Government of Western Australia
School Curriculum and Standards Authority

PHYSICS

Sample

WACE Examination 2016

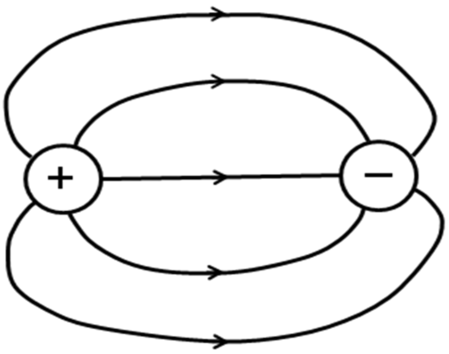
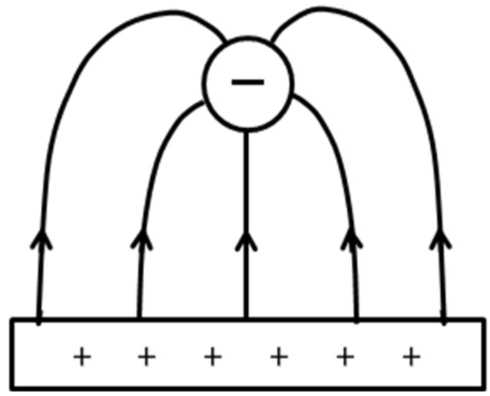
Marking Key

Marking keys are an explicit statement about what the examiner expects of candidates when they respond to a question. They are essential to fair assessment because their proper construction underpins reliability and validity.

Section One: Short response **30% (54 Marks)**

Question 1 **(3 marks)**

Draw the resultant electric field with at least **five** lines for each of the following situations.

Two opposite but equally-charged spheres	A charged sphere near a charged conductive plate
	

Description	Marks
Field lines are from positive to negative	1
90° entry/exit and no crossing over	1
Evenly distributed across plate	1
Total	**3**

Question 2 **(4 marks)**

The diagram below shows five points, labelled 'A' to 'E', in free space around a large mass M. You may wish to use a ruler to help you to answer this question.

	Point		Point
Which two points have the same magnitude of gravitational field strength due to M?	**A**	and	**C**

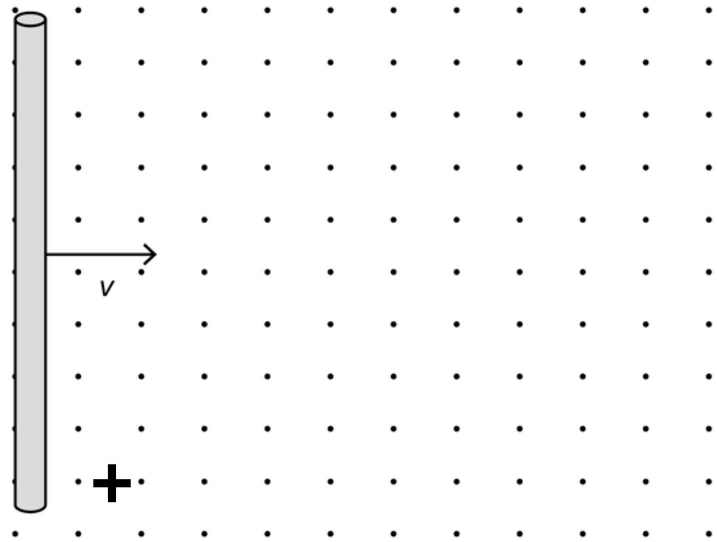
	Point		Point
Which two points experience the same direction of gravitational field due to M (as viewed in this diagram)?	**C**	and	**D**

	Point E		Point B
What is the ratio of the gravitational field strength at E to the gravitational field strength at B?	**9**	**:**	**1**

Description	Marks
A and C	1
C and D	1
9 : 1 (only 1 mark if distance measured to surface, 36 : 1 <u>OR</u> ratio reversed, 1: 9)	1–2
Total	**4**

Question 3 **(3 marks)**

A 12.5 cm long piece of copper wire is moved at a constant velocity of 6.56 m s^{-1} through a magnetic field of 0.150 T. Calculate the potential difference between the ends of the wire and indicate on the diagram which end of the wire is positive.



B field out of the page

Description	Marks
emf = $v\ell B = 6.56 \times 0.125 \times 0.150$	1
emf = 0.123 V	1
Bottom is positive	1
Total	**3**

Question 4 **(4 marks)**

All hadrons are composed of different combinations of fundamental particles called quarks.

Baryons are made from a combination of three quarks; antibaryons are made from a combination of three antiquarks; and mesons are made from two quarks; a quark and an antiquark.

All quarks have a baryon number of $+\frac{1}{3}$; all antiquarks have a baryon number of $-\frac{1}{3}$; all baryons have a baryon number of +1.

(a) A pion is a meson. Determine the baryon number of the pion. (1 mark)

Description	Marks
+1/3 – 1/3 = 0	1
Total	**1**

Baryon number **must** be conserved in all reactions.

