Government of **Western Australia**
School Curriculum and Standards Authority

PHYSICS

ATAR course examination 2020

Marking key

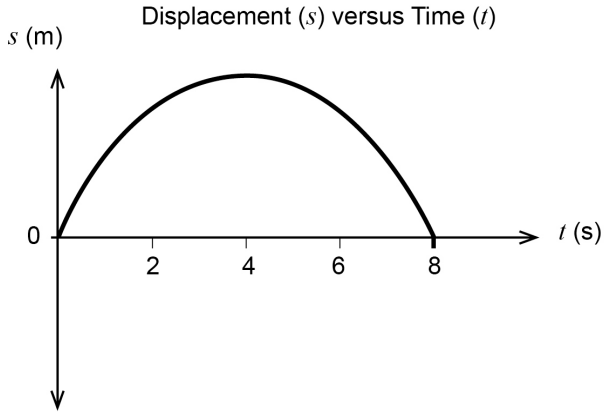
Marking keys are an explicit statement about what the examining panel expect of candidates when they respond to particular examination items. They help ensure a consistent interpretation of the criteria that guide the awarding of marks.

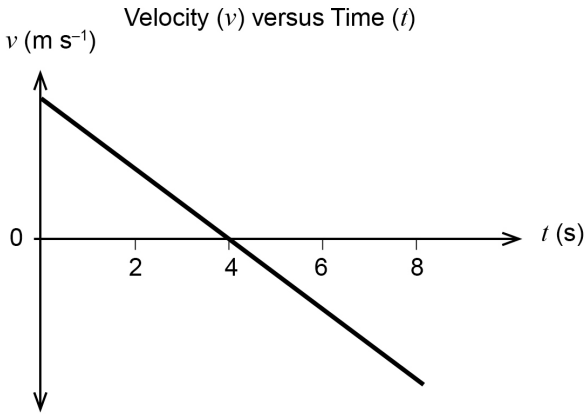
2020/65776

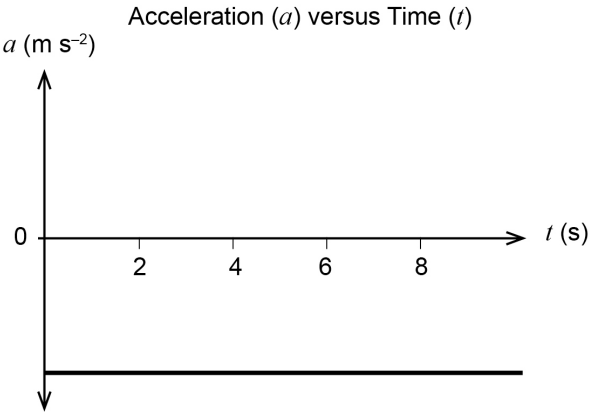
Section One: Short response **30% (53 Marks)**

Question 1 **(3 marks)**

A ball is launched vertically into the air with an initial velocity at t = 0 from ground level (s = 0) and returns to ground level. It takes four seconds for it to reach its maximum height. Taking upwards as positive, graph the ball's displacement, velocity and acceleration versus time from take-off to landing. Ignore air resistance and do not place any values on the y-axis.







Description	Marks
1 mark for each graph completely correct.	1–3
apex of parabola must be at 4.0 s. Velocity graph must go through (4,0).	
Total	**3**

Question 2 **(3 marks)**

Calculate the speed of an electron with a de Broglie wavelength of 1.23 nm.

Element	Description	Marks
substitutes mv for p and rearranges equation	$v = h/m\lambda$	1
uses m(e) and converts nm to m	$v = 6.63 \times 10^{-34} / 9.11 \times 10^{-31} \times 1.23 \times 10^{-9}$	1
performs calculation correctly	$= 5.91 \times 10^{5}$ m s^{-1}	1
	Total	**3**

Question 3 **(4 marks)**

A 10.0 watt monochromatic LED radiates light with a wavelength of 525 nm. How many photons does it emit per second? Assume all the energy is converted to light.

