STUDENT NUMBER: _____

North Sydney Boys High School
Year 12 Physics 2023
Trial HSC Examination

General Instructions

- Reading time – 5 minutes.
- Working time – 135 minutes.
- Board approved calculators may be used.
- Write using a black pen.
- Write your student number at the top of every separate page.
- Use the multiple-choice answer sheet provided at the end and may be separated.
- A NESA data and formula sheet is provided at the end and may be separated.

Total Marks – 75

Part A - 15 marks

- Attempt Questions 1–15.
- Allow about 20 minutes for this part.

Part B - 60 marks

- Attempt Questions 16–21.
- Allow about 115 minutes for this part.

PART A /15	
PART B /60	
Total Mark /75	
KU /47	
WS /28 (Q8, Q9, Q16, Q17 & Q21)	

This paper MUST NOT be removed from the examination room.

Part A – 15 marks

Choose the most correct answer. Use the multiple-choice answer sheet for Questions 1–15

1. A ball, initially at rest, takes time t to fall through a vertical distance h. If air resistance is ignored, the time taken for the ball to fall from rest through a vertical distance $9h$ is

A. $3t$.

B. $5t$.

C. $9t$.

D. $10t$.

2. The centripetal force that causes a car to go round a bend in the road is provided by

A. the force produced by the car engine acting on the wheels.

B. the friction between the tyres and the road.

C. the weight of the car.

D. the force exerted by the driver on the steering wheel.

3. Which **one** of the following is a true statement concerning the vertical component of the velocity and the acceleration of a projectile when it is at its maximum height? *(The acceleration of free fall is g.)*

	Vertical component of velocity	**Acceleration**
A.	maximum	zero
B.	maximum	g
C.	zero	zero
D.	zero	g

4. *Electric field strength* is defined as

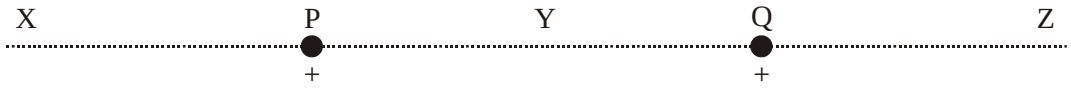
A. the force exerted on a test charge.

B. the force per unit positive charge.

C. the force per unit charge.

D. the force per unit charge exerted on a positive test charge.

5. Two **positive** point charges P and Q are held a certain distance apart.



At which point(s) could the electric field strength, due to the charges, be zero?

A. X only

B. Y only

C. Z only

D. X and Z only

6. High voltages are used for the transmission of electric power over long distances because

A. high voltages can be stepped down to any required value.

B. larger currents can be used.

C. power losses during transmission are minimized.

D. transformers have a high efficiency.

7. A thin copper ring encloses an area *S*. The area is linked by magnetic flux that is increasing. The rate of change of the magnetic flux from time $t = 0$ to time $t = T$ is *R*.

The emf induced in the copper ring during the time $t = 0$ to time $t = T$ is

A. *R*.

B. *RS*.

C. *RST*.

D. $\frac{RS}{T}$.

8. The unit, the electron-volt is equivalent to

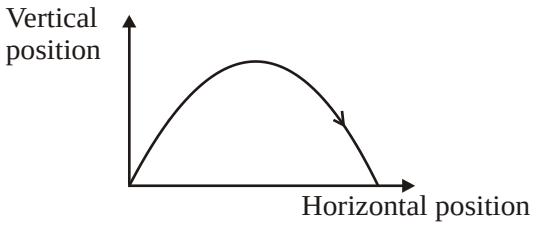
A. 1.6×10^{19} J.

B. 1.0 J.

C. 1.6×10^{-19} J.

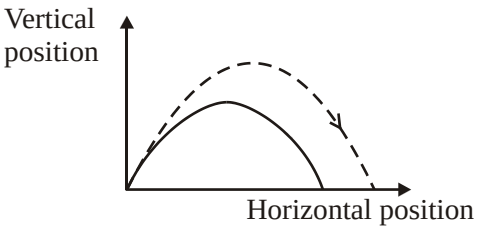
D. 9.1×10^{-31} J.