(b) Determine, by applying conservation of baryon number, whether the following reaction can take place. Justify your answer with appropriate workings. (3 marks)

proton + neutron → proton + pion

Description	Marks
Total baryon number on LHS = 1 +1 = 2	1
Total baryon number of RHS = 1 + 0 = 1	1
Reaction **cannot** occur as baryon number before and after reaction is not conserved.	1
Total	**3**

Question 5 **(4 marks)**

Bathroom scales measure weight (a force) but give the reading in kilograms (mass). A particular scale shows a person's mass as being 70 kg at the Earth's equator. The spinning of the Earth contributes to the scale's reading. What would the scale read at the South Pole, with the same person standing on it? (Circle the correct answer.)

the same less than 70 kg more than 70 kg

Explain your reasoning:

Description	Marks
'More than 70 kg' circled	1
Part of the gravitational force is used to provide centripetal force at the equator $F_g=F_w+F_c$ The centripetal force is zero at the poles so the weight force is correspondingly larger	1–3
or The Earth is not spherical. You are slightly closer to the Earth's centre at the poles so the gravitational force is slightly larger at the poles, hence weight is larger at the poles.	1–3
Total	**4**

Question 6 **(4 marks)**

Calculate the wavelength of the photon emitted in the transition from the level with energy of 136 keV to the level with energy of 14.4 keV.

Description	Marks
Energy of photon 136 keV – 14.4 keV = 121.6 keV	1
Convert to J 121.6 keV × 1000 × 1.6 ×10^{-19} C = 1.95 × 10^{-14}J	1
$\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.95 \times 10^{-14}}$	1
λ = 1.02 × 10^{-11} m	1
Total	**4**

Question 7 **(5 marks)**

Mick is watering the lawn and wants to estimate the initial velocity of the water coming from the hose. Use information from the photograph to estimate the magnitude of the initial velocity of the water. Express your answer to an appropriate number of significant figures.

Description	Marks
Estimate initial height 1.5 m Estimate distance = 1.5 m (accept 1–2 m as 1 sig fig)	1
s = ut + ½ at^2 (1 mark using an appropriate formula with u_v = 0)	1
1.5 = 0t + ½ $9.8t^2$ t = √(2 × 1.5/9.8) = 0.55 s (accept 0.45 s to 0.63 s)	1
v = s/t = 1.5/0.55 = 2.7 m s^{-1} (2.2 to 3.1 acceptable)	1
(1 mark answer to one or two significant figures)	1
Total	**5**

Question 8 **(4 marks)**

A crane (Diagram A) lifts a mass by raising its boom (Diagram B). Explain how this affects the tension in the guy line as the crane shifts the mass from its initial position in Diagram A to its position in Diagram B.

Description	Marks
The tension in Diagram B is less	1
The guy wire doesn't change its orientation to the boom (r × sin30° = constant)	1
The mass exerts a constant force, downwards, but the θ changes (90° to 30°)	1
τ = rFsinθ = rFsin30° which is half torque, so half the tension.	1
	Total 4

Question 9 **(4 marks)**

Describe briefly how Edwin Hubble's observations of the redshifts of galaxies were used to formulate Hubble's Law and explain how Hubble's Law is used to support the Big Bang theory.

Description	Marks
All moving objects have a Doppler effect in their spectrum showing the relative speed to the observer, Redshift means the object is moving away.	1
The more the redshift the faster the object is moving	1
Hubble's Law states the more distant the object, the faster it is moving –	1
this means there is a common origin, e.g. all started from an original point in a "big bang"	1
Total	**4**

Question 10 **(3 marks)**

The Standard Model categorises all particles as being matter (fermions) or force carriers (gauge bosons). The gauge bosons are exchange particles that are responsible for the interactions between matter involving three of the four fundamental forces.

Describe how exchange particles prevent you from falling through the chair you are sitting on. The Feynman diagram below may assist you.

Description	Marks
The Feynman diagram shows the exchange of a photon which is what causes the recoil or repulsion between the two electrons in the diagram.	1
The fundamental forces that interact with all matter in the chair and you are due to that matter exchanging gauge bosons between them.	1
You don't fall through the chair because you are exchanging photons between your particles and those of the chair.	1
Total	**3**

Question 11 **(4 marks)**

In the Stanford Linear Accelerator Center (SLAC), beams of electrons and positrons are accelerated and focused so they collide head-on.

Calculate the momentum, in kg m s^{-1}, of an electron that has been accelerated to a speed of 0.400c and explain why the force required to accelerate the electron uniformly must change as its speed increases.

Description	Marks
$p_v = \dfrac{mv}{\sqrt{\left(1-\dfrac{v^2}{c^2}\right)}} = \dfrac{9.11\times10^{-31}\times0.4\times3\times10^{8}}{\sqrt{\left(1-0.4^2\right)}}$	1
p =1.19 $\times$ 10^{-22} kg m s^{-1}	1
As the particle's speed increases, so does its relativistic momentum (mass) and a greater force is required to provide the same rate of acceleration.	1–2
Total	**4**

Question 12 **(5 marks)**

The diagram below shows the forces acting on a car following a curve on a banked track. The car is travelling at 17.0 m s^{-1} without slipping. Calculate the radius of the track.

Description	Marks
Centripetal force = (11.5×10^3 N × sin20°) + (1300 N × cos20) = 3933 N + 1222 N = 5155 N (1 mark each component)	1–2
Convert weight to mass m = W/g = 10 000/9.8 = 1020 kg	1
Rearrange and substitute $r = \frac{mv^2}{F} = \frac{1020 \times 17^2}{5155}$	1
r = 57.2 m	1
Total	**5**

Question 13 **(4 marks)**

Louis de Broglie thought that if a wave could behave like a particle, then perhaps a particle could behave like wave. He proposed that the wavelength of a material particle was related to its linear momentum $p = mv$.

