CHRIST CHURCH GRAMMAR SCHOOL

YEAR 12

ATAR PHYSICS

TRIAL EXAMINATION 2016

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1		
2		
3		
Total		/ 180 = %

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time for paper: three hours

Materials required/recommended for this paper

To be provided by the supervisor
Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short Answers	13	13	50	54	30%
Section Two: Problem-Solving	7	7	90	90	50%
Section Three: Comprehension	2	2	40	36	20%
				Total	180

Instructions to candidates

1. Write your answers in this Question/Answer Booklet

2. When calculating numerical answers, show your working or reasoning clearly. Give final answers to three significant figures and include appropriate units where applicable.

3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

4. The Formulae and Data booklet is **not** handed in with your Question/Answer Booklet.

YEAR 12
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Section One: Short Response

This section has **thirteen (13)** questions. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **50 minutes**.

Question 1 **(3 marks)**

Calculate the momentum of blue light that has a de Broglie wavelength of 450 nm.

$\lambda = \frac{h}{p}$ (1) so $p = \frac{h}{\lambda}$

$p = \frac{6.63 \times 10^{-34}}{4.50 \times 10^{-9}}$ (1)

$p = 1.47 \times 10^{-27}\ kgms^{-1}$ (1)

Question 2 **(5 marks)**

The table below contains information related to a planet orbiting a distant star.

Planet	Mass (kg)	Orbital Radius (m)	Radius of planet (m)	Length of day (s)
Zoot	1.21 x 10^{25}	4.00 x 10^{11}	8.00 x 10^{6}	9.50 x 10^{4}

Use data from the table to calculate the orbital period of planet Zoot.

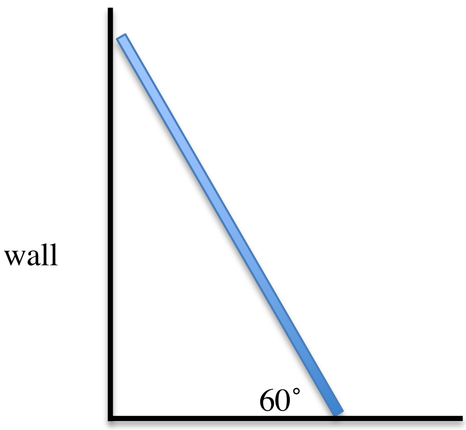
$F_c = \frac{mv^2}{r}$ (1/2) $F_G = \frac{G\, m_p \times m_s}{r^2}$ (1/2) $v = \frac{s}{t} = \frac{2\pi r}{t}$ (1/2)

$\frac{m_p\, 4\pi^2 r^2}{r T^2} = \frac{G\, m_p \times m_s}{r^2}$ (1/2) $T^2 = \frac{4\pi^2 r^3}{G\, m_s}$ (1)

$T = \sqrt{\frac{4\pi^2 (4\times 10^{11})^3}{(6.67 \times 10^{-11}) \times (1.21 \times 10^{25})}}$ (1) $T = 5.60 \times 10^{10} s$ (1)

Question 3 **(5 marks)**

A builder leans a 3.25 m long, uniform plank of wood with a weight of 495 N up against a smooth frictionless wall on a building site as shown in the diagram below. The plank makes an angle of 60.0˚ with the rough concrete floor. Calculate the frictional force between the base of the plank and the floor to keep the plank in this position.



$$\Sigma F = ma \quad (1/2)$$

$$\Sigma F_V = -mg + F_{N\,floor} = 0$$

$$\Sigma F_H = F_{wall} + F_F = 0 \quad (1/2)$$

$$\Sigma \tau = 0 \quad (1/2) \qquad \Sigma \tau = rF \quad (1/2)$$

$$\Sigma \tau_{cw} = 3.25 \times F_{wall} \sin 60° \quad (1) \qquad \Sigma \tau_{ccw} = 495 \times \frac{3.25}{2} \times \sin 30° \quad (1)$$

$F_{wall} = -F_F$ = 143 N towards the wall (1)

Question 4 **(4 marks)**

Explain why light can be described as an electromagnetic wave but not as a mechanical wave.

- A mechanical wave requires particles of matter in a medium to be oscillated to enable the energy to transfer from one point in space to another
- Light is propagated as an electric field and a magnetic field that are at right angles to each other
- This enables light to travel through a vacuum where no particles exist to be oscillated
- So light can not be classified as a mechanical wave.

Question 5 **(6 marks)**

The wireless technology employed in an office transmits information via microwave pulses that have a power output of 5.75 kW for each pulse. A signal is transmitted at a frequency of 2.40 x 10^9 Hz for a time of 10^{-6} seconds per pulse.

(a) Calculate the photon energy of each microwave pulse. (3 marks)

1

$$E = hf$$

$$E = 6.63 \times 10^{-34} \times 2.40 \times 10^{9}$$ 1

1 $$E = 1.59 \times 10^{-24}\ J$$

(b) Calculate how many photons are emitted in each pulse. (3 marks)

$$P = \frac{E}{t}$$ 1

$$P = 5.75 \times 10^{3} = \frac{E}{1.00 \times 10^{-6}}$$ 1

$$Number\ of\ photons = \frac{5.75 \times 10^{-3}}{1.59 \times 10^{-24}} = 3.62 \times 10^{21}\ photons$$ 1

Question 6 **(4 marks)**

When viewing different sources of light through a spectroscope, different types of spectrum would be seen. For each of the following examples **circle** the correct option from each group of responses.