9. The diagram below shows the path of a projectile in the absence of air resistance.

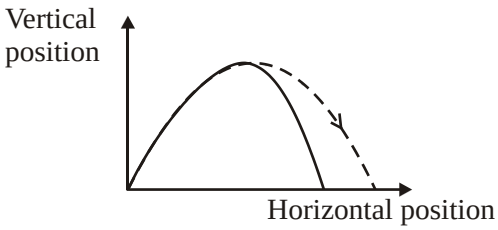


Which **one** of the following diagrams best represents the path of the projectile under the same initial conditions when the air resistance is taken into account? *(The path in absence of air resistance is shown for comparison as a dotted line.)*

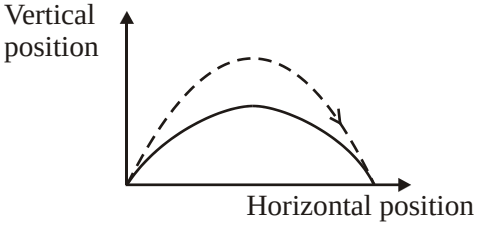
A.



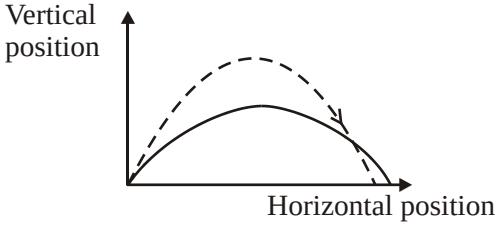
B.



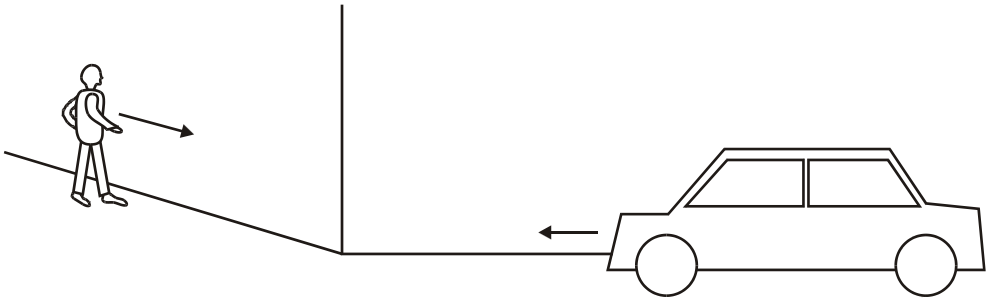
C.



D.



10. A person is walking along one side of a building and a car is driving along another side of the building.



The person can hear the car approach but cannot see it. This is explained by the fact that light waves

A. travel much faster than sound waves.

B. are diffracted less at the corner of the building than sound waves.

C. are refracted less at the corner of the building than sound waves.

D. are transverse waves.

11. A transverse travelling wave has amplitude A_0 and wavelength λ.

The distance between a crest and its neighbouring trough, measured in the direction of energy transfer of the wave is equal to

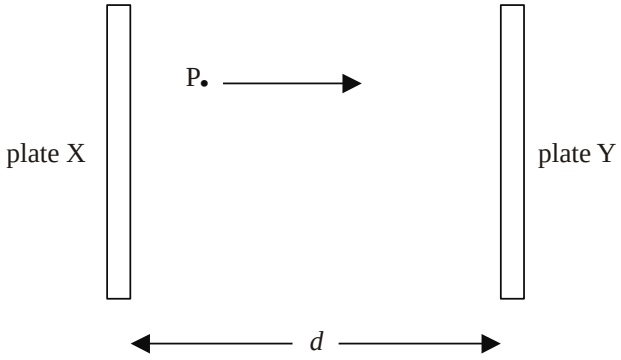
A. A_0.

B. $2A_0$.

C. $\frac{\lambda}{2}$.

D. λ.

12. A charged particle P is accelerated between two charged metal plates X and Y separated by a distance *d*. The particle starts from rest at plate X.



The kinetic energy of P, when it reaches plate Y, is *K*. The magnitude of the charge on P is *e*.