Element	Description	Marks
substitutes c/λ for f	$E = ch/\lambda$	1
converts nm to m and calculates energy of one photon	$E = (3.0 \times 10^{8} \times 6.63 \times 10^{-34)}/(525 \times 10^{-9})$ $E = 3.79 \times 10^{-19}$J	1
divides 10.0 J by energy of one photon	$= 10.0/3.79 \times 10^{-19}$	1
correct/consistent numerical answer	$= 2.64 \times 10^{19}$	1
	Total	**4**

Question 4 **(4 marks)**

(a) Calculate the magnetic field strength 25.1 cm from the vertical wire carrying a current of 2.78 A. (3 marks)

Element	Description	Marks
correct constant and conversion from cm to m	$B = (1.26 \times 10^{-6}) \times 2.78/(2\pi \times 0.251)$	1–2
correct answer	2.22×10^{-6} T	1
	Total	**3**

(b) Looking from above, which of the following diagrams shows the magnetic field around the wire correctly? (1 mark)

Description	Marks
A	1
Total	**1**

Question 5 **(4 marks)**

Emma stands 20.0 cm from the end of a 5.20 m long uniform diving board. Calculate the upwards force the support must exert on the 50.0 kg board for the system to remain in equilibrium.

Element	Description	Marks
takes moments around hinge	$\Sigma acm = \Sigma cm$	1
correctly identifies direction of moments	$(m_E \times g \times 5.0) + (m_b \times 9.8 \times 2.6) = 2F$	1
uses 5.0 m not 5.2 m, 2.6 m not 2.5 m	$(40 \times 9.8 \times 5.0) + (50 \times 9.8 \times 2.6) = 2F$	1
correct/consistent answer	1620 N or 1.62×10^3 N	1
	Total	**4**

Question 6 **(4 marks)**

(a) Calculate the electric field strength 2.25×10^{-3} m from a point charge of 4.00×10^{-18} C. (4 marks)

Element	Description	Marks
uses Coulomb's Law	$F = qq/4\pi\varepsilon r^2$	1
divides both sides by q to get E on LHS and eliminate q on RHS	$E = q/4\pi\varepsilon r^2$	1
uses correct constant and squares r	$E = (4.00 \times 10^{-18})/(4\pi \times 8.85 \times 10^{-12}) \times (2.25 \times 10^{-3})^2$	1
correct/consistent numerical answer	7.11×10^{-3} N C^{-1}	1
	Total	**4**

Question 7 **(5 marks)**

(a) Explain why the disc with the magnet slows down quickly. (4 marks)

Description	Marks
aluminium is a conductor	1
The changing magnetic field due to the magnet moving induces eddy currents in the aluminium.	1
Lenz's Law states that an induced current will flow in a way to oppose the change producing it.	1
The disc experiences a retarding force so it slows down.	1
Total	**4**

(b) The students deduce that the retarding force on the disc with the magnet is proportional to the speed of the disc. Which set of velocity and acceleration versus time graphs below best describe the motion of the disk with the magnet? (1 mark)

Description	Marks
B	1
Total	**1**

Question 8 **(5 marks)**

(a) What property of light causes this to happen? Circle your answer. (1 mark)

Description	Marks
wave	1
Total	**1**

(b) Explain how **both** the light and dark fringes are formed. (4 marks)

Description	Marks
as light waves pass through narrow slits they spread out: diffraction	1
the two waves interfere with each other to form an interference pattern on the screen	1
when the two waves are in phase, constructive interference when the two waves meet 180 degrees out of phase, destructive interference	1
constructive interference occurs: bright fringe destructive interference occurs: dark fringe	1
Total	**4**

Question 9 **(4 marks)**

With reference to the graph of γ vs β (v/c) and the equation for relativistic energy, explain why it is impossible for any particle with mass to achieve the speed of light.

