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

PHYSICS

Stage 3

WACE Examination 2014

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 answer **30% (54 Marks)**

Question 1 **(2 marks)**

Astronomers study stars use a variety of electromagnetic frequencies. Place the following sections of the electromagnetic spectrum in order from longest wavelength to smallest:

visible, infra red, X-ray and radio.

Description	Marks
radio infra red visible X-ray Only 1 for the opposite order	1–2
Total	**2**

Question 2 **(4 marks)**

Electromagnetic radiation (emr) is said to have both wave and particle properties. State and describe an example of each of these properties of emr.

Description	Marks
Wave – states one of the following: diffraction; refraction; passing through one another; other wave properties. Then gives a description of that term as applied to emr.	1–2
Particle – states one of the following: affected by gravity; photoelectric effect; does not require a medium; exerts pressure; quanta. Then gives a description of that term as applied to emr.	1–2
Total	**4**

Question 3 **(2 marks)**

Use the following table and show the calculation required to determine the charge of the Z (4430) particle.

Table of quarks		
Name	**Symbol**	**Electrostatic charge**
Up	u	$+\frac{2}{3}$ e
Down	d	$-\frac{1}{3}$ e
Strange	s	$-\frac{1}{3}$ e
Charm	c	$+\frac{2}{3}$ e
Bottom	b	$-\frac{1}{3}$ e
Top	t	$+\frac{2}{3}$ e

Description	Marks
a charm, an anti-charm, a down, and an anti-up $+\frac{2}{3}$ e + $-\frac{2}{3}$ e + $-\frac{1}{3}$ e + $-\frac{2}{3}$ e	1
= -1e (e optional)	1
If charges for antiparticles not reversed, zero marks	
Total	**2**

Question 4 **(3 marks)**

A space probe travels along a line from the Earth to Uranus at a constant speed of 0.95c relative to the solar system. Just as it reaches midway between the two planets, it sends laser beams out to the Earth and Uranus at the same time. What speed do the laser beams approach the Earth and Uranus, respectively?

Speed of laser beam approaching the Earth: _____

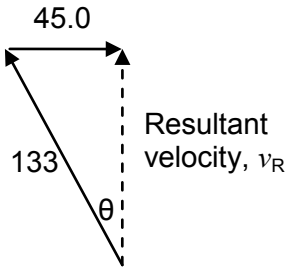
Speed of laser beam approaching Uranus: _____

To an observer on Uranus, will the light from the space probe appear red shifted, or blue shifted? Circle the correct answer.

Description	Marks
c or 3×10^8 m s^{-1}	1
c or 3×10^8 m s^{-1}	1
Blue shifted	1
	Total 3

Question 5 **(5 marks)**

An aircraft attempts to land along a north-south aligned landing strip. It approaches from the south and has an air speed of 133 km hr^{-1}. The wind is blowing from the west at 45.0 km hr^{-1}. Draw a vector diagram to show the direction the aircraft needs to head and calculate its actual velocity, in m s^{-1}, relative to the runway. Show **all** workings.

Description	Marks
Two vectors drawn at an appropriate angle to each other Resultant shown If directions incorrect, max. 1 mark 	1–2
$133^2 = v^2 + 45^2$ v_R = 125 km hr^{-1} North	1
v_R = 125/3.6= 34.7 m s^{-1} North (direction implied, so not required)	1
$\theta=\sin^{-1}(45/133)=19.8°$ (heading)	1
Total	**5**

Question 6 **(4 marks)**

The images below show hydrogen spectra.

Image 1: Bright lines on a black background.

Image 2: Dark lines on a continuous spectrum.

For each, name the type of spectrum and describe how it is created.

Description	Marks
Image 1: (Line) emission spectrum	1
Created by the emission of photons from excited electrons	1
Image 2: (Line) absorption spectrum	1
Electrons absorb certain frequencies of light, leaving missing frequencies in an otherwise continuous spectrum	1
Total	**4**

Question 7 **(5 marks)**

Shown below are three diagrams A, B and C representing fields. Use the diagrams to fill in the blanks in the following sentences. Any field diagram can be used more than once.

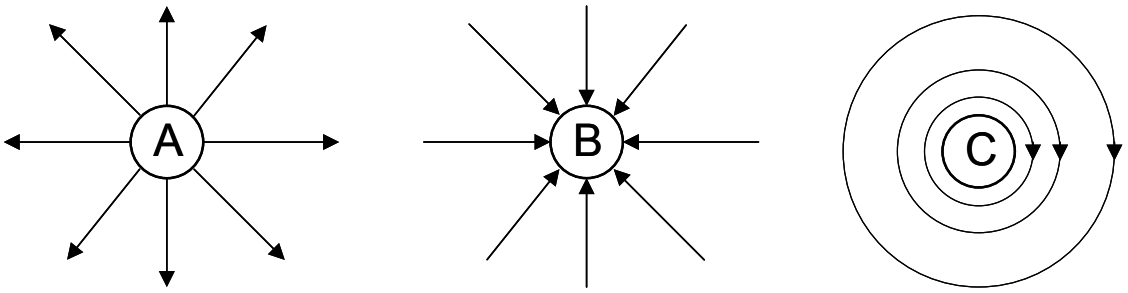


Diagram _____ could represent the gravitational field of a mass.