(a) A discharge tube filled with low pressure hydrogen gas powered by a high potential difference.
(1 mark)

line broadband continuous absorption emission

(b) A flame of a burning candle.
(1 mark)

line broadband continuous absorption emission

(c) A cold solution of chlorophyll illuminated from behind with an incandescent light globe
(1 mark)

line broadband continuous absorption emission

(d) Light originating from the Sun as viewed from Earth
(1 mark)

line broadband continuous absorption emission

Question 7 **(3 marks)**

(a) Explain why a proton and a neutron are classified as hadrons.
(1 mark)

- Both a proton and a neutron are composed of 3 quarks

(b) Explain why a proton has a charge of +1e, while a neutron is uncharged.
(2 marks)

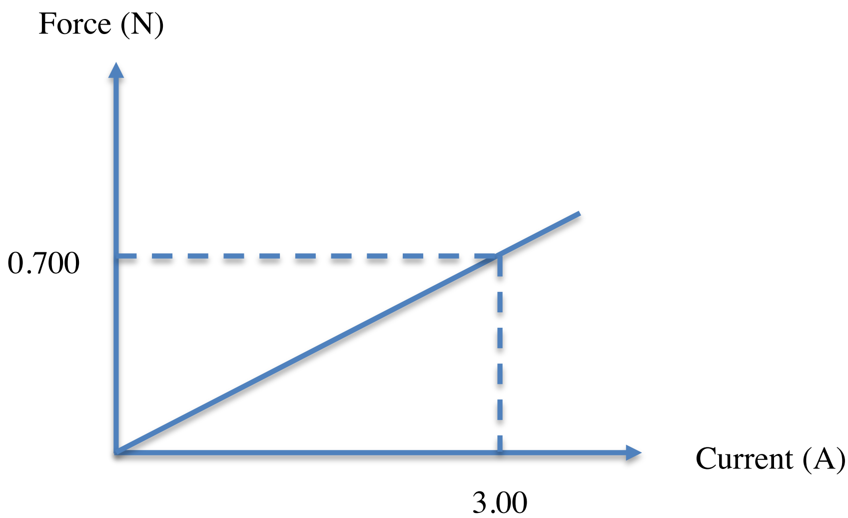
- A proton is made from two up and 1 down quark with charges of +2/3e, +2/3e, -1/3e =+1e

- A neutron is made from1 up and two down quarks with charges of +2/3e, -1/3e, -1/3e = 0 charge

Question 8 **(3 marks)**

A student performed an experiment to measure the force acting on a long current-carrying conductor placed perpendicular to an external magnetic field.

The graph below shows how the force on a 0.200 m length of the conductor varied as the current through the conductor was changed.



Determine the magnitude of the external magnetic field used in this experiment.

1 $F = BIl$

$B = \frac{F}{IL}$ 1 $B = \frac{0.700}{3.00 \times 0.200}$

1 $B = 1.17$ T

or could determine gradient (Force/Current) then divide by length to get same answer

Question 9 **(6 marks)**

In one of Einstein's thought experiments, a passenger is sitting in the middle of a carriage that is 22.0 m long as it travels through a train station at 60.0% of the speed of light. A person standing on a platform observes the train passing through the station.

When the middle of the carriage passes the person on the platform, lights at each end of the carriage are switched on, as shown in the diagram below.

(a) Do the two observers observe the lights coming on at the same time? Explain your reasoning.
(4 marks)

- No
- Although the speed of light is constant to each observer
- they are in different frames of reference
- So the two events are not simultaneous

OR

- Person on platform is equidistant from lights, and so time is the same
  Person on carriage travels a distance s = v.t in the time the light takes to reach him, and so the two lights will have different distances to travel, hence not occurring simultaneously.

(b) Calculate the length of the carriage as observed by the person standing on the station platform.
(2 marks)

(1) $L = L_0 \times \sqrt{1 - \frac{v^2}{c^2}}$

$L = 22.0 \times \sqrt{1 - 0.6^2}$

$L = 22.0 \times \sqrt{0.64}$

(1) $L = 17.6\ m$

Question 10 **(4 marks)**

The Standard Model explains that all matter is made up of elementary matter particles called quarks and leptons. Each type of particle interacts with the four fundamental forces differently.

(a) Describe how quarks and leptons are **different** in their interaction with the four fundamental forces.
(2 marks)

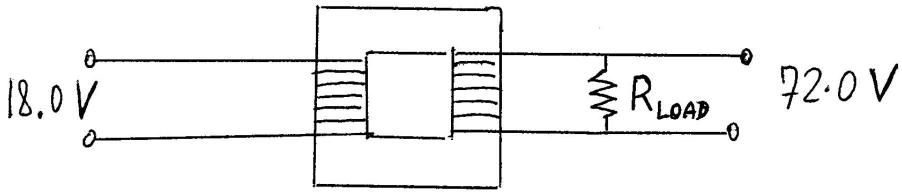
- Leptons do not interact with the strong force while quarks do

(b) Explain why baryons and mesons are categorised as **different** forms of hadrons.
(2 marks)

- Baryons are composed of 3 quarks (and have a Baryon number of 1)
- Mesons are a quark anti-quark pair (and have a Baryon number of 0)

Question 11 **(4 marks)**

An *ideal* transformer operates with an RMS input voltage of 18.0 V and an RMS current of 4.50 A drawn through the primary winding. The RMS output voltage is 72.0 V and there are 48 turns on the secondary winding.



(a) Calculate the RMS output current for the transformer. (2 marks)

$$P_{input} = P_{output}$$ 1/2

$$V_P I_P = V_S I_S$$ 1/2

$$I_S = \frac{I_P V_P}{V_S}$$

$$I_S = \frac{18 \times 4.5}{72} = 1.13\ A$$ 1

(b) Calculate the number of turns in the primary winding. (2 marks)

1 $$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

$$N_P = \frac{18}{72} \times 48$$

$$N_P = 12\ turns$$ 1

Question 12 **(4 marks)**

Hamish has a toy car set that contains a loop-the-loop, as shown in the diagram below. Estimate the minimum speed that the toy car should have at the top of the loop to be able to successfully complete the loop-the-loop without dropping off the track. You must state any assumptions or estimates that you have made.

Let r = 0.20 m (accept 0.15 - 0.25m)

$\Sigma F = ma_c$

$\Sigma F = -mg - F_N = ma_c$ (1)

$F_N = \frac{mv^2}{r} - mg$ $F_N = 0$ so $\frac{mv^2}{r} = mg$ (1)

$v = \sqrt{rg}$ (1/2) $v = \sqrt{0.20 \times 9.8}$ (1/2) $v = 1.4\ ms^{-1}$ (1)

[If use 0.15 m value = 1.2 ms^{-1}, if use 0.25 m value is 1.6 ms^{-1}]

Question 13 **(3 marks)**

The Standard Model explains three of the four fundamental forces (strong, weak and electromagnetic) in terms of an exchange of force-carrying particles called gauge bosons, where each force is mediated by a different type of gauge boson. State the type of gauge boson that mediates each of the three fundamental forces.