The magnitude of the electric field strength between the plates is

A. $\frac{de}{K}$.

B. $\frac{d}{Ke}$.

C. $\frac{K}{ed}$.

D. $\frac{Ke}{d}$.

13. The work function of a metal may be defined as

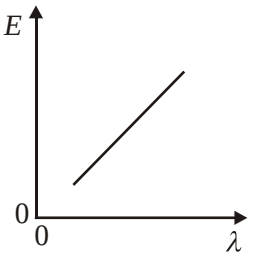
A. the minimum frequency of the incident electromagnetic radiation required to cause photoelectric emission.

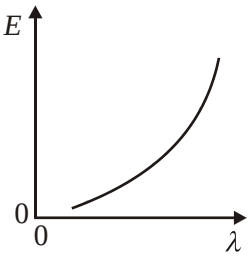
B. the minimum wavelength of the incident electromagnetic radiation required to cause photoelectric emission.

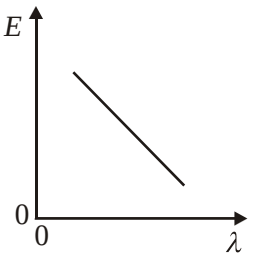
C. the minimum energy of photons incident on a surface required to cause photoelectric emission.

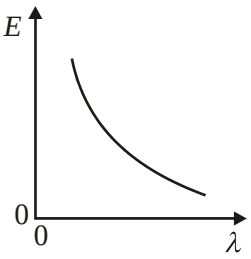
D. the minimum energy required to take an electron from the interior to the surface to cause photoelectric emission.

14. Which of the following graphs best shows how photon energy E varies with the wavelength λ of the light?

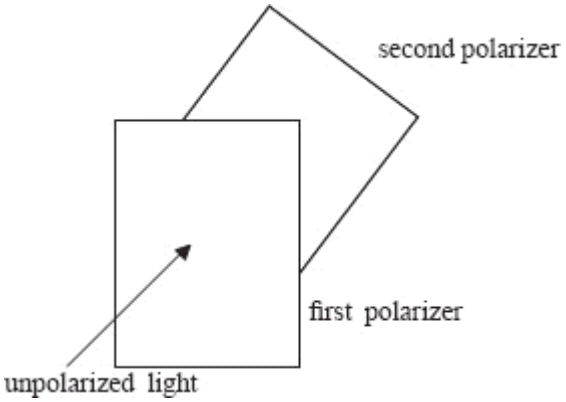
A. 

B. 

C. 

D. 

15. Unpolarised light of intensity I_0 is incident on a polariser. The transmitted light is then incident on a second polariser. The axis of the second polariser makes an angle of 60° to the axis of the first polariser.



The cosine of 60° is $\frac{1}{2}$. The intensity of the light transmitted through the second polariser is

A. I_0.

B. $\frac{I_0}{2}$.

C. $\frac{I_0}{4}$.

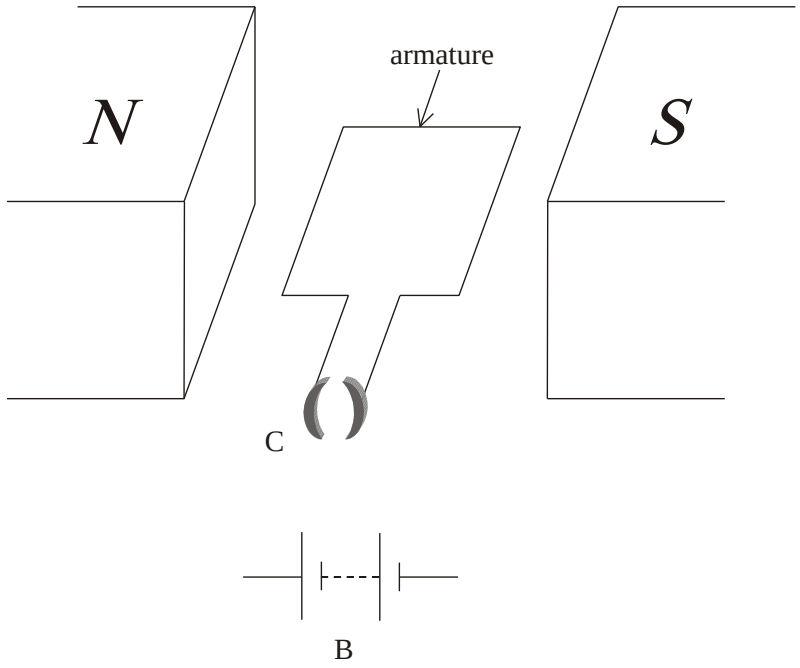
D. $\frac{I_0}{8}$.