Description	Marks
as v approaches c, β approaches 1	1
as β approaches 1, γ approaches infinity	1
to accelerate the mass particle to a greater speed requires energy	1
to achieve c, a mass particle requires infinite energy which is impossible	1
Total	**4**

Question 10 **(6 marks)**

A golfer hits a ball at 37.0 m s^{-1} at 31.0° to the horizontal on a flat fairway. It travels 123 m. She wants to hit a target 135 m away, so she increases the angle at which she hits the ball, without changing the launch speed. Calculate the smallest increase of angle that allows her to reach the target. (Hint: $2\sin\theta\cos\theta = \sin 2\theta$)

Element	Description	Marks
expresses t as range over horizontal velocity	$t = 135/37\cos\theta$	1
substitutes time into equation for vertical displacement ($s = 0$)	$0 = 37\sin\theta - 4.9\,(135/37\cos\theta)$ $37^2\sin\theta\cos\theta = 4.9 \times 135$	1–2
solves for angle using expression given	$\sin 2\theta = 2 \times 4.9 \times 135/37^2$ $2\theta = 75.1°$ $\theta = 37.5°$	1–2
subtracts initial angle to find change of angle	$37.5 - 31 = 6.5°$	1
	Total	**6**
Note: other equivalent methods can be used, such as $v = u + at$ or $s = ut + \frac{1}{2}at^2$ to get an expression that eliminates t		

Question 11 **(6 marks)**

(a) What is the magnitude of the acceleration of the books? (3 marks)

Element	Description	Marks
subtracts the weight force from the total upwards force	F_{net} = 32.4 – (3 × 9.8) = 3.0 N	1–2
uses net force to calculate the acceleration	$a = F/m$ = 3.0/3.0 = 1.00 m s^{-2}	1
	Total	**3**

(b) What is the magnitude of the force that the 2.00 kg book exerts on the 1.00 kg book during this acceleration? (3 marks)

Element	Description	Marks
adds weight force to net force to get total force	$F_{Tot} = mg + ma$ = 9.8 + 1.0	1–2
correct/consistent answer	10.8 N	1
	Total	**3**

Question 12 **(5 marks)**

(a) Choose the appropriate combination of relevant fundamental force and property from the table below that corresponds to the gauge bosons listed. Place the number of your choice in the spaces provided. (4 marks)

Description	Marks
(i) 1	1
(ii) 5	1
(iii) 4	1
(iv) 4	1
Total	**4**

(b) Which of the fundamental forces below has the longest range of interaction? (1 mark)

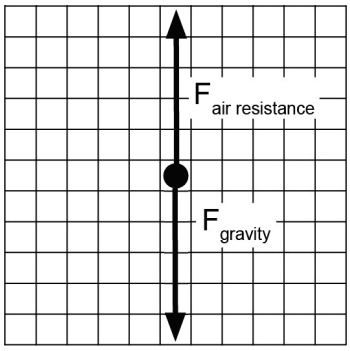
i. weak nuclear
ii. electromagnetic
iii. strong nuclear

Description	Marks
(ii)	1
Total	**1**

Section Two: Problem-solving **50% (92 Marks)**

Question 13 **(10 marks)**

(a) On the grid below, draw a free body diagram showing all the forces acting on the oil drop as it falls. (2 marks)



Description	Marks
correctly labelled weight and air resistance forces	1
must be equal magnitude	1
Total	**2**

(b) Name the **two** forces now acting on the oil drop. (2 marks)

Description	Marks
weight force	1
electrostatic force	1
Total	**2**

(c) If the plate separation is 7.71 mm, what is the electric field strength experienced by the oil drop? (2 marks)

Element	Description	Marks
converts mm to m	$E = V/d = 346/7.71 \times 10^{-3}$	1
correct/consistent answer	4.49×10^{4} V m^{-1}	1
	Total	**2**

(d) Calculate the electric charge of the oil drop. (3 marks)