Strong Force: gluon

Weak Force: W & Z boson

Electromagnetic Force: virtual photon

End of Section One

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Section Two: Problem-Solving

This section has **seven (7)** questions. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **90 minutes**.

NAME:______________________________________

Question 1 **(10 marks)**

A hydrogen atom is made up of a single proton in the nucleus of the atom and an orbiting electron, separated by a distance of 3.62 x 10^{-11} m.

(a) Calculate the electrostatic force that exists between the proton and the electron.

(3 marks)

$$F = \frac{1}{4\pi\varepsilon_0} \times \frac{q_1 \times q_2}{r^2}$$ (1)

$$F = \frac{1}{4\pi 8.85 \times 10^{-12}} \times \frac{(1.6 \times 10^{-19})^2}{(3.62 \times 10^{-11})^2}$$ (1)

$$F = 1.76 \times 10^{-7} \text{N attraction}$$ (1)

-1/2 if no direction

(b) Calculate the gravitation force of **attraction** that exists between the electron and the proton.

(3 marks)

$$F = \frac{G\, m_1 \times m_2}{r^2}$$ (1)

$$F = \frac{6.67 \times 10^{-11} \times (9.11 \times 10^{-31}) \times (1.67 \times 10^{-27})}{(3.62 \times 10^{-11})^2}$$ (1)

$$F = 7.74 \times 10^{-47} \text{N attraction}$$ (1)

(c) (i) Explain qualitatively how the electrostatic force would alter if the atom was deuterium, an isotope of hydrogen, containing both a proton and a neutron in the nucleus of the atom.

(2 marks)

There would be no change in the electrostatic force as it depends only on charge that has not altered with the addition of the uncharged neutron

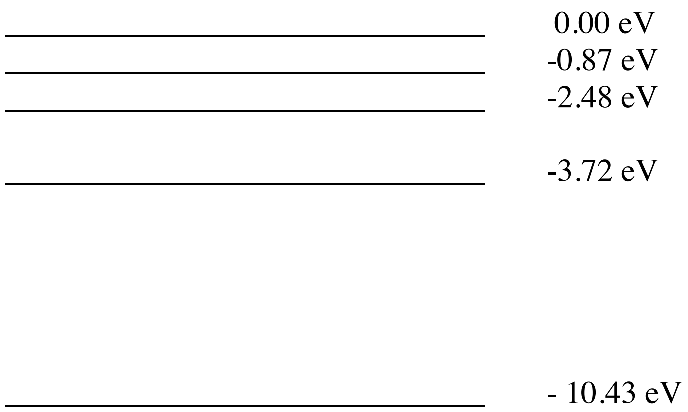
(ii) Explain qualitatively how the gravitational force would alter if the atom was deuterium containing both a proton and a neutron in the nucleus of the atom.

(2 marks)

The gravitational force would increase (double) as the gravitational force is dependent on mass. The addition of a neutron to the nucleus increases the mass (approximately doubles the mass) of the nucleus, so would increase (double) the gravitational force of attraction.

Question 2 **(11 marks)**

Some energy levels of the mercury atom are shown in the diagram (not to scale) below.



(a) Determine the maximum number of lines that could appear in the line emission spectrum of mercury using the energy levels shown.

(2 marks)

There are 6 emission lines (emission so can not decay from ionisation level)

(b) Calculate the longest wavelength of light that could be found in this emission spectrum.

(3 marks)

Longest wavelength will occur when there is the smallest energy transition as E α $1/\lambda$ so E=3 to E=2

-2.48- -3.72 = 1.24 eV 1

$E = \frac{h \times c}{\lambda}$ $\lambda = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{1.24 \times 1.60 \times 10^{-19}}$ 1

1.00×10^{-6} m 1

-1 mark if incorrect energy value used

(c) Calculate the highest frequency photon that could be emitted from the energy levels shown.

(3 marks)

Highest Frequency will occur during maximum energy change as Eα f so n= 4 to n=1

-0.87--10.43= 9.56 eV 1

$E = hf$ $f = \frac{9.56 \times 1.60 \times 10^{-19}}{6.63 \times 10^{-34}}$ 1

$f = 2.31 \times 10^{15}$ Hz 1

-1 if incorrect energy level used

(d) Determine the region of the electromagnetic spectrum from which the photon in part (c) above would be detected.

(1 mark)

Ultraviolet

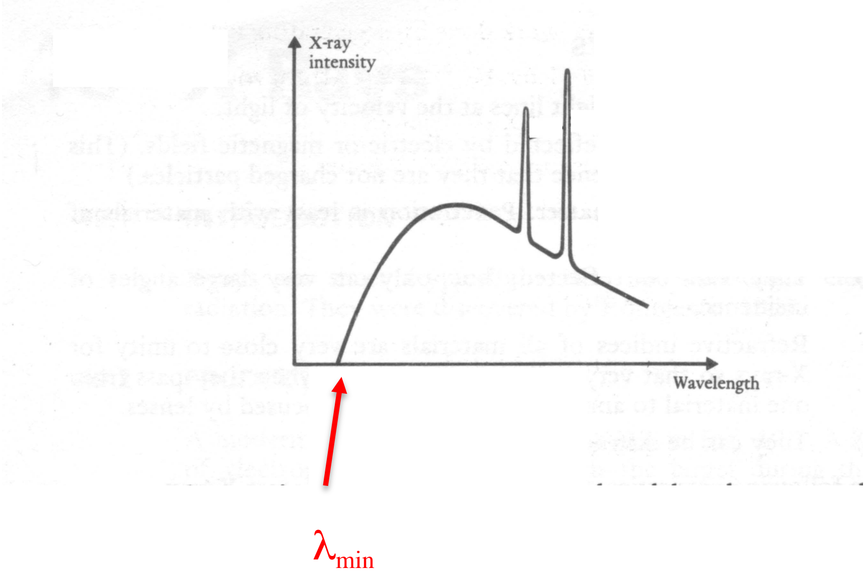
(e) Describe what occurs within the atom when an atom is induced to emit its line emission spectra.