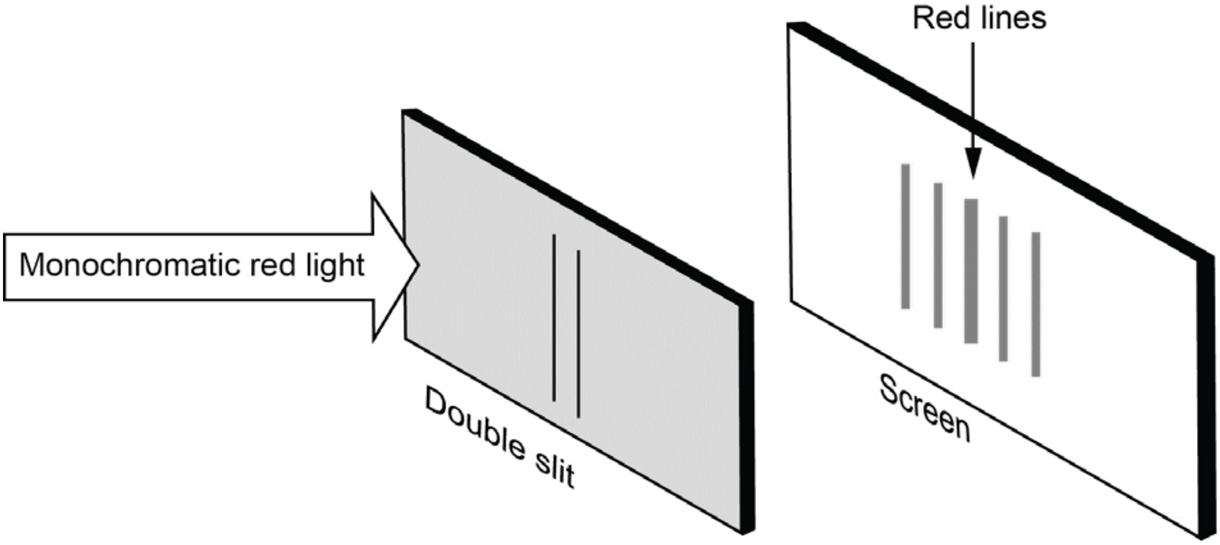
Compare, through calculation, the de Broglie wavelength for a 5 kg shot travelling at 14 m s^{-1} to an electron that has been accelerated through a potential difference of 100 V and is now travelling at 5.9×10^6 m s^{-1}.

From these results, determine which of these particles has a wavelength in the X-ray region of the electromagnetic spectrum.

Description	Marks
$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{5 \times 14} = 9.47 \times 10^{-36} m$	1–2
$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 5.9 \times 10^6} = 1.23 \times 10^{-10} m$	1
The electron wavelength is in the X-ray region.	1
Total	**4**

Question 14 **(3 marks)**

The pattern observed when monochromatic light passes through a piece of cardboard with twin slits close together is often considered evidence for the wave theory of light. A diagram of an experiment set up in a classroom is provided below.



Explain how the pattern of red lines is formed on the screen and why this is considered to be evidence for the wave theory of light.

Description	Marks
diffraction spreads the light sideways	1
Interference: dark where destructive, light where constructive	1
only wave theory explains interference pattern formed	1
Total	**3**

Section Two: Problem-solving **50% (90 Marks)**

Question 15 **(10 marks)**

An uncharged drop of oil is given **seven** excess electrons. It is then introduced into the space between two horizontal plates 25.0 mm apart with a potential difference between them of 1.50 kV. The drop of oil remains stationary.

(a) Calculate the magnitude of the electric field strength between the plates. (2 marks)

Description	Marks
$E = V / d = 1500/0.025$	1
$E = 6.00 \times 10^4$ V m^{-1}	1
Total	**2**

(b) Is the top plate positive or negative? Explain your reasoning. (2 marks)

Description	Marks
The top plate is positive.	1
This is because gravity is providing a downwards force on the drop since the drop is stationary the electric force must be upwards.	1
Total	**2**

(c) Calculate the magnitude of the electric force acting on the oil drop. (3 marks)

Description	Marks
$F = Eq = 6.00 \times 10^4 \times 7 \text{ x } 1.6 \times 10^{-19}$	1–2
$F = 6.72 \times 10^{-14}$ N NB: penalise 1 mark for incorrect or no units.	1
Total	**3**

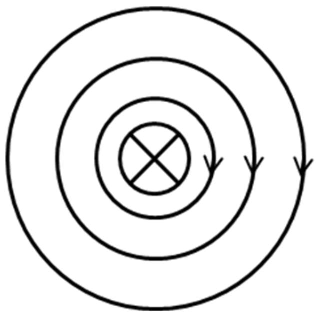
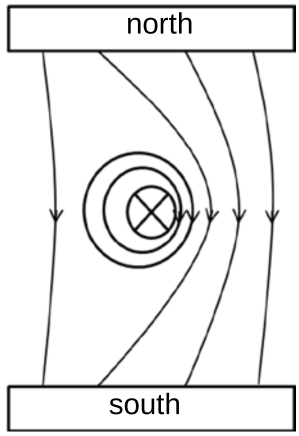
(d) Calculate the mass of the oil drop. (3 marks)

Description	Marks
If oil drop is stationary then electric force = gravitational force $F_e = mg$	1
$m = F_e / g = 6.72 \times 10^{-14} / 9.8$	1
$m = 6.86 \times 10^{-15}$ kg Note: penalise 1 mark for incorrect or no units.	1
Total	**3**

Question 16 **(10 marks)**

An apparatus that demonstrates the interactions between a current and a magnetic field is shown below. There are two metal rails on which a metal bar is free to roll. Contact between the rails and bar allows a current to flow through them from the power pack attached to the metal rails. Two magnets provide a uniform magnetic field around the bar.