Diagram _____ could represent the electric field around a positively charged particle.

Diagram _____ could represent the electric field of a negatively charged particle.

Diagram _____ could represent the magnetic field around a wire carrying current that is directed_____ the page.

Description	Marks
B; A; B; C; Into	1–5
Total	**5**

Question 8 **(3 marks)**

Describe briefly the relationship between the mass and energy of an accelerating object as its speed approaches, but cannot exceed, the speed of light in vacuum, c.

Description	Marks
Energy and mass are related, $E=mc^2$	1
An object increases in mass as it is accelerated (gains energy)	1
This will limit the speed of an object as its mass becomes very large as it approaches the speed of light	1
Total	**3**

Question 9 **(5 marks)**

Use the information given in the Formulae and Data Booklet to calculate the orbital period, in seconds, of the Moon around the Earth.

Description	Marks
$F_c=F_g$ so $v^2 / r = G M_E / r^2$ $T^2=4 \pi^2 r^3 / G M_E$	1–2
Uses correct values M_M = ... 7.35×10^{22} kg M_E = ... 5.97×10^{24} kg Mean Earth-Moon distance……r = 3.84×10^8 m Universal gravitational constant……..G = 6.67×10^{-11} N m^2 kg^{-2}	1
$T^2= 4 \times \pi^2 \times (3.84 \times 10^8)^3 / (6.67 \times 10^{-11} \times 5.97 \times 10^{24})$	1
T = 2 369 335 s = 2.37×10^6 s	1
Total	**5**

Question 10 **(4 marks)**

During a chase scene in a movie, an actor drops onto the top of an elevator that is descending at a constant speed of 1.00 m s^{-1}. The time taken to land on top of the elevator is 6.10×10^{-1} s. Determine the distance in metres the elevator is below the actor when she starts her drop. Show **all** workings.

Description	Marks
Distance travelled by elevator: $s = (v \times t)$ $= 1 \times 0.610 = 0.610$ m	1
Distance travelled by hero $s = ut + ½ at^2$ $s = 0 + 0.5 \times 9.8 \times t^2$ $s = 1.82$ m	1–2
distance below = 1.82-0.61 = 1.21 m	1
Total	**4**

Question 11 **(6 marks)**

Calculate the maximum tension in each of the angled sections of the rope that attach to the seat when a 27.0 kg boy is sitting on the swing and moving with a tangential velocity of 4.00 m s^{-1}. Show **all** workings.

Description	Marks
Total mass in motion = 1 + 27 = 28.0 kg	1
$T = mg + mv^2 / r$ $T = 28 \times 9.8 + 28 \times 4^2 / 7$ $T = 274 + 64$ $T = 338$ N	1–2
Let t_r = tension in each section of rope: $t_r \times \cos 15° = 338 / 4$ $t_r \times 0.966 = 84.5$ N	1–2
$t_r = 87.6$ N (no mark for unit)	1
Total	**6**

Question 12 **(5 marks)**

(a) The vertical axis is labelled 'redshift' with units for velocity (km s^{-1}). Explain briefly the relationship between redshift and the speed of the object. (2 marks)

Description	Marks
How much the lines are shifted is related to the star's velocity	1
States or explains that redshift increases with velocity.	1
Total	**2**

(b) Use the gradient of the graph to extrapolate a value for the maximum distance, in Mpc, for a galaxy to be observed from in the Earth. Show **all** workings. (3 marks)

Description	Marks
Maximum speed $c = 3\times10^8$ m s^{-1} or 3×10^5 km s^{-1}	1
Determines gradient 31 000/500= 62 km s^{-1}/Mpc. Allow range 60-65 km s^{-1}/Mpc.	1
Maximum distance of the Universe => 3×10^5/(62 km s^{-1}/Mpc) = 4800 Mpc Allow 4600-5000 Mpc	1
Total	**3**

Question 13 **(6 marks)**

A thin metal rod is bent into a right angle and hung on a nail from a wall, as shown in the diagram. Assume that there is no contact between the rod and wall. The longer side (L_2) is 0.800 m long and makes an angle of 14.0° to the vertical. The rod has uniform density and constant thickness. Calculate the length of the shorter side, L_1. Show **all** workings.

Description	Marks
Take moments about P $\Sigma\tau_{cw}=\Sigma\tau_{acw}$	1
Forces act through centre of mass which is in the middle of each length	1
Force on L_1 acts at 76° to L_1 arm	1
Uses torque=rF sin θ i.e. $L_1 M_1 g \sin 76° = L_2 M_2 g \sin 14°$	1
Recognises that M_1 is proportional to length i.e. $M_1 = kL_1$ $M_2 = kL_2 = 0.8\ k$	1
$\therefore$ $L_1 kL_1 g \sin 76° = L_2 kL_2 g \sin 14°$ $\therefore$ $L_1^2 \sin 76° = 0.8^2 \sin 14°$ $\therefore$ $L_1 = 0.399$ m	1
Total	**6**
Note: much of the above information may be shown on a diagram.	