(2 marks)

- Electrons that have been promoted to higher energy levels
- Cascade back to the ground state emitting discrete value photons equivalent to the energy of each line emission

Question 3 **(11 marks)**

The X-ray spectrum in the graph below was produced by an X-ray tube with a supply voltage of 50.0 kV. The target anode was made of copper.



(a) Clearly indicate on the graph above, with the label 'λ_{min}', the *wavelength* that corresponds to highest frequency of the *Bremsstrahlung* X-rays produced.

(1 mark)

(b) Explain how the different sections of the intensity vs wavelength graph are produced.

(4 marks)

- The smooth curve continuous section of the graph is created by the full range of Bremsstrahlung X-rays
- emitted by randomly decelerating electrons (above minimum value) emitting emr equivalent to the loss of kinetic energy as x-ray photons
- The peaks are due to the X-rays produced when colliding electrons knock electrons out from inner shell of the target anode
- A higher energy electron immediately drops back to fill the vacant position emitting an X-ray photon - this is a characteristic of the target anode used in the X-ray machine

(c) Calculate the maximum kinetic energy in joules of the thermionic electrons accelerated by the supply voltage of 50.0 kV.

(3 marks)

$E_{max} = qV$ (1)

$E_{max} = 1.6 \times 10^{-19} \times 5.00 \times 10^{4}$ (1)

$E_{max} = 8.00 \times 10^{-15} J$ (1)

-1/2 if no unit

(d) Calculate the wavelength of these X-rays if the kinetic energy is entirely transformed into energy of the X-ray photons.

(3 marks)

$$E = \frac{h\,c}{\lambda}$$ (1)

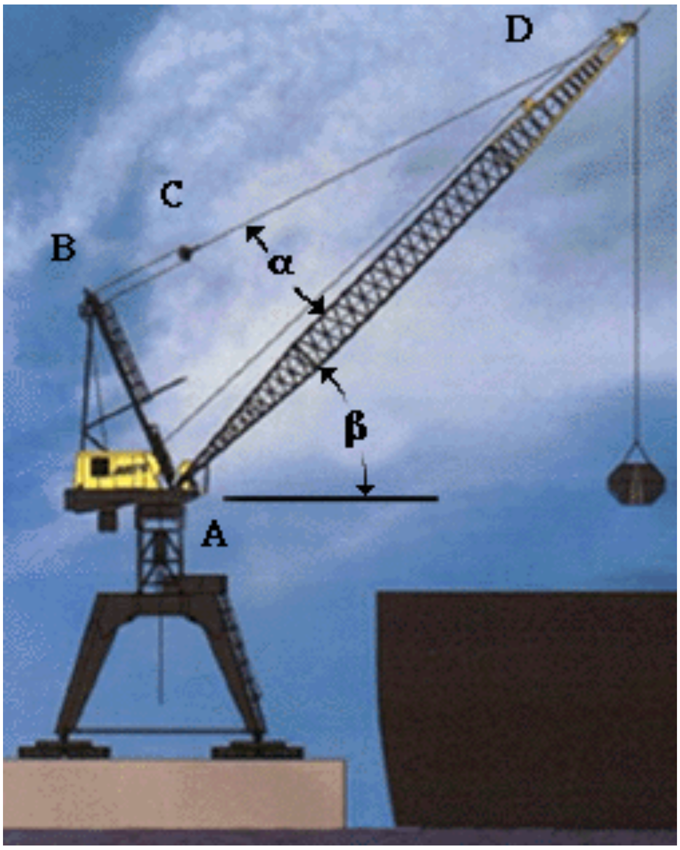
$$\lambda = \frac{h\,c}{E} \qquad \lambda = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{8.00 \times 10^{-15}}$$ (1)

$$\lambda = 2.49 \times 10^{-11}\ \text{m}$$ (1)

-1/2 if no unit

Question 4 **(17 marks)**

A crane at a port, similar to one in the image below, is used to lift heavy objects out of ships.



In the image, the crane is lifting an object that has a mass of 1.00 x 10^3 kg. The crane mast (AD) has a length of 30.0 m, with a uniform distribution of 4.00 x 10^2 kg mass, pivoting about point A The mast makes an angle β of 40.0˚ from the horizontal. The cable CD makes and angle α of 20.0˚with the top of the crane mast (point D). Note: Angle ABD is 90.0˚.

(a) Calculate the magnitude of the tension in cable CD.

(4 marks)

$\Sigma \tau = 0$ or $\Sigma \tau cw = \Sigma \tau ccw$ (1/2) $\tau = Fr\sin\theta$ (1/2)

$$\Sigma \tau cw = (m_{mast}g)\frac{30}{2} \times \sin 50^\circ + (m_{load}g \times 30 \times \sin 50)$$ (1)

$$\Sigma \tau ccw = (30\,T \sin 20^\circ)$$

$$T = \frac{45043 + 225217}{30 \sin 20}$$ (1) $T = 2.63 \times 10^4 N$ (1)

-1/2 if Σ is missing from calculations

(b) Calculate the reaction force acting on the crane mast at point A when in the position shown.

(5 marks)

$F_V = (1000 \times -9.8) + (400 \times -9.8) + (-2.63 \times 10^4 \times \sin 20^\circ) + F_{VR} = 0)$ 1

$F_V = 2.27 \times 10^4 N$

$F_H = (2.63 \times 10^4 \times \cos 20^\circ) = 2.47 \times 10^4 N$ 1

$F_R = \sqrt{(2.27 \times 10^4)^2 + 2.47 \times 10^4)^2}$

$F_R = 3.35 \times 10^4 N$ 1

$\text{Tan}\theta = \frac{2.27 \times 10^4}{2.47 \times 10^4} = 42.6^\circ$ above the horizontal 1