Part B – 60 marks

Write your answers in the spaces provided.

16. This question is about electric motors and generators.

(a) The diagram below is a representation of a simple dc electric motor. The armature consists of a single rectangular coil and rotates between the poles of a permanent magnet. The connections between the coil and the battery B are not shown. The split-ring is labelled C.



(i) On the diagram above, draw connections from the battery B to the split-ring so that the coil will rotate continuously in one direction.

(1)

(ii) On the diagram above, draw arrows to show the direction of the forces acting on the coil when connection to the battery is made and the coil is in the position shown in the diagram.

(1)

(iii) Describe how these connections enable the coil to rotate continuously in one direction.

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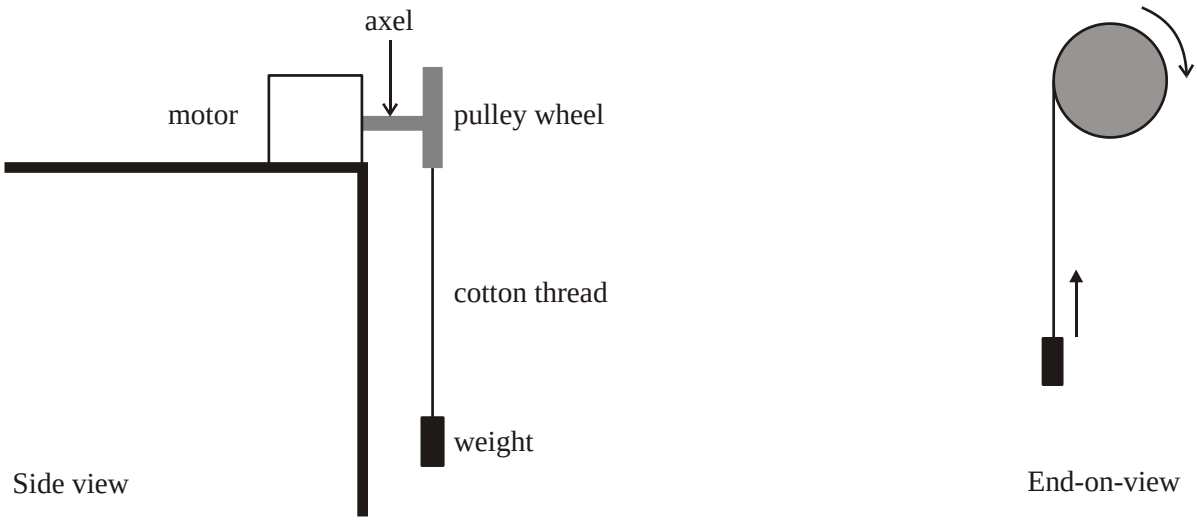
(3)

(b) In an experiment to measure the efficiency of a small dc electric motor, the motor is clamped to the edge of a bench. The motor is used to raise a small weight that is attached to a pulley wheel by cotton thread. The pulley wheel is rotated by the motor. The thread wraps around the pulley wheel, so raising the weight.



The running current in the motor is adjusted to 0.3 A so that a weight of mass 150 g is raised at constant speed. The motor is connected to a 6.0 V supply and the weight is raised through 0.84 m.

(i) If the motor's armature windings have a total resistance of 5.0 Ω, calculate the start-up current. Calculate the back E.M.F. induced in the motor during lifting.

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(3)

(ii) If it takes the motor 3.4 s to raise the weight, determine the power delivered to the weight by the motor.

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(2)

(iii) Estimate the efficiency of the motor.

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(2)

(Total 12 marks)

17. This question is about the photoelectric effect.

(a) State **one** aspect of the photoelectric effect that **cannot** be explained by the wave model of light. Describe how the photon model provides an explanation for this aspect.