End of Section One

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

Question 14 **(12 marks)**

(a) Estimate the frequency of the vibration if a car is travelling at 95 km hr^{-1}. Use appropriate significant figures and unit for the value. Show **all** assumptions and workings. (5 marks)

Description	Marks
Uses some method to average the distances between points e.g. (0.86-0)/3= 0.287 m (±0.03)	1
v= 95/3.6 m s^{-1}	1
v=fλ f=v/λ= (95/3.6)/.287 = 91.9 or 9.19 × 10^1 = 92 or 90 (accept 85–100)	1
2 or 1 significant figures	1
Hz	1
Total	**5**

(b) An old car slows down to stop on the side of the road. As it crosses the rumble strip, the frequency of sound decreases along with the speed and the vibrations cause the dashboard to rattle. The intensity of vibration of the dashboard varies and becomes very loud at one particular frequency. Explain this phenomenon, using appropriate physics terminology and concepts. (4 marks)

Description	Marks
Resonance	1
At a particular speed the driving frequency of the motion over the rumble strips matches the natural frequency of the dashboard	1–2
The dashboard's vibrations will be reinforced at the resonance frequency.	1
Total	**4**

(c) In another car, a test signal with a constant frequency and amplitude is being played on the radio. This test signal matches closely the frequency produced while driving over the rumble strip at a constant speed. Despite both sounds maintaining a constant frequency and amplitude, a fluctuation in the amplitude can be heard by the car's occupants, for whom the sounds grow louder and quieter. Explain this phenomenon, using appropriate physics terminology and concepts. (3 marks)

Description	Marks
Constructive and destructive interference.	1
Constructive interference gives louder sounds.	1
Destructive interference gives quieter sounds.	1
Total	**3**

Question 15 **(10 marks)**

(a) On the diagram above, draw an arrow to show the direction of acceleration of Clown 1's centre of mass at the point of maximum height. (1 mark)

Description	Marks
Arrow should be pointed downwards at the top point of the parabola. Slightly to the left is acceptable, but not to the right.	1
Total	**1**

(b) Describe qualitatively **two** effects of air resistance on projectile motion in this case. (2 marks)

Description	Marks
Clown 1 will not reach maximum height	1
Clown 1's horizontal velocity will not be constant and decrease over time. Range decreases or horizontal distance is less.	1
Total	**2**

(c) Show by calculation that the total time Clown 1 is in the air is just over 1.1 s. Ignore air resistance. (4 marks)

Description		Marks
$v_v = v \cos \theta = 7 \cos 15^0$ $= 6.76 \text{ m s}^{-1}$		1–2
$s=ut+½at^2$ $1.5=6.76t+½(-9.8)t^2$	Or $s=ut+½at^2$ $s=6.76(1.1)+½(-9.8)(1.1)^2$	1
$t= 1.102$ s (just over)	$s=1.507$ m (not quite to 1.5m)	1
	Total	**4**

(d) Determine the initial horizontal distance between Clown 1 and Clown 2. Ignore air resistance. Show **all** workings. (3 marks)

Description	Marks
$v_h = v \sin \theta = 7\sin 15°$ $= 1.81 \text{ m s}^{-1}$	1–2
$s_h = v_h \times t = 1.81 \times 1.10$ $s_h = 1.99$ m	1
Total	**3**

Question 16 **(10 marks)**

(a) Calculate the **horizontal force** in newtons exerted by the **upper bolt** used to attach this projector to the wall. Show **all** workings.
Hint: Take the bottom bolt of the wall plate as a pivot point. (4 marks)

Description	Marks
ΣACWM = ΣCWM $\tau_{Projector} + \tau_{Support\ Arm} = \tau_{Upper\ bolts}$	1
$(7 \times 9.8 \times 0.5) + (1 \times 9.8 \times 0.45) = (F_{upper} \times 0.08)$	1
$F_{upper} = 38.71 / 0.08$	1
$F_{upper} = 484$ N	1
Total	**4**

(b) Explain quantitatively the effect on the centre of mass of the projector/support arm system as the projector is moved further away from the wall. (3 marks)

Description	Marks
The projector is 7 times more massive than the arm, so as the projector is moved the centre of mass of the system is moved 7/8 the distance of the projector (or other correct calculation or equation)	3
or	
As the projector is moved, only part of the system's mass is moved, so the centre of mass moves, but not as much as the projector	2
or	
The centre of mass is moved away from the wall.	1
Total	**3**

(c) Explain quantitatively the effect on the horizontal force exerted by the upper bolt as the projector is moved further away from the wall, assuming the system maintains its stability. (3 marks)

Description	Marks
Some quantification attempted e.g. as the distance of the centre of mass doubles, so does the restoring horizontal force needed or states that $F_{upper} = \frac{7 \times 9.8 \times d + (1 \times 9.8 \times 0.45)}{0.08}$ $\therefore$ as d increases, F_{upper} increases.	3
or	
The bolt would need to increase the force to maintain the restoring torque	2
or	
As the projector increases its distance the torque increases	1
Total	**3**

