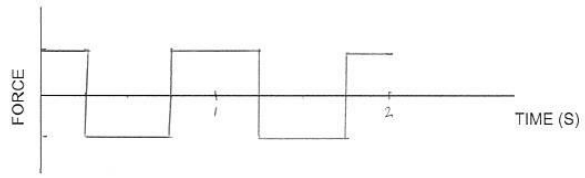
(c) As viewed from P, in what direction does the coil ABCD rotate? Circle the correct answer. (1 mark)

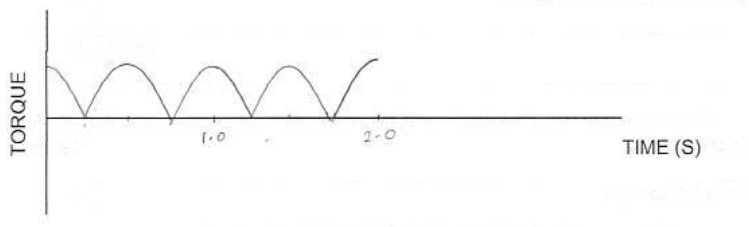
Description	**Marks**
clockwise	1
Total	**1**

(d) The motor is rotating at a constant rate of one rotation per second. On the axes below, show:

(i) How the force on AB varies over for the first two seconds of rotation from the position shown. (Note: specific values on the force axis are not required). (2 marks)

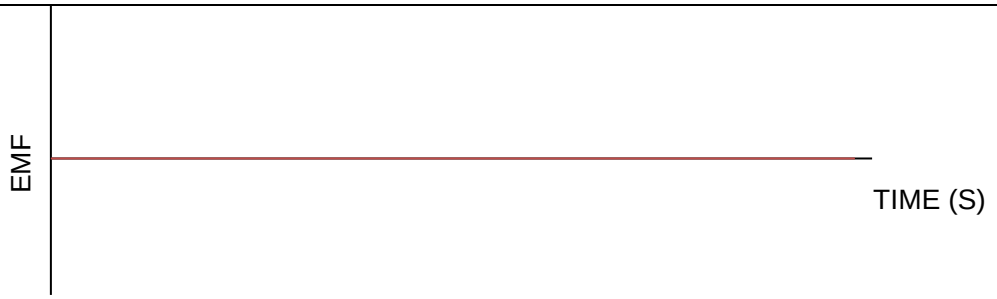
Description	**Marks**
	
Graph is stepwise (not curved)	1
Graph alternates between positive and negative force with a period of 1 second	1
Total	**2**

(ii) How the torque on coil ABCD varies over for the first two seconds of rotation from the position shown. (2 marks)

Description	**Marks**
	
Graph is cosinusoidal and positive i.e. absolute value of cosine. Starts positive.	1
Graph alternates between maximum and zero torque with a period of 0.5 second	1
Total	**2**

See next page

(e) Anil decides to remove the power supply and rotate coil ABCD to produce an emf. On the axes below, show how the emf produced varies with time. Explain any features of your sketched graph. (3 marks)

Description	Marks
	
NO emf is produced. Straight line along time axis.	1
The magentic field is provided by (stator) windings and without an applied emf (or permanent magnetic field), no field is present and therefore no emf is induced.	0-2
Total	**3**
• Fun fact: Western Power has battery banks for "cold starts" when the grid has zero emf to activate field windings in its generators	

Question 19 **(19 marks)**

(a) Explain why it is preferential to use protons or muons in particle accelerators compared to electrons. (2 marks)

Description	Marks
Either: Protons and muons have much greater mass which means that much more energetic collisons are possible.	**0-2**
Or: Protons and muons due to their mass, lose much less energy in accelerators than lightweight particles such as electrons.	**0-2**
Total	**2**

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(b) Explain the advantages associated with colliding muons compared with protons in particle accelerators. (2 marks)

Description	Marks
Muons are elementary particles and do not consist of bound quarks.	1
Protons are hadrons and consist of bound quarks, and when collided, only 1/6 of the energy is available for new particle production.	0-2
Total	**2**

(c) The article states that muon collision would be a superior method than electron/positron collision for large scale production of Higgs bosons. What is the practical advantage of using muon collisions and explain the Physics of how muon collisions would give rise to more Higgs bosons, compared with electron/positron collisions. (3 marks)