Element	Description	Marks
rearranges $E = F/q$ and substitutes mg for F	$q = mg/E$ $q = (6.88 \times 10^{-16}) \times (9.8/4.49 \times 10^{4})$	1–2
correct/consistent answer	$q = 1.50 \times 10^{-19}$ C	1
	Total	**3**

(e) Solely on the basis of this data, what does the student estimate the electron charge is most likely to be? (1 mark)

Description	Marks
1.50×10^{-19} C	1
Total	**1**

Question 14 **(15 marks)**

(a) Complete the table below and use your answers to identify the missing particle X. (3 marks)

Description	Marks
charge = +1	1
lepton number = $^{-}1$	1
particle is a positron	1
Total	**3**

(b) Use non-relativistic physics to calculate the mean distance muons moving at 2.991×10^8 m s^{-1} could travel. (2 marks)

Description	Marks
$s = vt$	1
$s = 2.991 \times 10^8 \times 2.20 \times 10^{-6} = 658$ m	1
Total	**2**

(c) (i) Calculate the mean lifetime of muons travelling at $0.997c$ as observed from the Earth. (2 marks)

Element	Description	Marks
uses time dilation formula correctly	$t = \gamma \times 2.20 \times 10^{-6}$	1
correct/consistent answer	$= 2.84 \times 10^{-5}$ s	1
	Total	**2**

(ii) What is the actual mean distance travelled by such muons through the atmosphere as observed from the Earth? (2 marks)

Description	Marks
$s = vt = 2.84 \times 10^{-5} \times 2.991 \times 10^8 = 8494$ m	1
$s = 8.49$ km (correctly converts to km)	1
Total	**2**

(d) Using information from the question, explain why a small number of muons reach the Earth. (2 marks)

Description	Marks
The lifetime is a mean lifetime. Some will live longer and reach the Earth.	1
The muons with a longer lifetime due to time dilation will live long enough to reach Earth.	1
Total	**2**

(e) With the use of a calculation, explain why these muons reach the Earth from the perspective of the muons. (4 marks)

Element	Description	Marks
uses length contraction formula correctly	$l = l_o / \gamma$	1
calculates length contraction correctly	l = 7.746 × 10^{-1} km	1
calculates lifetime required to reach Earth	t = 774.6/2.991 × 10^{8} = 2.59 × 10^{-6} s	1
compares time to mean lifetime	this is slightly greater than the mean lifetime of 2.20 × 10^{-6} s therefore some muons reach Earth	1
	Total	**4**

Question 15 **(12 marks)**

(a) Calculate the velocity of Harper as measured by Adhita. (4 marks)

Element	Description	Marks
uses consistent sign convention.	v = -0.5c u = 0.75c	1
correctly identifies frames of reference	looking for u'	1
enters correct values and directions into correct equation.	u' = (0.75c – (-0.5c))/(1 – (0.75 x -0.5))	1
correct answer	0.909c	1
can be solved from Earth's perspective finding u', where u = 0.93c and v = –0.50c		
	Total	**4**

(b) Harper fires a missile with a velocity of 0.600c with respect to her in the direction of Adhita. Calculate the velocity of the missile as measured by an observer on the Earth. (4 marks)

Element	Description	Marks
uses correct sign convention	all velocities are positive	1
correctly identifies FOR	looking for u	1
enters correct values into correct equation	(0.75 + 0.6)c/(1 + (0.75 × 0.6))	1
correct/consistent answer	0.931c	1
	Total	**4**

(c) Calculate the velocity of the missile as measured by Adhita. (4 marks)

Element	Description	Marks
uses consistent sign convention	all velocities are positive	1
correctly identifies FOR	looking for u	1
enters correct values into correct equation	u = (0.91 + 0.6)c/(1 + (0.91 × 0.6))	1
correct/consistent answer	u = 0.976c	1
	Total	**4**
Note: The problem can be resolved from Earth's perspective using u', where u = 0.931c and v = -0.500c		