Question 17 **(17 marks)**

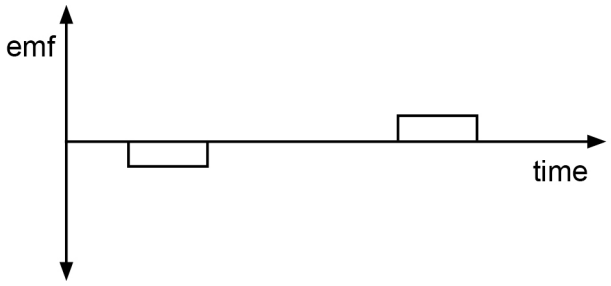
(a) A meter is connected to the loop to measure the emf generated in the circuit during one movement through the field. Fill in the following details of the meter: (2 marks)

Description	Marks
Type: Voltmeter or galvanometer (or one to measure the potential difference)	1
Units: Volts	1
Total	**2**

(b) During a second movement through the field, a light globe is attached between U and Y, making a circuit. Explain why the loop requires a force when entering and leaving the magnetic field. (4 marks)

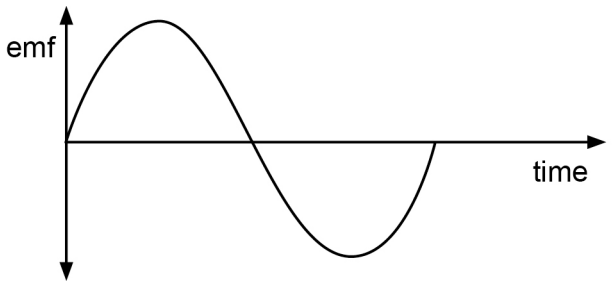
Description	Marks
The loop of wire experiences a change in magnetic flux and therefore induces current that opposes the change in flux (or relates to emf=-BΔA/Δt)	1–2
While the loop is partly in the magnetic field (entering), only the current in the Y-X segment experiences a force to the left (F=Iℓ B),	1
Similarly when the Y-X segment has left the field, the changing flux produces a current in the other direction, and the U-V segment experiences a force to the left.	1
Total	**4**

(c) Given that the velocity of the loop is constant, complete the graph below for the emf induced in the loop over the time that it moves into and out of the field. (4 marks)

Description	Marks
 Graph shows the following features: • Negative to start • Two generations that are opposite to each other • Large gap in the middle • Two rectangular shapes that are the same	1–4
Total	**4**

(d) Another method of generating an emf is to move the magnet in a circular motion as shown in the diagram below.

(i) Complete the graph below for the current induced in the loop over one complete rotation of the magnet. (3 marks)



Description	Marks
Sinusoidal wave (arbitrary starting point)	1
One complete cycle	1
Has positive and negative components	1
Total	**3**

(ii) The loop of wire above is a square 5.00 × 5.00 cm. If the magnet rotates once every 1.00 s and has a magnetic field strength of 0.789 T, calculate the magnitude of the maximum emf generated. Assume that the field is completely reversed in the loop during the magnet's rotation. Show **all** workings. (4 marks)

Description	Marks
emf = 2 N Bℓv	1
where $v = \frac{2\pi r}{T} = 2\pi rf = 2\pi \times 0.025 \times 1 = 0.157$ m s^{-1}	1
$\therefore$ emf = 2 × 1 × 0.789 × 0.05 × 0.157	1
= 1.24 × 10^{-2} V (units not needed)	1
or	
emf = 2π BANf	1–2
= 2π × (0.789) × 0.0025 × 1 ×1	1
= 1.24 × 10^{-2} V (units not needed)	1
or, if **average** emf calculated, max 3 marks as shown below.	
A = 0.05×0.05 = 2.5×10^{-3} m^2	1
For maximum ¼T=t= ¼×1=0.25 s	1
emf=-NBA/t=-1(0.789)(2.5×10^{-3})/0.25 emf= 7.89×10^{-4} V (units not needed)	1
Total	**4**

Question 18 **(13 marks)**

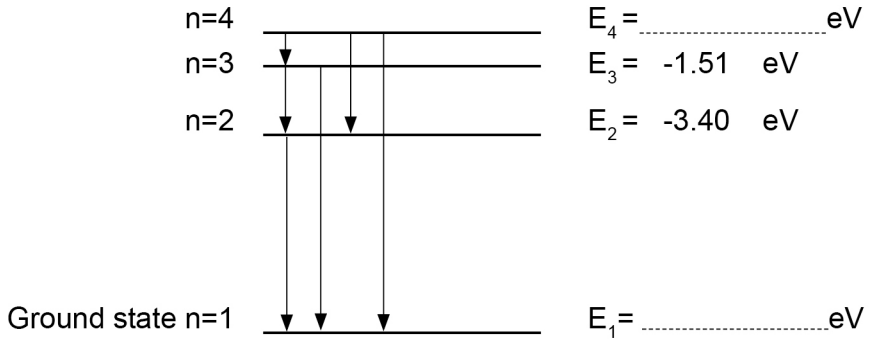
(a) Does the average radius of the electron orbital remain the same, increase or decrease in value during this transition? Circle the correct answer. (1 mark)