Aspect: .....

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Explanation: .....

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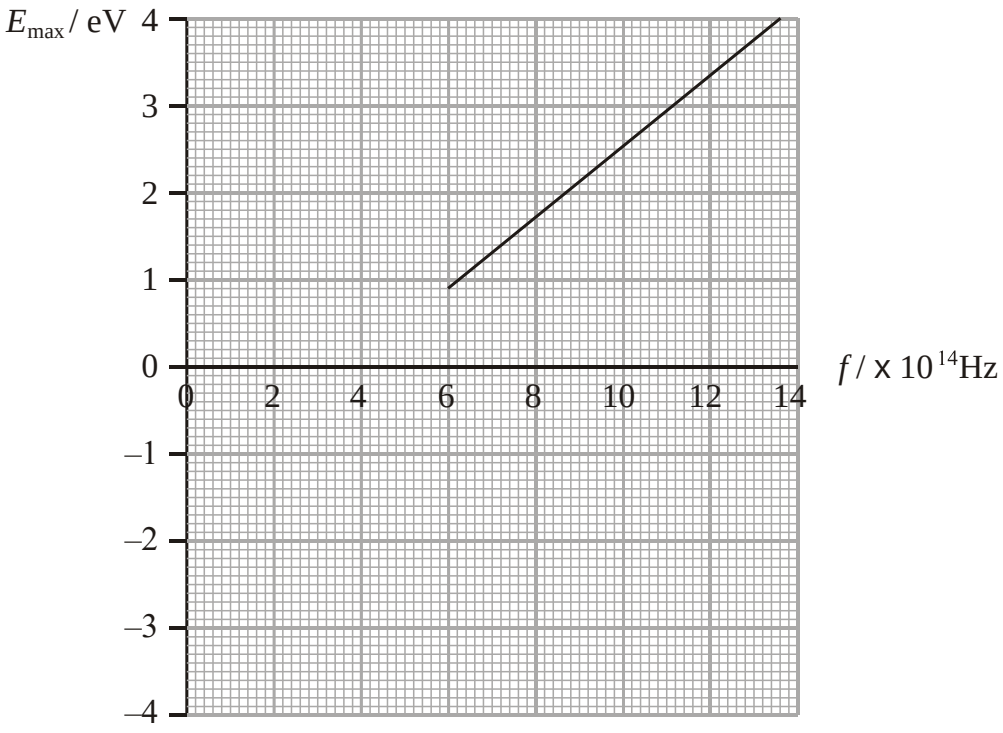
(2)

Light is incident on a metal surface in a vacuum. The graph below shows the variation of the maximum kinetic energy E_{max} of the electrons emitted from the surface with the frequency f of the incident light.



(b) Use data from the graph to determine

(i) the threshold frequency.

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(2)

(ii) a value of the Planck constant.

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(2)

(iii) the work function of the surface.

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(2)

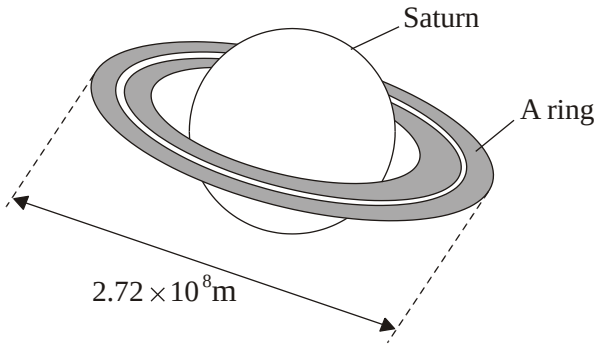
The threshold frequency of a different surface is 8.0×10^{14} Hz.

(c) On the axes opposite, draw a line to show the variation with frequency f of the maximum kinetic energy E_{max} of the electrons emitted.

(2)
(Total 10 marks)

18. This question is about gravitation

The diagram below illustrates the planet Saturn.



Saturn has several rings, each of which consists of many small particles that orbit the planet. Saturn may be considered to be a sphere with its mass M concentrated at its centre.