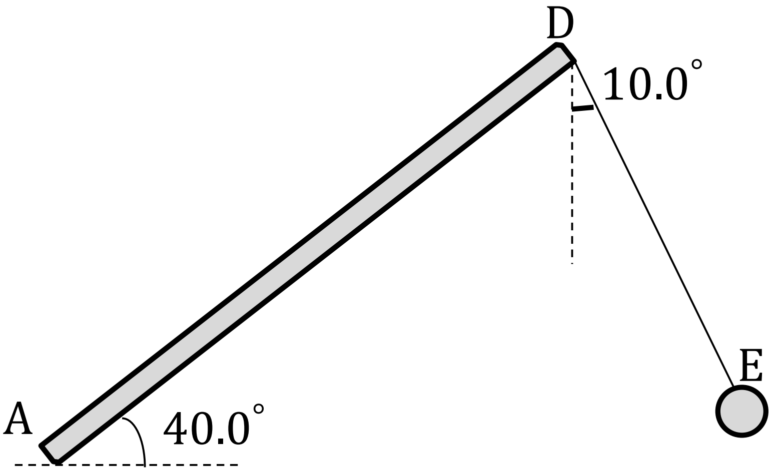
3.35×10^4 N at 42.6° above the horizontal 1

(c) The position of the crane mast can be lowered so that $\beta \rightarrow 0$. It can be assumed that α remains constant. Explain the effect this would have on the magnitude of the tension in the cable CD.

(3 marks)

- As β approaches 0° the tension in the cable would increase
- The clockwise component of the torque would increase due to increased value of r at right angles to the weight of the mast
- To maintain equilibrium the tension must increase to increase the counter clockwise torque

The crane can rotate horizontally about point A to position the object removed from the ship, onto a waiting truck on the dock. This causes the cable DE to create an angle of 10.0° to the vertical, as shown in the diagram below.



(d) Calculate the centripetal acceleration of the object that was lifted, if the crane is rotated horizontally at a uniform speed through 120° in a time of 30.0 s.

(5 marks)

r = 30cos 40 +(30 sin40 x sin10)
r = 23.0 + (3.35) = 26.4 m (1)

$C = 2\pi r = 2\pi 26.4 = 166\text{ m}$ (1/2)

$s = 166/(360/120) = 55.3\ m$ (1/2)

$v = \frac{55.3}{30} = 1.84\ ms^{-1}$ (1)

$ac = \frac{v^2}{r}$ (1/2)

$ac = \frac{(1.84)^2}{26.4}$ (1/2)

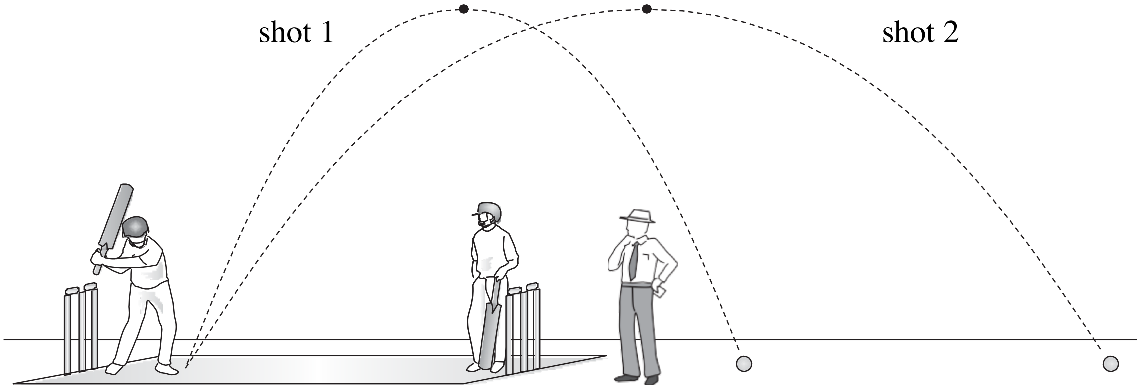
$ac = 0.128\ ms^{-2}$ (1)

-1/2 if no direction specified

allow for variation in method of calculating value of r

Question 5 **(15 marks)**

The picture below shows two consecutive shots by a batsman in a game of cricket.



Both balls achieve the same height above the ground but shot 2 reaches twice the distance (range) compared to shot 1 before hitting the ground.

(a) Neglecting air resistance, compare shot 1 with shot 2, with an explanation using the projectile concepts of initial velocity, time of flight, and acceleration due to gravity, why shot 2 has a greater range than shot 1.

(5 marks)

- The initial velocity of both shot 1 and 2 have a vertical and horizontal component.
- As time of flight is determined by the acceleration due to gravity acting on the vertical component of velocity and as both reach same height, time of flight is the same for shot 1 and shot 2
- So both have the same magnitude of initial vertical component of velocity
- To achieve a greater range, Shot 2 must have greater component of horizontal velocity.
- Therefore Shot 2 must have a greater initial velocity than shot 1.

The cricket field used in the game has a boundary of 55.0 m from the batsman. A six is required to win the game on the last ball of the game. The batsman hits the ball with the base of his bat at ground level with an initial speed of 24.2 ms^{-1} at an angle of 39.0˚above the horizontal. (Disregard air resistance in part (b) and (c) of this question).

(b) Calculate the height that the ball reaches.

(3 marks)

$v_V = \text{v} \sin\theta = 24.2 \sin 39.0 = 15.2 \text{ ms}^{-1}$ 1

$\text{v}^2 - \text{u}^2 = 2\text{as}$

$s = \frac{0^2 - (15.2)^2}{-(2\times 9.8)}$ 1

$\text{s} = 11.8 \text{ m}$ 1

-1/2 if calculator values used are greater than 3 sig fig.

(c) The ball is hit towards a fieldsman on the boundary who can only catch the ball if it is below a height of 2.55 m as it reaches his position. Does the batsman win the game? Verify your answer with a calculation.