Question 16 **(12 marks)**

(a) Calculate the maximum EMF produced by the generator. (5 marks)

Element	Description	Marks
uses correct equation	$EMF_{max} = 2\pi NBAf$	1
converts rpm to Hz	240 rpm = 4 Hz	1
converts cm to m	6.0 cm = 0.06 m	1
converts mT to T	1.85×10^2 mT = 0.185 T	1
correct answer	2.51 V	1
	Total	**5**

(b) Calculate the RMS voltage produced. (1 mark)

Description	Marks
$emf_{rms} = 2.51/\sqrt{2} = 1.78$ V	1
Total	**1**

(c) (i) Explain why the force required varied as the handle went through one rotation. (3 marks)

Element	Description	Description	Marks
Recognises that emf varies as rate of change of flux varies as coil rotates.	The amount of flux through the coil varies with $\sin\theta$. As rotational speed is constant, rate of change of flux also varies.	Conservation of energy. As electrical energy is produced, mechanical energy must be consumed.	1
Links light produced with greater emf.	The light is brighter when the emf is greatest.	When the light is brightest, maximum work must be done by the student turning the handle.	1
Recognises that force required will increase as greater emf is produced.	The induced emf is trying to stop the coil rotating therefore the greater the emf the greater the force required to maintain constant speed.	As the speed of rotation is kept constant, the force required to turn the handle is greatest when the most electrical energy is produced.	1
		Total	**3**

(ii) In what position was the plane of the rotating coil relative to the field when the light bulb went out? Explain why it went out. (3 marks)

Description	Marks
perpendicular	1
when perpendicular to the field, rate of change of flux = 0	1
therefore emf = 0 so no current produced	1
Total	**3**

Question 17 **(10 marks)**

(a) Calculate the period of the satellite. (5 marks)

Element	Description	Marks
converts km to m	$T^2 = 4\pi^2 (4.0 \times 10^6 + 6.37 \times 10^6)^3 / (6.67 \times 10^{-11} \times 5.97 \times 10^{24})$	1
adds altitude to radius of Earth		1
cubes distance and square roots answer		1
correct answer	1.05×10^4 s	1
converts to hours	2.92 hours	1
	Total	**5**

(b) (i) With reference to Kepler's Third Law, describe how a straight line graph could be generated using the same two variables. (Do not refer to logarithms.) (2 marks)

Description	Marks
in Kepler's 3rd Law, T^2 is proportional to r^3	1
graph T^2 vs r^3	1
Total	**2**

(ii) Explain how you could use the gradient of this straight line and Kepler's Third Law to estimate the magnitude of the Newtonian constant of gravitation (G). (Do not try to calculate G from the graph.) (3 marks)

Element	Description	Marks
isolates expression for gradient from Kepler's Third Law.	gradient = $T^2/r^3 = 4\pi^2/GM$	1
isolates G from equation including gradient	G = 1/gradient × $4\pi^2/M$	1
recognises M (of the Sun) is constant therefore G can be calculated		1
	Total	**3**

Question 18 **(14 marks)**

(a) Calculate the tension in the rope when the drawbridge is just lifted off the rest on the other side of the moat. (4 marks)

Element	Description	Marks
takes moments around hinge	$acm = cm$	1
identifies acm and cm	$T \times d = 500 \times 9.80 \times 3.00$	1
calculates perpendicular distance from hinge to rope	$d = 6 \sin 35$	1
correct answer	$T = 4270$ N or 4.27×10^3 N	1
	Total	**4**

(b) Calculate the reaction force of the hinge (O) on the drawbridge at this point. (5 marks)