(a) Draw the magnetic fields associated with the following situations. (4 marks)

The bar carrying current into the page		The current carrying bar in a uniform magnetic field
		

Description	Marks
LH diag. Field directions shown and magnitude changes with distance	1–2
RH diag. Field direction of both shown and field interaction with a higher density on the right	1–2
Total	**4**

(b) The rails are 8.50 cm apart and the magnetic field strength due to the magnets is $B = 1.50 \times 10^{-3}$ T.

Calculate the magnitude of the force acting on the bar when an electric current of 5.00 A is passed through the bar.

On the photograph on page 18, draw and label the direction of the force and current. (4 marks)

Description	Marks
$F = BI\ell$ $F = 1.5 \times 10^{-3} \times 15 \times 10.085$	1
$F = 6.375 \times 10^{-4}$ N	1
Current direction chosen correctly (into page)	1
Direction shown on the diagram correctly (to the left)	1
Total	**4**

(c) The apparatus in the photograph is then tilted at a small angle to the horizontal by lifting the left side when the current is flowing. The bar rolls toward the right-hand side, away from where the power supply is connected, due to the effects of gravity acting on the bar.

Describe **two** changes that could be made, either to the circuit or apparatus, to enable the force due to the current's interaction with the magnetic field to hold the bar stationary. (2 marks)

Description	Marks
Any **two** of the following: • increase potential difference across the circuit (to increase current) • get bigger/stronger magnets • move magnets closer to bar.	1–2
Total	**2**

Question 17 **(12 marks)**

The planet Jupiter has a mass of 1.90×10^{27} kg, a radius of 71 500 km and many moons.

The closest moon, Metis, has a mass of 9.56×10^{16} kg and a mean orbital radius of 1.28×10^{5} km. Metis has an average planetary radius of 21.5 km.

(a) Calculate the gravitational force of attraction between Jupiter and Metis. (3 marks)

Description	Marks
$F_g = \dfrac{GM_J m_M}{r^2}$	1
$F_g = \dfrac{6.67 \times 10^{-11} \times 1.90 \times 10^{27} \times 9.56 \times 10^{16}}{(1.28 \times 10^{8})^2}$	1
F = 7.39×10^{17} N	1
Total	**3**

(b) Calculate the time it takes in hours for Metis to orbit around Jupiter. (4 marks)

Description	Marks
$F_c = \dfrac{mv^2}{r}$ and v =2πr/t Substitute for v in F_c $F_c = \dfrac{m\left(\dfrac{2\pi r}{t}\right)^2}{r} = \dfrac{4\pi^2 mr}{t^2}$ or $\dfrac{T^2}{r^3} = \dfrac{4\pi^2}{GM}$ $\therefore T = \sqrt{\dfrac{4\pi^2 r^3}{GM}}$	1
Rearrange for t and substitute values in $t = \sqrt{\dfrac{4\pi^2 mr}{F_c}} = \sqrt{\dfrac{4\pi^2 \times 9.56 \times 10^{16} \times 1.28 \times 10^{8}}{7.39 \times 10^{17}}}$ $T = \sqrt{\dfrac{4\pi^2 \times (1.28 \times 10^{8})^3}{(6.67 \times 10^{-11})(1.90 \times 10^{27})}}$ t = 25560 s or 2.56×10^4 s = 7.10 hours	1
t = 25568 seconds or 2.56×10^4 s	1
Convert to hours 25568 s /3600 = 7.10 hours	1
Total	**4**

(c) Calculate the magnitude and direction of the net gravitational force acting on a 1.00 kg mass resting on the surface of Metis that faces Jupiter. (5 marks)

Description	Marks
(1 mark for two forces) $F_{gnet} = \frac{GM_J 1kg}{{r_J}^2} - \frac{GM_M 1kg}{{r_M}^2}$ where towards Jupiter is positive	1
(1 mark for numbers in) $F_{gnet} = \frac{6.67 \times 10^{-11} \times 1.90 \times 10^{27} \times 1}{(1.28 \times 10^8 - 21.5 \times 10^3)^2} - \frac{6.67 \times 10^{-11} \times 9.56 \times 10^{16} \times 1}{(21.5 \times 10^3)^2}$	1
(1 mark for realising opposite directions) $F_{g\ net}$ = 7.736-0.0138	1
(1 mark for answer with units) $F_{g\ net}$ = 7.72 N	1
(1 mark for direction given somewhere) Towards Jupiter	1
Total	**5**

Question 18 **(13 marks)**

(a) Determine the ratio of windings of primary:secondary coils in the transformer. (2 marks)

Description	Marks
$V_p:V_s = N_p:N_s$	1
120:9 or 40:3 or 13.3:1	1
Total	**2**

(b) Using the information on the compliance plate, calculate the power output of the transformer to determine the percentage efficiency of the transformer. (3 marks)

Description	Marks
P_s = VI = 9 × 0.500	1
P_s = 4.5 W	1
efficiency = $\frac{4.5}{9} \times 100 = 50\%$	1
Total	**3**

(c) Explain why the input voltage must consist of an alternating current rather than a direct current. (2 marks)

Description	Marks
There is no changing voltage/current with DC so no changing flux	1
To induce a current in the secondary coil there should be a changing flux	1
Total	**2**

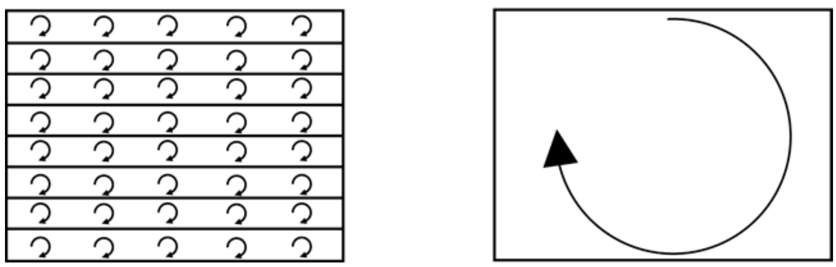
(d) Describe the purpose and properties of the core. (2 marks)

Description	Marks
Purpose: Direct and strengthen the flux	1
Properties: Soft (non-permanent ferromagnetic) material and laminated	1
Total	**2**

(e) The photograph below shows the laminae (a number of thin iron sheets separated by non-electrically conductive material, such as plastic) that make up the core. These laminae are used to reduce 'eddy currents' or 'back emf' and make transformers more efficient.