(6 marks)

$v_H = \text{v} \cos\theta = 24.2 \cos 39.0 = 18.8 \text{ ms}^{-1}$ 1

$\text{s}_\text{H} = \text{v}_\text{H} \times \text{t}$ 1/2 $\text{t} = \frac{55.0}{18.8} = 2.93 \text{ s}$ 1/2

$s_V = \text{ut} + \frac{1}{2}\text{at}^2$ 1

$s_V = (15.2\times 2.93) + \frac{1}{2}(-9.8)(2.93)\text{t}^2$ 1

s = 2.47 m 1

As 2.47 m< 2.55 m The batsman does not win the game. 1

If alternative method of calculation is used determining time of flight as 2.92 s then s = 2.60 m as 2.60 m> 2.55 m, batsman wins the game

Question 6 **(11 marks)**

A farmer needs to supply a water pump with a high voltage of 1.20 kV RMS but only has access to a 240 V RMS supply. He connects a transformer with 220 turns of wire on the primary coil to a secondary coil to step up to the voltage required. (Assume that the transformer is 100% efficient).

(a) Calculate the number of turns required on the secondary winding of the transformer.

(3 marks)

$$\frac{N_S}{N_P} = \frac{V_S}{V_P}$$ 1

$$N_S = \frac{V_S \times N_P}{V_P} = \frac{1200 \times 220}{240}$$ 1

$$N_S = 1100 \text{ turns}$$ 1

The maximum allowable voltage drop (potential difference) across the cables that connect the secondary coil of the transformer to the water pump is 5% of the output voltage. The transformer has an electrical power output of 8.25 kW.

(b) Calculate the maximum allowable resistance of the cables connecting the secondary coil of the transformer to the water pump.

(3 marks)

$$V_{drop} = \frac{5}{100} \times 1200 = 60.0\ V$$ 1

$$P_{out} = V \times I \qquad I = \frac{8250}{1200} = 6.88\ A$$ 1

$$V = I \times R, \quad R = \frac{60}{6.88}$$

1 $$R = 8.72\ \Omega$$ 1

(c) Calculate the electrical power that is available to the water pump.

(3 marks)

$$V_P = V_S - V_D$$ 1/2

$$V_P = 1200 - 60 = 1140\ V$$ 1

$$P = V \times I$$ 1/2

$$P = 1140 \times 6.88 = 7.84 \text{ kW}$$ 1

(d) In such a transformer the energy output is not 100%. Describe two methods used in transformer construction to increase efficiency.

(2 marks)

- Use of laminations to reduce eddy currents and resulting restive heating
- Use of soft iron core to confine change of magnetic flux between primary and secondary windings

or other suitable answer

Question 7 **(16 marks)**

In an experiment a group of students investigate the photoelectric effect. They measure the energy of photo-electrons ejected from a polished metal in eV as the frequency of the incident light used was varied. The results of the experiment are shown below.

E (eV)	**f (x 10^{14} Hz)**	E (x 10^{-19} J)
2.00	13.0	3.20
1.60	12.0	2.56
1.10	11.0	1.76
0.700	10.0	1.12
0.500	9.50	0.800
0.250	9.00	0.400

(a) Process the data in order to construct a graph E (joules) v f

(3 marks)

1 mark column title, 1 mark column unit (-1/2 if does not show x 10^{-19} J), 1 mark correct values

(b) Construct a graph of E v f on the following page. The y-axis should be started from -7.00 x 10^{-19} J.

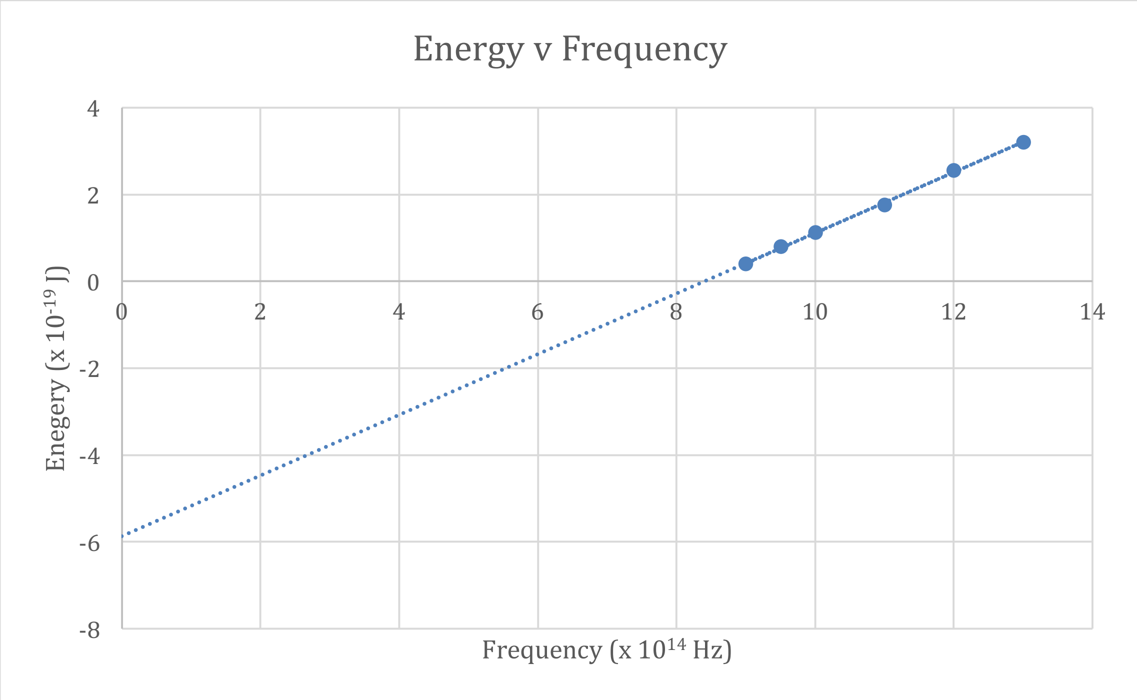
(5 marks)

1 mark label axis, 1 mark axis unit, 1 equidistant scales, 1 mark plot,
1 mark line of best fit
- 1/2 mark if y axis does not begin at -7.00 x 10^{-19} J
-1/2 if axes not ruled up correctly

(c) Explain, in relation to electron-photon interaction, the significance of the x-intercept of the graph.

(2 marks)

The x-intercept is equivalent to the threshold frequency (f_0) below which no electrons can be emitted from the metal surface.



(d) Explain the significance of the y-intercept of the graph.

(2 marks)

The y-intercept is equivalent to the work function, the energy required to ionise an electron from the metal surface

(e) Calculate the gradient of the graph.