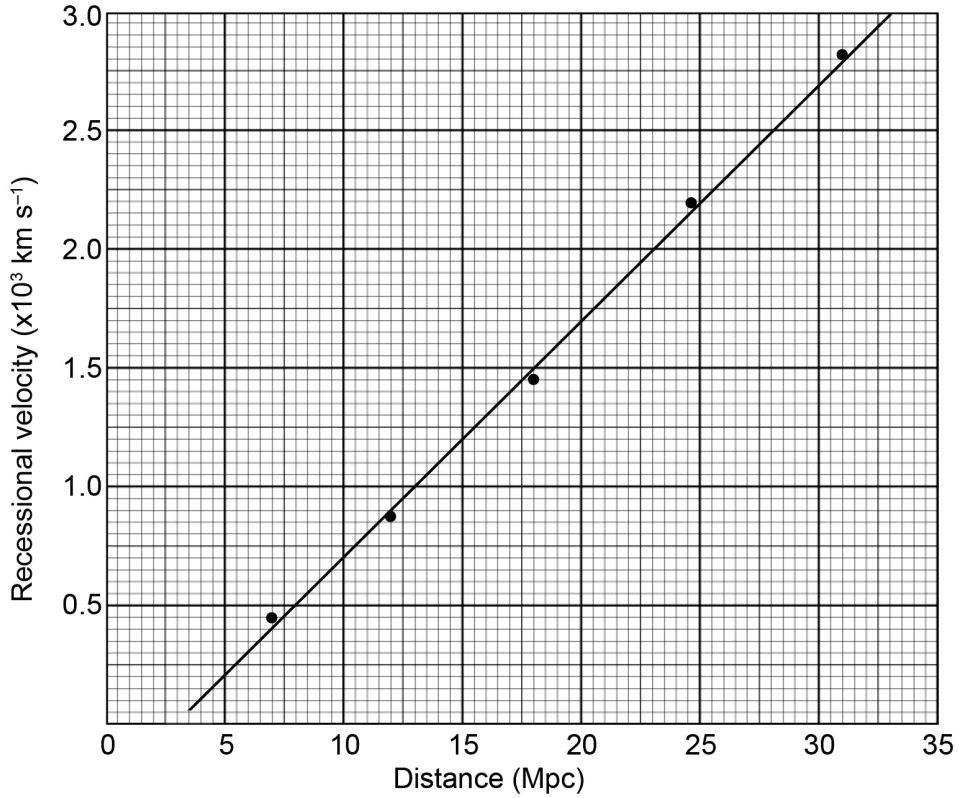
Element	Description	Marks
Calculates the horizontal component of the reaction force from horizontal component of tension.	$R_H = 4271 \cos 35 = 3500$ N	1
Calculates vertical component of reaction force by subtracting vertical component of T from mg.	$R_V = mg - T_V = 4900 - 4271 \sin 35$ $= 2450$ N	1
Adds the two components using Pythagoras.	$R_N^2 = 3500^2 + 2450^2$	1
correct answer	4271 N	1
calculates angle correctly	$\tan \Theta = 2450/3500$ $\Theta = 35.0°$	1
	Total	**5**
Note: Candidates could identify that $R = T$ through vector diagram but they would have to give a good explanation of what they did.		

(c) Calculate the new tension in the rope as he hangs from the end. Assume the drawbridge is stationary at this time. (5 marks)

Element	Description	Marks
takes moments around hinge	$acm = cm$	1
correctly identifies acm and cm	$T \times d_1 = (m_d \times g \times d_2) + (m_s \times g \times d_3)$	1
calculates three new distances from pivot	$d_1 = 6.00 \sin 40 = 3.86$ m $d_2 = 3.00 \cos 15 = 2.90$ m $d_3 = 6.00 \cos 15 = 5.80$ m	1–2
correct/consistent answer	5080 N or 5.08×10^3 N	1
	Total	**5**

Question 19 **(19 marks)**

(a) Graph the recessional velocity versus distance on the set of axes provided below and draw a line of best fit. Do not take your line through the origin. (3 marks)



Description	Marks
correctly plotted all points	1
line of best fit clear and straight	1
not connected to origin	1
Total	**3**

(b) Use two non-data points on your line of best fit to calculate Hubble's constant. Circle the two points you used and give your answer to two significant figures. (4 marks)