Description	Marks
decreases	1
Total	**1**

(b) Use the formula $E_n = -\frac{13.6}{n^2}\text{eV}$ to complete the energy level diagram below. The diagram is **not** drawn to scale. (2 marks)

Description	Marks
$E_4 = -(13.6/4^2) = -0.85$ eV	1
$E_1 = -(13.6/1^2) = -13.6$ eV	1
Total	**2**

(c) On the diagram above, draw in all the possible transitions when an electron undergoes relaxation from n = 4 to the ground state. (3 marks)



Description	Marks
There are 6: 4-1, 4-2, 4-3, 3-1, 3-2 and 2-1 (1 mark if at least 4-1, 4-2 and 4-3 are drawn)	1–2
Transitions are drawn downwards	1
Total	**3**

(d) (i) Calculate the wavelength of the photon emitted from the E_3 to E_2 transition. Show **all** workings. (4 marks)

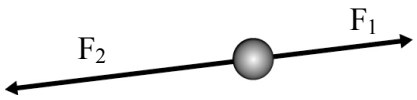
Description	Marks
$E = 3.40 - 1.51 = 1.89$ eV	1
$E = hf = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.89 \times 1.6 \times 10^{-19}}$ $\lambda = 6.58 \times 10^{-7}$m	1–3
Total	**4**

(ii) The transitions of E_4 to E_2 and E_3 to E_2 produce red and green photons. Explain which transition produces which colour. (3 marks)

Description	Marks
Transitions E_4 to E_2 has more energy so will produce the photon with the shorter wavelength, green.	1–2
E_3 to E_2 will produce red	1
Total	**3**

Question 19 **(10 marks)**

(a) Draw a free body diagram for M_1. (3 marks)

Description	Marks
	
Force drawn towards the centre of the circle (left)	1
2 forces drawn in opposite direction	1
F_1 is larger than F_2	1
Total	**3**

(b) Complete the following for M_1 and M_2.

(i) Write an appropriate expression for the tangential velocity v_1 of M_1 in terms of R_1, R_2 and T. (2 marks)

Description	Marks
$v = s/t = (2\pi R / T)$	1
$v_1 = (2\pi R_1 / T)$	1
Total	**2**

(ii) Write an appropriate expression for the tension F_1 acting in the string between M_1 and M_2, in terms of the mass m_2, the radius R_2 and the period T. (2 marks)

Description	Marks
$F_1 = m_2 v_2^2 / R_2$	1
$= m_2(2\pi R_2/T)^2/R_2 = m_2 (4\pi^2 R_2) / T^2$	1
Total	**2**

(iii) Write an appropriate expression for the tension F_2 acting in the string between P and M_1, in terms of the masses m_1 and m_2, the radii R_1 and R_2 and the period T. (3 marks)

Description	Marks
$F_c = F_2 - F_1$	1
$F_2 = m_1 v_1^2 / R_1 + m_2 v_2^2 / R_2$	1
$= m_1(2\pi R_1/T)^2/R_1 + m_2(2\pi R_2/T)^2/R_2$ $= (m_1 R_1 + m_2 R_2)(4\pi^2 / T^2)$	1
Total	**3**

Question 20 **(18 marks)**

(a) Using the photograph above, for magnets labelled Q and R, write either 'North' or 'South' in the space below to indicate which pole the magnet would need to have next to the channel to provide the magnets with a force directed downward (into the pan of the balance). (2 marks)

Description	Marks
Q is North and R is South (Poles are incorrect but opposite, 1 mark only)	1–2
Total	**2**

(b) A table of results for this investigation is shown below:

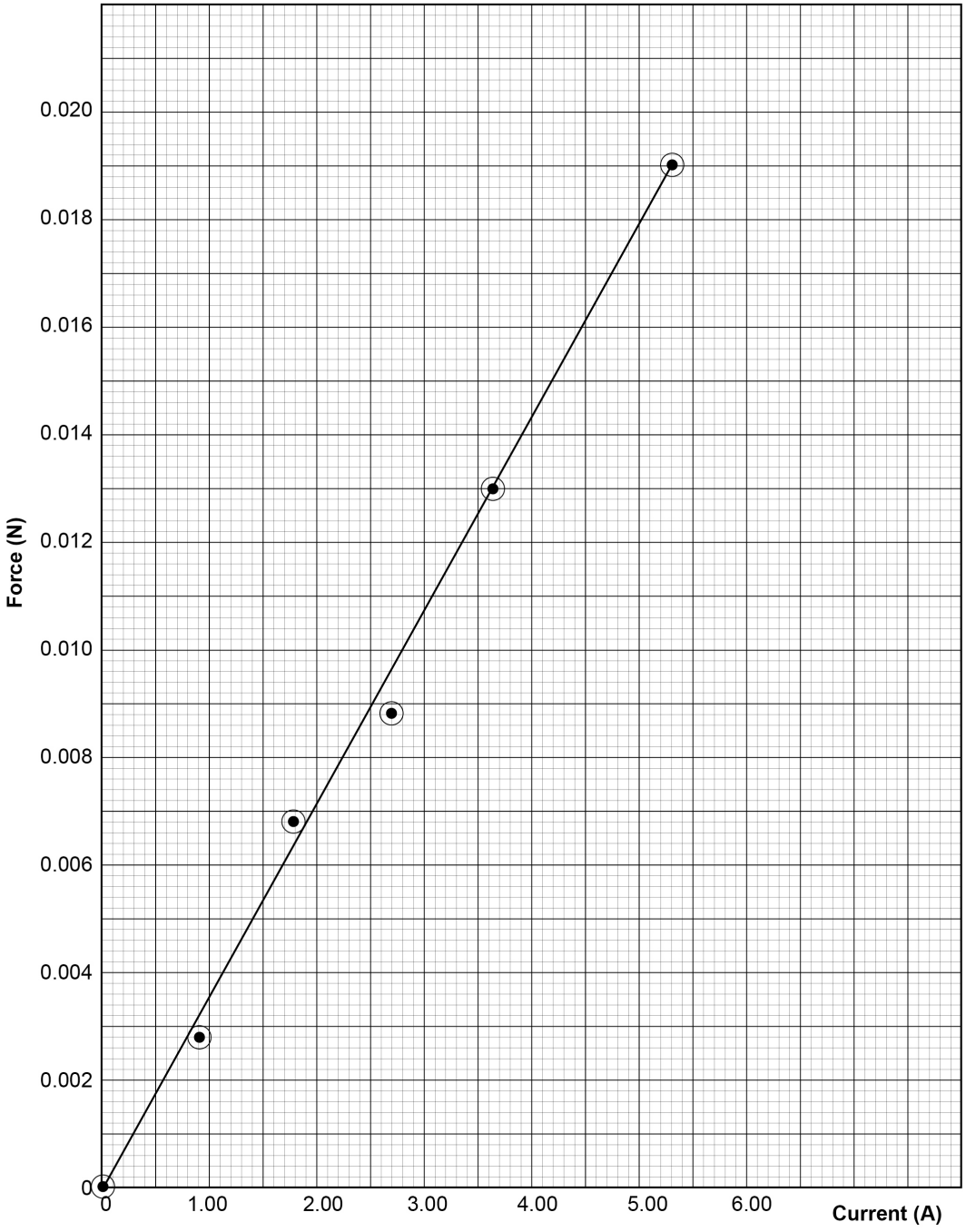
Potential difference (V)	Current (A)	Scale reading (g)	Force (N)
0.00	0.00	0.00	0.0
2.0	0.94	0.30	2.9×10^{-3}
4.0	1.81	0.70	6.9×10^{-3}
6.0	2.67	0.90	8.8×10^{-3}
8.0	3.66	1.3	1.3×10^{-2}
12	5.30	1.9	1.9×10^{-2}

(i) Complete the last column in the table above with values expressed to **two** significant figures. (2 mark)

Description	Marks
Table completed correctly	1
2 significant figures	1
Total	**2**

(ii) Use the data from the table to plot a straight line graph on the grid provided, demonstrating the relationship between the current and force. (4 marks)

Description	Marks
Current is on the x axis	1
Axes labelled with units	1
Points correct	1
Line of best fit	1
Total	**4**



(iii) Use your graph to determine the force that should be measured when a current of 4.0 A flows through the copper rod. Express your answer using appropriate significant figures. (3 marks)

Description	Marks
Shows evidence of using graph (line on graph or correct value stated)	1
14×10^{-3} (determined by graph)	1
2 significant figures	1
Total	**3**

(iv) Determine the gradient of your line of best fit. Include units in your answer. (3 marks)

Description	Marks
Uses line of best fit and not data points	1
gradient = 3.2 to 3.8×10^{-3} (actual=3.5×10^{-3})	1
Units $N\ A^{-1}$	1
Total	**3**

(v) Use your gradient to determine the experimental value of the magnetic field strength. Include units in your answer. Show **all** workings. (4 marks)

Description	Marks
$F = B\ I\ \ell$ Gradient = $F / I = B\ell$	1
ℓ = 0.02 m Diameter of magnets, rather than the length of rod; can accept larger with justification of expanding field, but not 0.2 m	1
$3.46 \times 10^{-3} = B\ \ell$ $3.46 \times 10^{-3} = B \times 0.02$ B = 0.17 Allow range 0.15–0.19	1
tesla (T) (or $N\ A^{-1}m^{-1}$ or $N\ ms^{-2}\ A^{-1}m^{-1}$ or $N\ s^{-2}\ A^{-1}$)	1
Total	**4**

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

Question 21 **(18 marks)**

(a) Estimate the velocity of the of the Chelyabinsk meteor. Give your answer to an appropriate number of significant figures. Show **all** workings. (4 marks)