(3 marks)

1 mark triangle on graph, 1 mark calculation, 1 mark correct Unit

gradient = $((2.3-1.10)\times10^{-19})/((12-10)\times 10^{14}) = 6.0 \times 10^{-34}$ J Hz^{-1} (or Js)

-1/2 if gradient calculation does not show values taken from line of best fit

(f) State what the gradient represents.

(1 mark)

Planck's Constant

End of Section Two

YEAR 12
ATAR PHYSICS
TRIAL EXAMINATION 2016

Section Three: Comprehension

This section has **two (2)** questions. Answer **both** questions. Write your answers in the space provided.

Suggested working time for this section is **40 minutes**.

NAME:___SOLUTIONS__________________________

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Question 1 **(19 marks)**

Photoconductivity

Big companies sometimes make big mistakes. When American inventor Chester Carlson (1906–1968) approached some of the largest corporations in the world with his idea for a photocopying machine, they simply did not want to know. They could not imagine who would want to make lots of copies of documents. It took Carlson years to turn the idea into one of the most important office inventions of the 20th century - and those companies kicked themselves when they realised just how big an opportunity they had missed. Photocopiers look complex, but they work using two areas of science; static electricity and photoconductivity.

The science of static electricity is put to practical use inside a photocopier. Static electricity, however, is only one of the two scientific principles that makes a photocopier work. The other is photoconductivity.

Photoconductivity is a phenomenon in which some materials become more electrically conductive due to the absorption of electromagnetic radiation. Certain crystalline semiconductors, such as silicon, germanium, lead sulfide, and cadmium sulfide, and the related semi-metal selenium are all strongly photoconductive. Normally, semiconductors are relatively poor electrical conductors because they have only a small number of electrons that are free to move when they experience a potential difference. Most of the electrons are bound to their atomic lattice in the set of energy states called the *valence band*. But if an external source of energy such as heat or light is provided, some electrons can be raised to a higher energy *conduction band*, where the electrons can be moved in an electric field. The current formed will cease when the light source is removed.

Photoconductivity can occur when the semiconductor material is bombarded with photons of sufficient energy to excite electrons across the band gap, the region between the valence and conduction bands. This increases the number of free electrons and leaves behind electron holes from where the electron has been promoted, raising the material's electrical conductivity. In metals these electron holes are quickly filled by a higher energy electron dropping back, as there is an abundance of free electrons. To cause excitation the photons that strike the semiconductor must have enough energy to raise electrons across the band gap.

(a) Briefly describe the similarities and differences between the photoelectric effect and photoconductivity.

(4 marks)

- Both effects involve the absorption of light in the form of photons to increase the energy of electrons within a material.
- In the photoelectric effect, photons are absorbed by electrons giving them sufficient energy to escape from the surface of a metal.
- In photoconductivity, photons are absorbed by electrons to enable electrons to jump energy level gaps within the atom.
- The photoelectric effect occurs in metals whereas, photoconductivity occurs in crystalline solids

The initial chemical element used in xerography, the process used in modern photocopiers, was selenium. To cross the band gap, selenium requires an energy equivalent to 2.60 eV.

(b) Calculate the wavelength of the photon required to excite an electron across the band gap of a selenium atom.

(3 marks)

$E = hf$ $E = hc/\lambda$ $\lambda = hc/E$ (1)

$\lambda = (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (2.60 \times 1.60 \times 10^{-19})$ (1)

$\lambda = 4.78 \times 10^{-7}$ m (1)

(c) State the part of the electromagnetic spectrum that match the photons required to cross the band gap of selenium.

(1 mark)

blue/violet light

Selenium is a poor electrical conductor but when light of a particular frequency is absorbed by some of its valence band electrons and a potential difference is applied, these electrons are able to pass more freely from one atom to another. When the light is removed, the mobility of the electrons falls. Xerography typically used an aluminum drum coated with a layer of selenium. The selenium has largely been replaced by more efficient photoconductive polymers such as polyvinylcarbazole.

The photoconductor inside a photocopier is similar to a solar cell. When sunlight shines onto a solar panel, the solar cells inside the panel take in the available energy in the light and convert it directly into electrical energy by removing the electrons that exist in the excited state as an electric current.

Instead of producing an electric current when light shines onto it as in the solar cell, the photoconductor captures the pattern of the light as a pattern of static electricity.

After a great deal of research and tinkering in his laboratory, Chester Carlson figured out how he could use these two bits of science—static electricity and photoconductivity—to help him make copies of documents. He found that if you shine an *extremely* bright light onto a document, you can make a shadow of the black and white areas on the page. If the light is shone onto the document at an angle, it does not reflect straight back - it bounces off at an angle. So, by shining the light at an angle onto the document, you can reflect an 'electrical shadow' of the document onto another object, the photoconductor. This forms a reflected image of the document on the photoconductor.

(d) Explain what is meant by the term 'electrical shadow'.

(2 marks)

- Light reflects off the white areas and is absorbed by the dark areas. A shadow is considered to be the absence of light.
- The pattern of light that is reflected is captured as a pattern of static electricity – the electrical shadow is where there is no static electricity.

The cylindrical drum in a photocopier has a photoconductive coating that is electrostatically charged by a high voltage wire called a corona wire or a charge roller. The bright lamp then illuminates the original document, and the white areas of the document reflect the light onto the surface of the photoconductive drum. The areas of the drum that are exposed to light become conductive by giving electrons sufficient energy to jump the band gap and and can then discharge to the ground. The area of the drum not exposed to light (those areas that correspond to black portions of the original document) remains negatively charged; an electrical copy of the light shining onto it. This is the key to how a photocopier works.

(e) Describe how areas on the photoconductor become charged.

(4 marks)

- The photoconductive coating on the drum is charged by a high voltage wire called a corona.
- The photons of light reflected from the white areas of a document are absorbed by electrons in the drum coating, exciting them to the conduction band.
- These electrons can then flow through the conduction band, which is earthed. This discharges these areas of the drum.
- The areas which no light was reflected from remain charged.

Ink powder, known as toner, is then brought very near to the photoconductor. The toner particles are positively charged so are attracted to it, and will stick to the negatively charged areas of the 'electrical shadow'.