Use the following diagrams, which represent the centre pillar of the transformer, and any relevant formula to explain why a transformer with a laminated core is more efficient than a transformer with a solid core. (4 marks)

Laminated core Solid core



Description	Marks
Changing magnetic field induces emf in the iron core, large current if not laminated.	1
Relates induced/eddy current to cross sectional area	1
A laminated core increases the efficiency of transformer by reducing induced or eddy currents and therefore power loss through $P = 1^2 R$	1
Uses the diagram to show a difference in sizes current (e.g. little loops vs big loops)	1
Total	**4**

Question 19 **(12 marks)**

A group of astronauts is sent on a on a mission to collect data about an exoplanet that could possibly sustain human life. The spacecraft travels at a constant speed of 0.850c.

Two identical clocks that have been synchronised carefully on the Earth are to be used during the mission. One clock is left with an observer on Earth and the other is placed on the spacecraft. In the Earth's frame of reference, the clocks are observed to tick once every second.

(a) How much time, in seconds, would pass between ticks of the clock on the moving spacecraft in the spacecraft's reference frame? (1 mark)

Description	Marks
1 second	1
Total	**1**

(b) How much time, in seconds, would appear to pass between ticks of the clock on the moving spacecraft according to an observer in the Earth's frame of reference? (2 marks)

Description	Marks
$t = \dfrac{t_0}{\sqrt{\left(1 - \dfrac{v^2}{c^2}\right)}} = \dfrac{1}{\sqrt{\left(1 - 0.85^2\right)}}$	1
t = 1.90 s	1
Total	**2**

(c) Explain why the values in (a) and (b) are different. (3 marks)

Description	Marks
The observer on the spacecraft is not moving relative to the clock and so is measuring a proper time	1
There is relative motion between the observer on Earth and the spacecraft	1
To maintain the ratio of distance to time to keep the speed of light constant, there must be a dilation in time for the observer in the Earth's reference frame	1
Total	**3**

When measured on the Earth, the spacecraft is 119 m in length.

(d) Calculate the length of the moving spacecraft, in metres, as measured by an observer in the Earth's frame of reference. (2 marks)

Description	Marks
$\ell = \ell_0 \sqrt{\left(1 - \dfrac{v^2}{c^2}\right)} = 119 \times \sqrt{\left(1 - (0.850)^2\right)}$	1
ℓ = 62.7 m	1
Total	**2**

(e) Would the Earth observer notice any change in the height or width of the spacecraft? Explain your answer. (2 marks)

Description	Marks
No change	1
Length contraction only occurs in the direction of motion.	1
Total	**2**

A rocket probe is launched from the spacecraft. The rocket probe moves at 0.500c relative to the spacecraft.

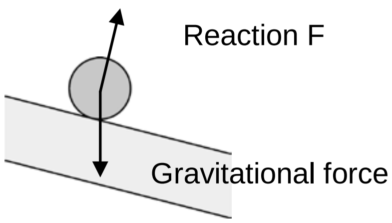
(f) To an observer in the Earth's frame of reference, what would be the speed of the rocket probe in terms of the speed of light? (2 marks)

Description	Marks
$u = \dfrac{v+u'}{1+\dfrac{vu'}{c^2}} = \dfrac{0.850c+0.500c}{1+\dfrac{0.850c \times 0.500c}{c^2}}$	1
u = 0.947c	1
Total	**2**

Question 20 **(19 marks)**

Below is a diagram of a photograph taken using a strobe light flashing at 10.0 Hz. The camera is able to take multiple photographs of a single ball moving down a frictionless inclined plane over a short period of time. Each square on the background grid measures 5.0 cm × 5.0 cm. Ignore air resistance unless instructed otherwise.

(a) Draw and label the force(s) acting on the ball while it is on the inclined plane below. (2 marks)



Description	Marks
Normal, perpendicular to surface shown and labelled	1
Gravitational force acting downwards Note: maximum 1 mark if friction or resultant force shown and labelled	1
Total	**2**

As the ball leaves the inclined plane its motion changes.

(b) (i) Describe the horizontal and vertical accelerations when the ball has left the inclined plane. (2 marks)

Description	Marks
Horizontally – acceleration changes to 0	1
Vertically – increases to 9.8 m s^{-2}	1
Total	**2**

(ii) How would each of these accelerations be affected if air resistance was considered? (2 marks)

Description	Marks
Horizontally – becomes a negative acceleration	1
Vertically – decreases to less than 9.8 m s^{-2}	1
Total	**2**

(c) Use the diagram to determine the horizontal velocity of the ball after it has left the inclined plane. Express your answer to an appropriate number of significant figures. (3 marks)

Description	Marks
A displacement and time value accurately determined e.g. s = 0.64 m, t = 0.4 s	1
v = s/t =0.64/0.4 v = 1.6 m s^{-1}	1
Value within ±0.2, sig fig important	1
Total	**3**

(d) The angle of the plane to the horizontal is 14°. Determine the component of gravitational acceleration that acts along the inclined plane. (2 marks)