Element	Description	Marks
uses non data points		1
circles points used		1
calculates gradient	$\Delta y/\Delta x$	1
two significant figures	0.10×10^3 km s^{-1} Mpc^{-1}	1
	Total	**4**
Note: accept gradient between 0.095 to 0.105		

(c) (i) The galaxy NGC 2013 is 7.42×10^7 ly away from the Earth. Convert this distance into megaparsecs (Mpc). (2 marks)

Description	Marks
uses conversion factor from data sheet	1
$(7.42 \times 10^7)/(3.26 \times 10^6) = 22.8$ Mpc	1
Total	**2**

(ii) Using your line of best fit and the value from part (c)(i), calculate the observed red-shifted wavelength emitted from NGC 2013 if λ_0 is 840.0 nm. (6 marks)

Element	Description	Marks
correctly locates value of distance corresponding to value in part (i)		1
correctly reads velocity	2.0×10^3 km s^{-1}	1
uses correct values in calculation	$\Delta\lambda = 2.0 \times 10^6 \times 840 \times 10^{-9}/3.0 \times 10^8$	1–2
calculates $\Delta\lambda$ correctly/consistently	$\Delta\lambda = 5.6 \times 10^{-9}$ m = 5.6 nm	1
adds $\Delta\lambda$ to λ_0	840.0 + 5.6 = 845.6 nm	1
	Total	**6**

(d) In Hubble's early data, he noticed that one particular spiral galaxy close to the Earth, seen edge on, had two values of v at its extremes. One was positive and one was negative. Assuming this was not an instrumental or human error, explain how this could occur. (4 marks)

Description	Marks
Positive value of v means galaxy is moving away from observer.	1
Negative value of v means light is blue shifted and galaxy is moving towards the Earth.	1
This means galaxy is swirling where one side is coming towards the Earth.	1
Rotational speed of side of galaxy must be greater than recessional velocity of galaxy.	1
Total	**4**

Section Three: Comprehension **20% (39 Marks)**

Question 20 **(19 marks)**

(a) The diagram above shows the acceleration of a positive particle in a cyclotron. Describe one change that would need to be made in order to use the same machine to produce a beam of negatively-charged particles exiting from the same place, and explain why. (3 marks)

Description	Marks
reverse the direction of the magnetic field	1
The direction of the force on the negatively-charged particle will be in the opposite direction.	1
This will negate the reversal of force direction due to change of charge so the particles will go in the same direction as before.	1
Total	**3**

(b) (i) Calculate the wavelength of the photons produced in the annihilation described in the diagram above. (3 marks)

Element	Description	Marks
substitutes c/λ for f	$E = hf = ch/\lambda$	1
converts Ev to Joules	$= (3.0 \times 10^{8} \times 6.63 \times 10^{-34})/(511 \times 10^{3} \times 1.6 \times 10^{-19})$	1
correct answer	$= 2.43 \times 10^{-12}$ m	1
	Total	**3**

(ii) To which part of the electromagnetic spectrum does the photon belong? (1 mark)

Description	Marks
gamma rays or x-rays	1
Total	**1**

(c) Explain why increasing the strength of the magnetic field would increase the velocity of the particles leaving the cyclotron. (4 marks)

Description	Marks
$r = mv/Bq$	1
as B increases, r decreases	1
If r decreases, the number of revolutions before exiting increases.	1
The particle accelerates every time in passes between the dees so its velocity will be greater when it exits.	1
Total	**4**

(d) (i) Explain why the voltage across the dees must alternate. (2 marks)

Description	Marks
In order to accelerate across a potential difference, the plate opposite must have the opposite charge to the particle to attract it.	1
When the particle approaches the electric field from the opposite direction, the polarity of the field must change for the acceleration to remain positive.	1
Total	**2**

(ii) Derive an expression for the cyclotron frequency and use the expression to explain why this statement is correct. (Ignore relativistic effects.) (6 marks)