Description	Marks
$E_k = 0.5\ m\ v^2$ $1.8 \times 10^{15}\ J = 0.5\ (12 \times 10^6) \times v^2$	1–2
$v^2 = 1.8 \times 10^{15} / 6 \times 10^6$ $v^2 = 3 \times 10^8$ $v = 17\ 320\ m\ s^{-1}$	1
$v = 1.7 \times 10^4\ m\ s^{-1}$ (<3 significant figures)	1
Total	**4**

(b) (i) The width, in Earth diameters, of the impact window is (circle your answer): (1 mark)

Description	Marks
One or more than one	1
Total	**1**

(ii) Calculate the length of time that an 'impact window' has for any collision of an object with the Earth, to occur. Ignore the size of the object. Show **all** workings. (3 marks)

Description	Marks
Velocity of Earth = 30.0 km s^{-1} = 3×10^4 m s^{-1}	1
Mean radius of the Earth (R_E) = 6.38×10^6 m (from data sheet) Mean diameter of the Earth = $2 \times 6.38 \times 10^6$ m = 1.276×10^7 m	1
The Earth will take 1.276×10^7m /3×10^4 m s^{-1}= 425 seconds to move out of the way of any incoming object.	1
Total	**3**

(c) The NEO Apophis is on an orbit that will bring it close to the Earth in 2036. it has an assumed mass of 4.00×10^{10} kg and diameter of 325 m.

(i) Suppose that a spacecraft arrives and begins interacting with Apophis in 2016. Determine the change in velocity required to avoid a collision with the Earth. (3 marks)

Description	Marks
t = 2036 – 2016 = 20	1
Change in velocity = 3.5×10^{-2} / t $\Delta v = 3.5\times10^{-2}$ / 20	1
$\Delta v = 1.75 \times 10^{-3}$ m s^{-1}	1
Total	**3**

(ii) If a gravity tractor type of intervention is decided upon, and does not begin interacting until 2021, then Apophis will require a change in velocity of 2.33×10^{-3} m s^{-1}. Determine the mass of the gravity tractor spacecraft needed, given that the centres of mass will be 175 m apart. (4 marks)

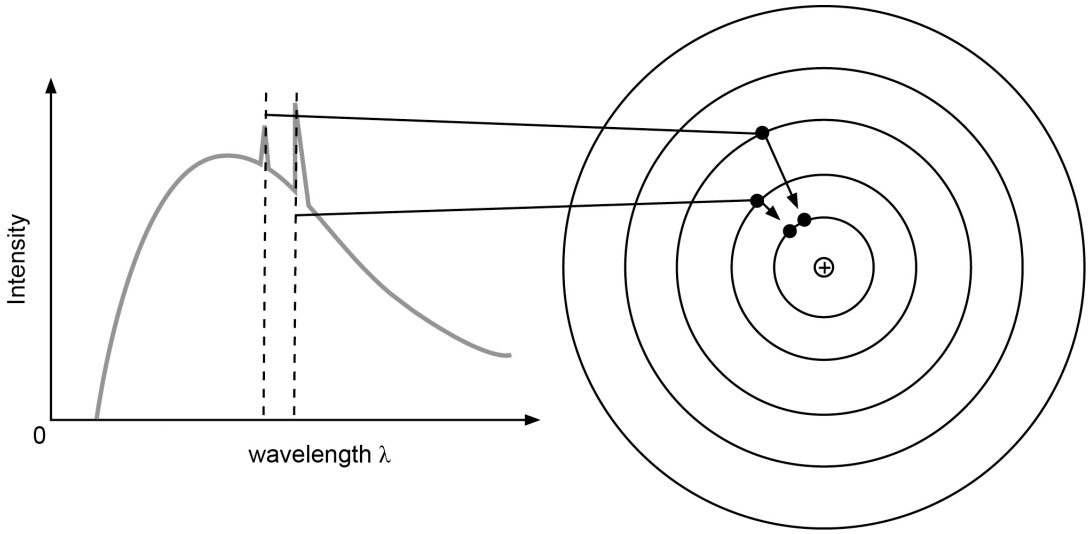
Description		Marks
$a=(v-u)/t$ $=(2.33\times10^{-3}-0)\div(15\times365.25\times24\times60\times60)$ $=4.92\times10^{-12}$ m s^{-2} $F= m_a a= Gm_a m/r^2$ $a= Gm/r^2$	$a=(v-u)/t$ $=(2.33\times10^{-3}-0)\div(15\times365.25\times24\times60\times60)$ $=4.92\times10^{-12}$ m s^{-2} $F=ma= 4\times10^{10}\times4.92\times10^{-12}=0.197$ N	1–2
$m= ar^2/G$ $m=4.92\times10^{-12}\times175^2/6.67\times10^{-11}$ m=2260 kg	$F= Gm_a m/r^2$ $0.197=6.67\times10^{-11}\times4\times10^{10}\times m/175^2$ $m=0.197\times175^2/(6.67\times10^{-11}\times4\times10^{10})$ m=2260 kg	1–2
	Total	**4**

(d) When using a gravity tractor, explain why 'the earliest of interventions' is desirable if an asteroid is to be deflected sufficiently to avoid collision with the Earth. (3 marks)