Description	Marks
Muons colliders would only need to have a circumferance of 0.3 km, compared to conventional linear accelerators 20 – 30 km in length.	1
The Higgs boson is a fairly massive particle, therefore incredibly energetic collisions are required for its production. Unlike in electron – positron annihilation, because muons have 200 times their mass (from data sheet) their collisions would produce far more Higgs bosons.	0-2
Total	**3**

(d) Explain why it is necessary to cool the beam of muons prior to colliding them. (1 mark)

Description	Marks
Cooloing the muon beam decreases its spread.	1
Total	**1**

(e) The article mentions “focusing magnets”. Explain how magnets could be used to focus a beam of muons. (2 marks)

Description	Marks
Any moving charged particle perpendicular to a magnetic field will experience a force perpendicular to its motion. This force could be used to focus or concentrate a beam of muons.	0-2
Total	**2**

See next page

(f) A particular linear accelerator has a length of 5.00 km. Calculate the potential difference requires to accelerate an electron to a speed of 0.1 c. You may ignore any relativistic effects. (3 marks)

Description	Marks
KE gained = ½ mv^2 = (½)(9.11 x 10^{-31})(3 x 10^7)^2	1
= 4.10 x 10^{-14} J	1
W = Vq V = W/q = 4.10 x 10^{-14}/1.6 x 10^{-19} = 2.56 x 10^5 V	1
Total	3

(g) Muons are highly unstable and have a typical half-life of 2.2 μs. In a future particle accelerator, muons are accelerated to speeds of 0.995 c.

(i) Calculate the half-life a muon travelling at this speed, in the reference frame of the observers at the particle accelerator. (3 marks)

Description	Marks
$$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$$ $$t = \frac{2.2}{\sqrt{1-\frac{(0.995c)^2}{c^2}}}$$	1
= 2.2/ 0.09987	1
= 22.0 μs	1
Total	3

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(ii) Calculate the kinetic energy of these muons, in the reference frame of observers at the particle accelerator. (3 marks)

Description	Marks
$$KE = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2$$ $$KE = \frac{105.7}{0.09987} - 105.7$$	0-2
= 953 MeV	1
Total	3

Question 20 **(19 marks)**

(a) Explain why black bodies are called "black bodies". (2 marks)

Description	Marks
They absorb all incident radiation and therefore appear totally black.	0-2
Total	2

(b) In terms of photon energy, why do hotter stars emit shorter wavelength light? (3 marks)

Description	Marks
Hotter stars will emit more energetic photons $E = hf = hc/\lambda$ i.e. The energy of emitted photons is inversely proportional to wavelength and shorter wavelength photons are more energetic.	0-2
Total	2

(c) Explain why all three stars in the figure have the same maximum intensity. (2 marks)

Description	Marks
The y axis shows the normalised intensity. i.e. all intensity values for a particualr star have been divided by the maximum intensity for that star. Max = 1	0-2
Total	2

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(d) Using information from the article and data from the Formula and Data booklet, show that the luminosity of the Sun is approximately 3.8×10^{26} W m^{-2}. (4 marks)

Description	Marks
$L = \sigma 4\pi R^2 T^4$	1
$= (5.67 \times 10^{-8})(4\pi)(6.96 \times 10^8)^2(5800)^4$	0-2
$= 3.90 \times 10^{26}$ W m^{-2}	1
Total	4

(e) Some data for the variable star Betelgeuse are given below.

Average apparent brightness = 1.6×10^{-7} Wm^{-2}

Radius = 79 solar radii

Earth – Betelgeuse distance = 1.38×10^{-4} Mpc

(i) Calculate the distance between the Earth and Betelgeuse in metres. (2 marks)

Description	Marks
1 Mpc = 3.09×10^{19} km (from data sheet) $D = 1.38 \times 10^{-4} \times 3.09 \times 10^{19} \times 10^3$	1
$= 4.26 \times 10^{18}$ m	1
Total	2

(ii) Calculate the luminosity of Betelgeuse. (3 marks)

Description	Marks
$b = \frac{L}{4\pi d^2}$ $1.6 \times 10^{-7} = \frac{L}{4\pi(4.26 \times 10^{18})^2}$	0-2
$L = 3.65 \times 10^{31}$ W m^{-2}	1
Total	3

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_____ Wm^{-2}

(iii) Calculate the surface temperature of Betelgeuse. (3 marks)

Description	**Marks**
$L = \sigma 4\pi R^2 T^4$ $3.65 \times 10^{31} = (5.67 \times 10^{-8})(4\pi)(79 \times 6.96 \times 10^8)^2(T)^4$	**0-2**
$T = 11{,}400\ K$	**1**
Total	**3**

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