(a) Deduce that, for a particle in one ring moving in a circular orbit of radius R, the linear speed v of the particle in its orbit is given by the expression

$$GM = Rv^2.$$

Explain your reasoning.

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(2)

(b) One ring, the A ring, has an outer diameter of 2.72×10^8 m. The mass of Saturn is 5.69×10^{26} kg. A particle orbits on the outer edge of this ring. Determine the time for the particle to complete one orbit of Saturn.

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(3)

(c) Explain the concept of *escape speed*.

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(1)

(d) A planet has radius R and the acceleration of free fall at its surface is g. The planet may be considered to be a sphere with its mass concentrated at its centre.

Deduce that the escape speed v_{es} is given by the expression:

$$v_{es} = \sqrt{(2gR)}.$$

Explain your working and state **one** assumption that is made in the derivation.

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(4)

(e) Calculate the escape speed for a spherical planet of radius 1.7×10^3 km having an acceleration of free fall at its surface of 1.6 m s^{-2}.

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(2)

(Total 12 marks)

19. This question is about the effects of special relativity.

(a) State the **two** postulates of the special theory of relativity.

Postulate 1: .....

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Postulate 2: .....

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(2)

A super-fast spacecraft is moving at a speed of 0.80*c* with respect to observers on Earth. The spacecraft leaves Earth in May 2004 on its way to a distant solar system.

(b) (i) According to the observers in the spacecraft, 6.0 years have elapsed since leaving Earth. Calculate the time elapsed according to an observer on Earth.

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(3)

(ii) Explain whether either measured time interval can be considered to be "correct".

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(2)

(iii) Calculate the distance of the spacecraft from Earth according to an observer on Earth.

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(2)

(iv) The observers in the spacecraft send a radio message to Earth to say that they have been travelling for 6.0 years. Determine how long it will take the message to get to Earth according to the **spacecraft observers**.

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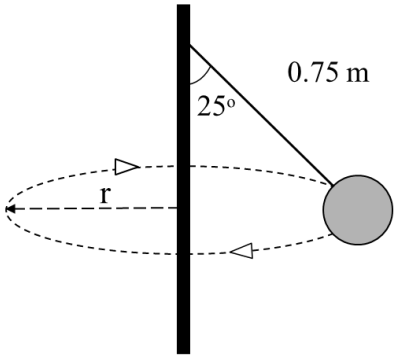
(3)

(Total 12 marks)

20. The diagram below shows a small ball of mass 1.8 kg travelling in a horizontal circular path at a constant speed while attached to a vertical rod by a 0.75 m long string on a frictionless sleeve.



(a) Use labelled arrows to indicate on the diagram above, the two physical forces acting on the ball.

(2)

(b) Derive a suitable expression and use it to calculate the speed of the ball in the scenario above. Show your working.

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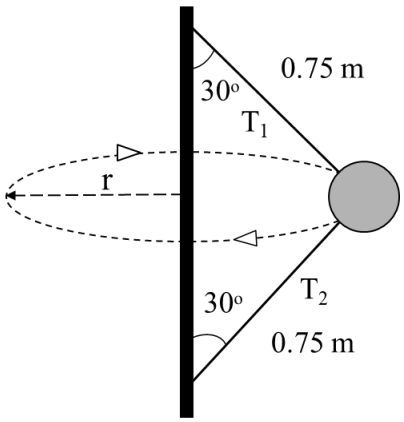
(3)

(c) A second string of the same length is now attached to the rod and mass (see diagram below) using a frictionless sleeve. The mass rotates in a horizontal circle with a constant speed of 3.0 ms^{-1}. Calculate the tension in each string, T_1 and T_2. Show your working.