Description	Marks
$\text{Sin}14^{o} = a_{Slope}/ 9.8$	1
a_{Slope} = 2.37 m s^{-2}	1
Total	**2**

(e) Calculate the horizontal component of the ball's acceleration. Given that the ball starts from rest on the first strobe light flash and reaches the end of the inclined plane on the eighth flash, use the horizontal component of acceleration to determine the ball's horizontal velocity component as it leaves the inclined plane. (5 marks)

Description	Marks
t = 0.70 s (8-1 flashes × $^{1}/_{10}$ of a second)	1
$\cos 14^{o} = a_H / a_{Slope}$	1
a_H = 2.30 m s^{-2}	1
v = u + at = 0 + 2.30 × 0.70	1
v = 1.61 m s^{-1}	1
Total	**5**

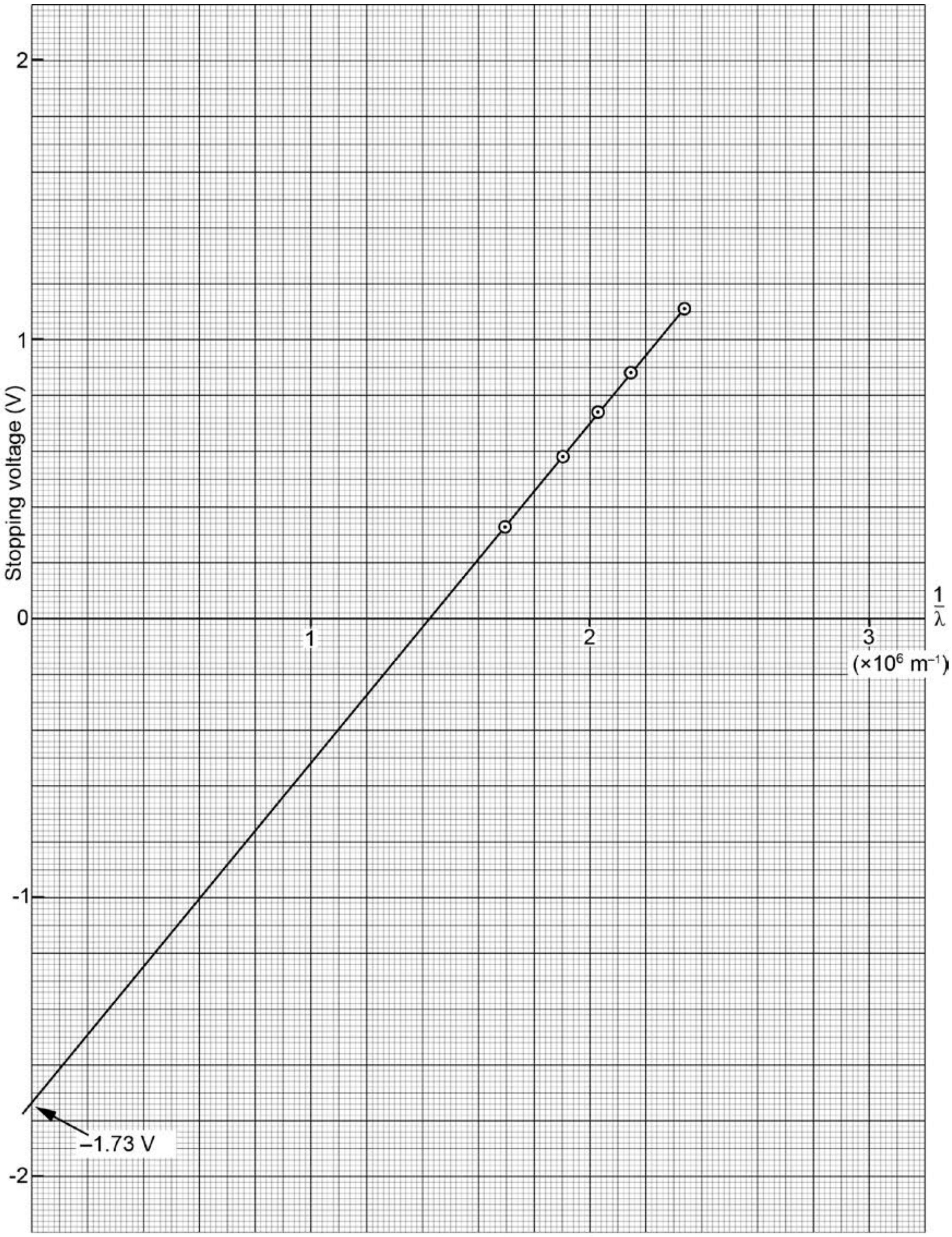
(f) Use the motion of the ball to calculate the length of the inclined plane. (3 marks)

Description	Marks
Number of methods exist for this. Give credit where physics calculations and reasoning exists. Example below. (1 mark only if length measurements from graph are used)	
a_{Slope} = 2.37 m s^{-2}; t= 0.7 s from (e) or graph (uses appropriate values)	1
s = 0t + 0.5 × 2.37 × 0.7^2 (calculation appropriate)	1
s = 0.58 m (answer close to value)	1
Total	**3**

Question 21 **(14 marks)**

A group of students set up a photocell to investigate the photoelectric effect and determine a value for Planck's constant.