The resulting toner image on the surface of the drum is transferred from the drum onto a piece of paper which has a higher negative charge than the drum. The paper is pushed onto the photoconductor and heated to fuse the ink to the paper. The paper now has a copy of the original document.

(f) Explain why the paper must have a stronger electrical charge than that created on the photoconductor drum.

(2 marks)

- A stronger electrical charge on the paper will mean that the force between the paper and the toner is greater than the force between the toner and the drum.
- This will mean the toner is attracted to the paper, rather than staying on the drum, so that it can be fused to the paper.

(g) Calculate the electrostatic force that exists between a -2.50 μC charged area of the photocopier drum and ink toner that has a charge of +3.00 μC if they are initially separated by a distance of 5.00 x 10^{-3} m.

(3 marks)

$$F = \frac{1}{4\pi\varepsilon_0} \times \frac{q_1 \times q_2}{r^2}$$ (1)

$$F = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{-2.50 \times 10^{-6} \times 3.00 \times 10^{-6}}{(5.00 \times 10^{-3})^2}$$ (1)

$F = 2.70 \text{ x } 10^3\ N$ attraction (1)

-0.5 mark if no direction

Question 2 **(17 marks)**

Investigating Jupiter

NASA has sent various probes out in space to investigate our neighbours in space. One of the more ambitious projects was to send the Juno probe to investigate Jupiter, as a follow up to a previous visit by Galileo in 2003. Juno has the ability to send back images of Jupiter and detailed information never achieved with such clarity before as it orbits the large gas giant.

The Juno probe has a mass of 1600 kg.
The Equatorial Radius of Jupiter is 7.15×10^7 m
Polar Radius of 6.69×10^7 m
Orbital Period of = 3.12×10^9 s
Rotational period 3.57×10^8 s
Mean Earth Jupiter distance is 7.50×10^9m.

With the exception of the Sun, Jupiter is the most dominant object in the solar system. Because of its enormous size and the fact that it was likely the first of the planets to form, it has profoundly influenced the formation and evolution of the other bodies that orbit our star.

The trip to Jupiter took Juno about 5 years being launched in August 2011. Its journey enabled the use of the Earth's gravity to increase the probes speed. To do this the probe first was put into an elliptical heliocentric (sun-centered) orbit around the inner solar system over a two-year period. Juno then swung back past the Earth in October 2013, when the Earth was travelling towards Jupiter. Juno used the Earth's gravitational field to get a boost to propel it towards Jupiter by boosting its speed by 3.9 kms^{-1}.

Juno arrived at Jupiter in July of this year. Jupiter's gravity accelerated Juno to a speed of 74 kms^{-1} before it fired its main engines to slow Juno down by 542 ms^{-1} to slip to be captured and placed into a polar orbit with a period of 53.5 days to begin its primary scientific mission.

(a) Calculate the altitude at which Juno was orbiting Jupiter at this stage of its mission.

(4 marks)

$v = 7.40 \times 10^4\ ms^{-1} - 542\ ms^{-1} = 7.35 \times 10^4\ ms^{-1}$ (1)

$v = \frac{2\pi r}{T}$ $\quad \frac{7.35 \times 10^4 \times (53.5 \times 24 \times 60 \times 60)}{2\pi} = (r + h)$ (1)

altitude = $(5.41 \times 10^{10}) - (6.69 \times 10^7)$ (1)

altitude = 5.40×10^{10} m (1)

-1 mark if the equatorial radius of Jupiter is used

A primary piece of research is to map Jupiter's gravitational and magnetic fields to learn more about what its interior structure looks like. Scientists want to understand what powers the auroras, Jupiter's northern and southern lights.

(b) Explain how auroras form, and what the northern and southern auroras show us about Jupiter's magnetic field.

(4 marks)

- Charged particles from solar winds become trapped in a planet's magnetic field, spiraling around the magnetic field lines moving towards the poles
- At the poles the magnetic field lines are closest to the atmosphere and the charged particles collide with atoms in the atmosphere.
- Energy is transferred to the atoms which are excited. They then decay back to their ground state emitting photons of light, equal in energy to the difference between energy levels – these light is called an aurora.
- The location of the auroras suggests that Jupiter must have a similar magnetic field structure to that of Earth

The final orbit of Juno will be a polar orbit as these are best for mapping and monitoring a planet. Juno will be slowed down to end up in an orbit that will take 14 days to complete. In each orbit Juno will sit 5000 km above the planet.

(c) Explain why a polar orbit is best used to map a planet like Jupiter.

(3 marks)

- As the probe orbits about Jupiter's poles, the planet is rotating on its axis beneath the probe.
- The part of the planet beneath the probe is altering with every orbit
- Over a number of orbits every part of Jupiter will be mapped and analysed.

(d) Calculate the orbital speed of Juno in its final polar orbit about Jupiter.

(3 marks)

T = 14 days = 14 x 24 x 60 x 60 =1.21 x 10^6 s (1)

$$v = \frac{s}{T} = \frac{2\pi R}{T}$$

$$v = \frac{2\pi\,(6.69 \times 10^7 + 5.00 \times 10^6)}{1.21 \times 10^6}$$ (1)

$v = 373\ ms^{-1}$ (1)

Juno is fitted with various pieces of scientific equipment including ultraviolet and infrared cameras to take images of the atmosphere and the auroras. These cameras and an on board spectrometer will help fingerprint the chemical gases present in Jupiter's atmosphere. Other equipment will measure the strength of the magnetic field and electric field that surrounds Jupiter.

(e) Explain how the gas make up of the atmosphere will be determined using the on board spectrometer.

(3 marks)

- Light from the auroras will be passed through the spectrometer that will refract the light into individual wavelengths.
- Emission spectra will be visible on the spectrum as coloured lines on a black background which correspond to the differences between energy levels.
- These differences between energy levels are unique for each element and so the spectra obtained can be compared to the spectra of known elements and compounds on Earth to determine the composition of the atmosphere.

Juno's scientific mission will be complete in February 2018 when it will be directed to dive into Jupiter's atmosphere, where it will burn up like a meteor that enters the Earth's atmosphere.

End of Section 3