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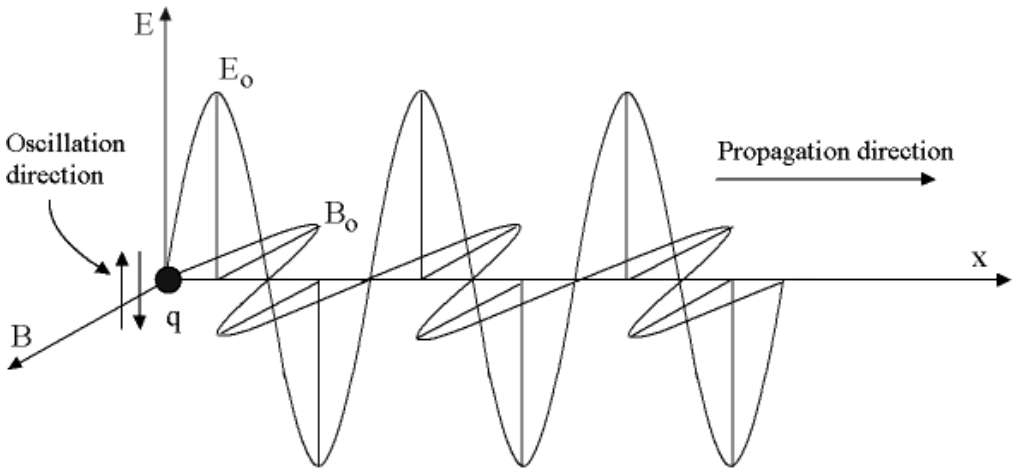
(5)

(Total 10 marks)

21. The diagram below shows a model of electromagnetic waves. Relate this model to predictions made by Maxwell.



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(Total 4 marks)

End of paper

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	3.00×10^8 m s^{-1}
Electric permittivity constant, ε_0	8.854×10^{-12} A^2 s^4 kg^{-1} m^{-3}
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}$ N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth, M_E	6.0×10^{24} kg
Radius of Earth, r_E	6.371×10^6 m
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	1.097×10^7 m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^3 kg m^{-3}
Specific heat capacity of water	4.18×10^3 J kg^{-1} K^{-1}
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

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

$$v = u + at$$

$$v^2 = u^2 + 2as$$

$$\vec{F}_{net} = m\vec{a}$$

$$\Delta U = mg\Delta h$$

$$W = F_{||}s = Fs\cos\theta$$

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

$$K = \frac{1}{2}mv^2$$

$$P = F_{||}v = Fv\cos\theta$$

$$\sum \frac{1}{2}mv^2_{before} = \sum \frac{1}{2}mv^2_{after}$$

$$\sum m\vec{v}_{before} = \sum m\vec{v}_{after}$$

$$\Delta\vec{p} = \vec{F}_{net}\Delta t$$

$$a_c = \frac{v^2}{r}$$

$$\omega = \frac{\Delta\theta}{t}$$

$$F_c = \frac{mv^2}{r}$$

$$\tau = r_\perp F = rF\sin\theta$$

$$F = \frac{GMm}{r^2}$$

$$v = \frac{2\pi r}{T}$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$U = -\frac{GMm}{r}$$

Waves and thermodynamics

$$v = f\lambda$$

$$f_{beat} = \left| f_2 - f_1 \right|$$

$$f = \frac{1}{T}$$

$$f' = f\frac{\left(v_{wave} + v_{observer}\right)}{\left(v_{wave} - v_{source}\right)}$$

$$d\sin\theta = m\lambda$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$n_x = \frac{c}{v_x}$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$I = I_{max}\cos^2\theta$$

$$I_1 r_1^2 = I_2 r_2^2$$

$$Q = mc\Delta T$$

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

FORMULAE SHEET (continued)

Electricity and magnetism

$E = \frac{V}{d}$

$V = \frac{\Delta U}{q}$

$W = qV$

$W = qEd$

$B = \frac{\mu_0 I}{2\pi r}$

$B = \frac{\mu_0 NI}{L}$

$\Phi = B_{||}A = BA\cos\theta$

$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$

$\frac{V_p}{V_s} = \frac{N_p}{N_s}$

$\vec{F} = q\vec{E}$

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

$I = \frac{q}{t}$

$V = IR$

$P = VI$

$F = qv_{\perp}B = qvB\sin\theta$

$F = lI_{\perp}B = lIB\sin\theta$

$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$

$\tau = nIA_{\perp}B = nIAB\sin\theta$

$V_p I_p = V_s I_s$

Quantum, special relativity and nuclear

$\lambda = \frac{h}{mv}$

$K_{max} = hf - \phi$

$\lambda_{max} = \frac{b}{T}$

$E = mc^2$

$E = hf$

$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$

$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$

$p_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$

$N_t = N_0 e^{-\lambda t}$

$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

PERIODIC TABLE OF THE ELEMENTS

KEY: Atomic Number / Symbol / Standard Atomic Weight / Name — 79 Au 197.0 Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