(a) Plot stopping voltage on the *y*-axis against $\frac{1}{\lambda}$ on the grid below. Draw the *x*-axis in the middle of the grid, and extend the y-axis to ±2 volts. (3 marks)



Description	Marks
Points plotted, axes labelled, line of best fit drawn.	1–3
Total	**3**

(b) Given the aim of the experiment, explain why the students graphed $\frac{1}{\lambda}$. (1 mark)

Description	Marks
So the graph is linear	1
Total	**1**

(c) Determine the gradient of the line of best fit and give its units. (3 marks)

Description	Marks
Gradient calculated from graph line (Note: if just use data from table then zero)	1
Value about 1.2×10^{-6} V m (accept 1.0×10^{-6} to 1.3×10^{-6}). 1 mark for value and 1 mark for unit	1–2
Total	**3**

(d) Use the gradient from part (c) to determine the experimental value in J s for Planck's constant. (2 marks)

Description	Marks
Gradient = hc/q_e so h = grad $\times$ q_e/c	1
$h = 1.2 \times 10^{-6} \times 1.6 \times 10^{-19}/3 \times 10^{8} = 6.4 \times 10^{-34}$ J s	1
Total	**2**

(e) Use the graph to determine the work function, and give its units. (3 marks)

Description	Marks
Work function = y intercept	1
Which = $1.7/1.6 \times 10^{-19} = 1.1 \times 10^{-19}$ J or 1.7 eV	1–2
Total	**3**

(f) Explain what information the intercept with the x-axis provides and how this supports Einstein's theory that light is made up of photons. (2 marks)

Description	Marks
The intercept is the maximum wavelength (or minimum frequency) required to eject an electron	1
Electrons will be emitted when supplied a precise amount of energy, and no electrons will be emitted below the cutoff frequency no matter how great the intensity.	1
Total	**2**

Section Three: Comprehension **20% (36 Marks)**

Question 22 **(19 marks)**

Muons and Relativity

(a) The table below contains information about some subatomic particles. Complete the last column of the table by writing baryon, meson or lepton to indicate the group of particles to which the individual particle belongs. (4 marks)

Particle	Quark structure	Decay products	Baryon, meson or lepton
Lambda	charm, up, down	proton, pion, kaon	
Tau		tau neutrino, electron, electron anti-neutrino	
Kaon+	strange, charm	muon and muon neutrino	
Xi	up, strange, strange	lambda and pion	

Description	Marks
baryon	1
lepton	1
meson	1
baryon	1
Total	**4**

(b) Muons travel at almost the speed of light. Calculate the average distance that a muon created in the upper atmosphere would travel before it decayed. Assume that its speed is equal to c and that there are no relativistic effects. (2 marks)

Description	Marks
$s = v/t = 3 \times 10^8 \times 2.2 \times 10^{-6}$	1
$s = 6.6 \times 10^2$ m [0.66 km]	1
Total	**2**

(c) Muons created by cosmic rays in the upper atmosphere can be detected by detectors on the Earth's surface. This means that the muons have travelled much further than expected. An explanation of this phenomenon involves the effects of relativity.

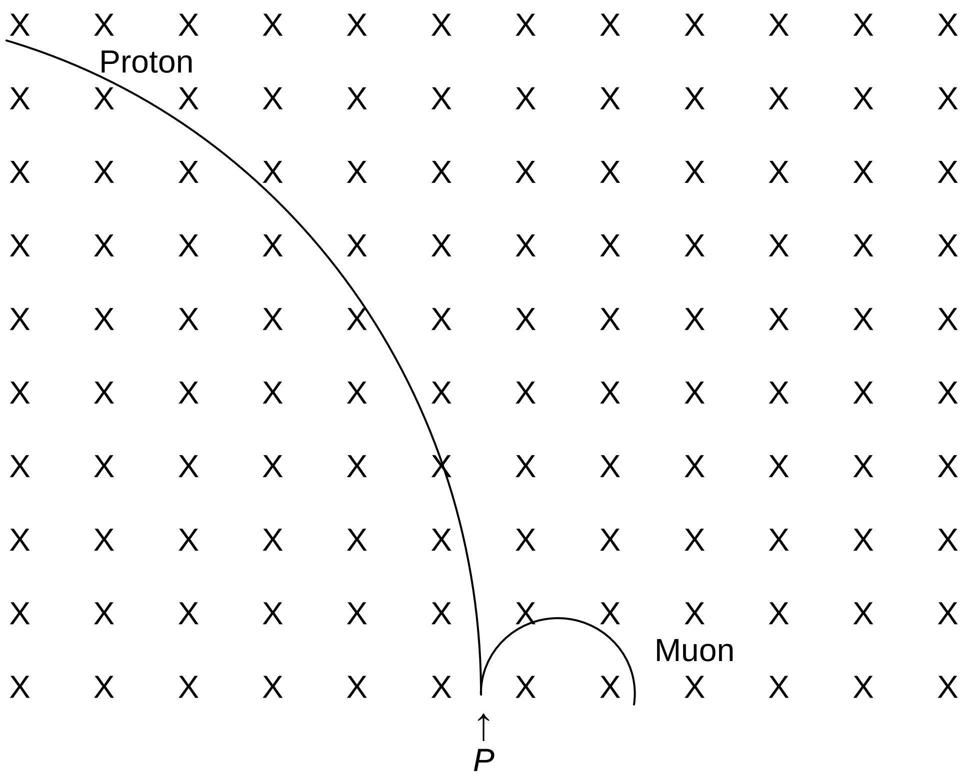
Explain how relativity affects the muons and enables them to travel over a greater distance than that calculated in part (b). (3 marks)

Description	Marks
Time measured on Earth depends on the speed of the observer and the object being viewed	1
As the speed increases the time [dilation] increases (either frame reference of muon or Earth is valid) (correct length contractional , so valid)	1
Muons last longer since they travel so fast	1
Total	**3**

(d) Express the rest mass of a muon in kilograms, and compare this to the rest mass of a proton. (3 marks)