Description	Marks
$r = mv/Bq$	1
$v = rBq/m$	1
$T = 2\pi r/2v$ or $v = \pi r/T$ (or $v = 2\pi r/T$)	1
substitute f for $1/T$	1
$\pi rf = Bqr/m$ or $f = Bq/\pi m$	1
frequency is independent of both velocity and radius of the circular path	1
Total	**6**

Question 21 **(20 marks)**

(a) (i) Explain why a step-up transformer is used to increase the voltage before transporting the electricity into the National Grid. Use specific equations in your answer. (4 marks)

Description	Marks
It is more efficient to step-up the voltage.	1
$P = VI$ so if we increase V we have less current for the same power.	1
$P_{lost} = I^2R$ power is lost as heat	1
The lower the current, the lower the power lost due to heat.	1
Total	**4**

(ii) Calculate the output voltage of the transformer if the turbine produces 690 V and the ratio of turns is 100 in the primary coil to 2500 in the secondary coil. (2 marks)

Element	Description	Marks
uses ratio of coils = ratio of voltages correctly	$V_S = N_S V_P / N_P$	1
correct answer	= 2500 × 690/100 = 17.2 kV	1
	Total	**2**

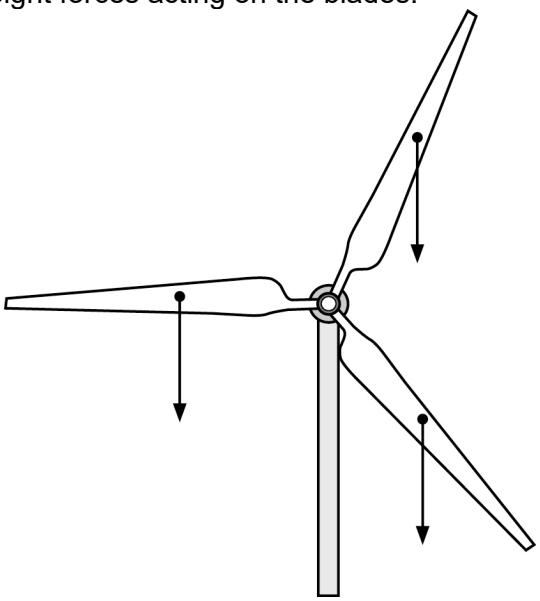
(b) With specific reference to the text, explain why the pitch of the rotor blades is changed by the operators of the turbine. (4 marks)

Description	Marks
The power input (wind energy) must match the power output (voltage produced).	1
The power output depends on rotational speed which must be kept constant.	1
The operators use pitch control which changes the angle of the blades.	1
This reduces or increases the amount of energy collected by the turbine and controls the force applied.	1
Total	**4**

(c) If the 60 m long blades on an average sized turbine are rotating at 0.20 Hz, estimate the speed of the centre of mass of one of the blades. (4 marks)

Element	Description	Marks
Takes average length of 60 m and estimates the distance of COM from pivot as less than half of the length.	Take COM as 20 m from pivot	1
converts f to T	0.2 Hz = 5 s period	1
uses v = circ/T	$v = 2\pi \times 20/5 = 25$ m s^{-1}	1
two significant figures		1
	Total	**4**

(d) (i) Draw the weight forces acting on the blades. (2 marks)



Description	Marks
all three mg drawn equal distance from axle along blade	1
all same size	1
Total	**2**

(ii) Show mathematically that the turbine is balanced in this position. (4 marks)

Element	Description	Marks
calculates angles correctly	Angle between blades is 120° therefore angle to calculate r is 60°	1
identifies acm and cm correctly in equation and	$(mg \times r\cos 60) + (mg \times r\cos 60) = mg \times r\cos 0$	1
derives the correct moment equation		1
solves equation to show LHS = RHS	$\cos 60 + \cos 60 = \cos 0$ $0.5 + 0.5 = 1.0$	1
	Total	**4**

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