Description	Marks
Early intervention gives us more time to cause the change in velocity (acceleration)	1
From the equation $\Delta v = 3.5 \times 10^{-2} / t$ we can see that a smaller Δv is required.	1
This allows a smaller force to be exerted (and a less massive spacecraft is required)	1
Total	**3**

Question 22 **(18 marks)**

(a) The spectrum produced by an X-ray tube consists of two features. One is a smooth curve due to *bremsstrahlung* (the electron losing its energy as high energy photons). The second consists of peaks which are characteristic for the metal in the target of the tube. Explain what is meant by 'characteristic peaks', with reference to the diagram below. (3 marks)



Description	Marks
Extrapolates information from the text: '…changes in kinetic energy associated with changes in electron energy' and /or '...energy of electrons from a particular energy level … is different …' e.g. states that elements have different levels	1
Refers to the inner shell electrons in diagram above	1
States that 'characteristic' defines unique material/atom	1
Total	**3**

(b) A 1486.6 eV X-ray is used for (i), (ii) and (iii) below, which relate to X-ray photoelectron spectrometry.

(i) Determine the minimum accelerating potential difference required to produce 1486.6 eV photons in the X-ray tube, rounding your answer to **two** significant figures. (2 marks)

Description	Marks
(i) 1486.6 V (Realises that eV=>V)	1
Rounds to 1.5×10^3 V	1
Total	**2**

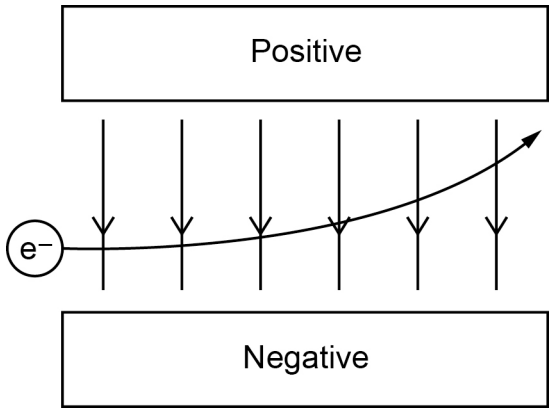
(ii) Calculate the wavelength of the 1486.6 eV X-rays. Show **all** workings. (2 marks)

Description	Marks
$hc/\lambda = 1486.6$ eV $\lambda = 4.14 \times 10^{-15} \times 3 \times 10^8 / 1486.6$	1
$\lambda = 4.14 \times 10^{-15} \times 3 \times 10^8 / 1486.6 = 8.35 \times 10^{-10}$ m	1
Total	**2**

(iii) The 1486.6 eV X-rays are directed onto a sample containing silicon, which has a work function of 4.50 eV. A photoelectron from a distinct energy level with binding energy of 99.7 eV is ejected from the sample. Calculate the kinetic energy and speed of this photoelectron. Show **all** workings. (5 marks)

Description	Marks
$E_k = hf - E_b - W$	1
$E_k = 1486.6 - 99.7 - 4.50 = 1382.4$ eV (rounding and units not required) 1382.4 eV	1
$E_k = ½ mv^2 = (1382.4 \times 1.6 \times 10^{-19})$ $v^2 = (1382.4 \times 2 \times 1.6 \times 10^{-19}) / (9.11 \times 10^{-31})$ $v^2 = 4.86 \times 10^{14}$	1–2
$v = 2.20 \times 10^7$ m s^{-1} (rounding and units not required)	1
Total	**5**

(c) Complete the simplified electrostatic lens diagram below. The electron shown is initially moving from left to right. Write the appropriate charge sign in each box to make the electron move along the path shown. Draw the field in the space between the boxes to aid your diagram. (3 marks)



Description	Marks
Labels top box as a positive plate and bottom negative	1
Field drawn showing field down (or appropriate for plates reversed or magnetic field moving into or out of page if drawn): parallel lines, evenly spread	1–2
Total	**3**

(d) The energy analyser section of an XPS consists of parallel, curved plates that can be electrically charged. A photoelectron passing between these plates is affected by them. Explain how the voltage on the plates results in only photoelectrons having a specific energy reaching the detector. (3 marks)

Description	Marks
The voltage creates an electric field for the particle to move through	1
The electric field exerts a force on the electron	1
By varying the field strength (voltage across plates) only electrons of the desired velocity will curve with the correct radius and end up on the detector, therefore E_k (or v) can be determined.	1
Total	**3**

ACKNOWLEDGEMENTS

Section One

Question 3 Data source: CERN. (n.d.). *Large Hadron Collider Beauty experiment* (LHCb). (n.d.). Retrieved January 9, 2014, from http://lhcb-public.web.cern.ch/lhcb-public/

Question 6 Adapted from: Sassospicco. (2007). *Spectrum* [Image 1] (Public domain). Retrieved February 13, 2014, from http://en.wikipedia.org/wiki/

Adapted from: Sassospicco. (2007). *Spectrum* [Image 2] (Public domain). Retrieved February 13, 2014, from http://en.wikipedia.org/wiki/

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