Description	Marks
106 $\frac{\text{MeV}}{\text{C}^2}$ to mass $= \frac{106 \times 10^6 \times 1.6 \times 10^{-19}}{(3 \times 10^8)^2}$	1
$= 1.88 \times 10^{-28}$ kg	1
Proton to muon ~ 9× larger	1
Total	**3**

(e) On the diagram below sketch and label two lines representing the paths you would expect a proton and a muon to follow in the given magnetic field. Assume both particles are injected into the field at *P* with the same velocity. (3 marks)



Description	Marks
The curve with the larger radius moves to the left = proton	1
The smaller curve moves to the right = muon	1
Scale of curve ~1/9th the size	1
Total	**3**

(f) Injecting and directing a charged particle using magnetic and electric fields is a commonly-used phenomenon. It is used in old (cathode ray tube) television technology as well as in high-technology applications such as the CERN Large Hadron Collider.

Using formulae from your Formulae and Data Booklet, show the derivation of the formula below that determines a particle's velocity from its mass (*m*) and charge (*q*), having been accelerated through a potential difference (*V*). You must show all steps.

(4 marks)

$$v = \sqrt{\frac{2Vq}{m}}$$

Description		Marks
Accelerated through electric field E or over a potential difference V		1
F = Eq or Vq/d = ma	W = Vq = E_k	1
a = Vq/md and $v^2 = u^2 + 2as$, where u = 0	$E_k = ½mv^2 - ½mu^2$, where u = 0	1
v^2 = 2Vqs/md (s = d) so v^2 = 2Vq/m $v = \sqrt{\frac{2Vq}{m}}$	v^2 = 2Vq/m $v = \sqrt{\frac{2Vq}{m}}$	1
	Total	**4**

Question 23 **(17 marks)**

(a) Which of diagrams (i), (ii) or (iii) illustrates correctly the radiation emitted by a laser? Circle your answer. (1 mark)

Description	Marks
(i) The waves are monochromatic (same frequency) and in phase.	1
Total	**1**

(b) Circle your response to the following: (2 marks)

(i) The electrons in a population inversion are mostly located in the:

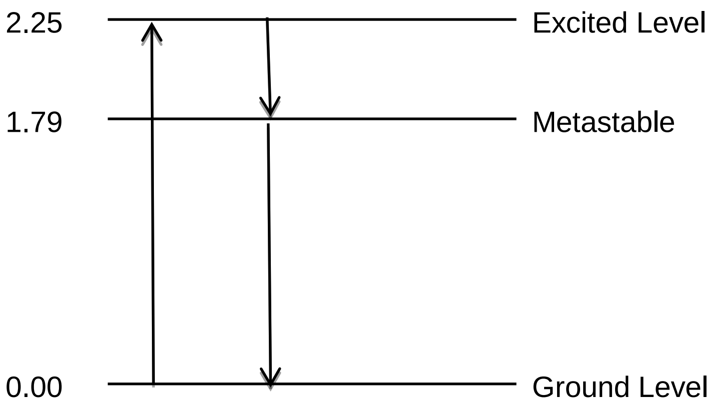
ground level metastable level excited level

(ii) The pulse in a pulsed laser describes the:

movement of electrons input light output light

Description	Marks
metastable level	1
output light	1
Total	**2**

(c) Sketch on the diagram above the **three** transitions required to produce the laser light. (3 marks)

Description	Marks
 1 mark per arrow	1–3
Total	**3**

(d) Calculate the wavelength, in metres, of the photon required for optical pumping in a ruby laser. (2 marks)

Description	Marks
$E = \dfrac{hc}{\lambda}$ $\lambda = \dfrac{hc}{E} = \dfrac{6.63\times10^{-34}\times3.00\times10^{8}}{2.25\times1.6\times10^{-19}}$	1
$\lambda = 5.50 \times 10^{-7}$ m	1
Total	**2**

(e) Calculate the wavelength, in metres, of the photon that is produced in the laser transition in a ruby laser. (2 marks)

Description	Marks
$E = \dfrac{hc}{\lambda}$ $\lambda = \dfrac{hc}{E} = \dfrac{6.63\times10^{-34}\times3.00\times10^{8}}{1.79\times1.6\times10^{-19}}$	1
$\lambda = 6.94 \times 10^{-7}$ m	1
Total	**2**

(f) The energy of the metastable level of the neon atom is greater than that of the helium atom. Where does the extra energy come from to excite the neon atom? (1 mark)

Description	Marks
Kinetic energy of the helium atoms	1
Total	**1**

(g) Explain why the helium-neon laser, unlike the ruby laser, can be operated continuously. (2 marks)

Description	Marks
The electrical discharge ensures the population inversion is occurring continuously	1
Not just when a photon of the correct wavelength is shone on the system.	1
Total	**2**

(h) A certain helium-neon laser emits red light with a wavelength of 633 nm at a power level of 2.50 mW. What minimum number of excited electrons per second producing an emission is required to produce this beam? (3 marks)

Description	Marks
$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{633 \times 10^{-9}}$ =3.14×10^{-19} J	1–2
$\frac{2.50 \times 10^{-3}}{3.14 \times 10^{-19}} = 7.96 \times 10^{15}$ electron jumps/sec	1
Total	**3**

(i) The final transition in the neon atom produces no radiation (i.e. no photon is emitted). State how the neon atom could lose this energy. (1 mark)

Description	Marks
Collisions between the neon atoms and the wall of the container or other atoms.	1
Total	**1**

Published by the School Curriculum and Standards Authority of Western Australia
27 Walters Drive
OSBORNE PARK WA 6017