STUDENT NUMBER: _____

North Sydney Boys High School
Science Faculty
Year 12 Physics 2023
Assessment 3

MULTIPLE CHOICE ANSWER SHEET

1.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
2.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
3.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
4.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
5.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
6.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
7.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
8.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
9.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
10.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
11.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
12.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
13.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
14.	**A**	☐	**B**	☐	**C**	☐	**D** ☐
15.	**A**	☐	**B**	☐	**C**	☐	**D** ☐

Marking Guideline Year 12 Physics Trial Exam 2023

i. Answers not conforming to this guideline will NOT be considered unless you have used a different but acceptable method.
ii. Answers written (or graphed) in pencil will NOT be considered for appeals.
iii. Carry forward errors will only be considered for ONE prior error only, in subsequent expressions or calculations.
iv. All correct units should be written in your intermediate or final answers.

1. A (1 mark each for MCQ)

2. B

3. D

4. D

5. B

6. C

7. A

8. C

9. A

10. B

11. C

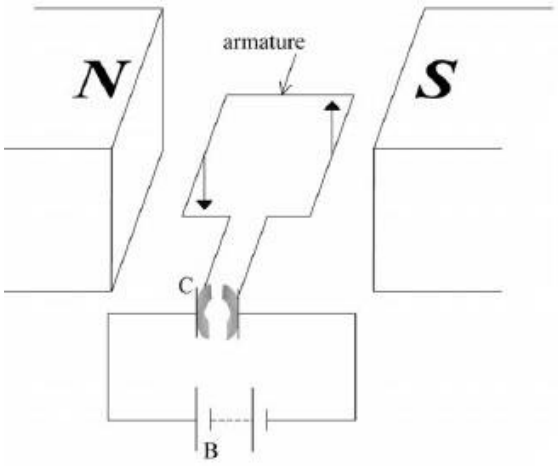
12. C

13. C

14. D

15. D

16.



(a) (i) showing connection via brushes (or a spring-loaded mechanism); 1

(ii) two correct forces as shown in the diagram above; 1

(iii) when the split ring is in contact with the brushes the current in the coil will always be in the same direction (or a similar statement); 1
this will be so even after the coil has rotated through 180° and sides of coil are reversed (or a similar statement); 1
when the split ring is not in contact with the brushes, the momentum of the coil will keep it rotating (or a similar statement); 1

Marker's comment: you may also state that the current is reversed in the coil to get a mark. Also, do not state "according to the right-hand rule" as it's just a tool and not a quotable theory.

(b) (i) start-up current = 6V/5Ω = 1.2 A; 1
input voltage = back emf + IR (running current x winding resistance); 1
back emf = 6 – (0.3 x 5.0), or back emf = 4.5V; 1

(ii) increase in potential energy = $0.15 \times 9.8 \times 0.84 = 1.23$J; 1
rate of work-done = power needed = 1.23/3.4 = 0.36 W 1

(iii) power input to motor while lifting = $VI = 6.0 \times 0.3 = 1.8$ W; 1
Efficiency = $P_{out}/P_{in} = 0.36/1.8 = 0.20$ ***or*** 20%; 1

[12]

17. (a) *Aspect (any one of the three statements below for 1 mark):*
electrons will not be emitted unless the frequency of light exceeds a certain minimum value **(or)** electrons are emitted almost instantaneously with the light falling on the surface even if light is of very low intensity **(or)** the energy of the electrons emitted is not affected by the intensity of light falling on the surface; 1

E*xplanation (any one of the three corresponding explanations below for 1 mark)*:
light consists of photons whose energy is *hf* hence no electrons are emitted unless *hf* is larger than the energy needed to escape the metal **(or)** an electron is emitted as soon as it absorbs a photon. If the photon has sufficient energy no delay is required **(or)** the intensity of light plays no role in the energy of the electron only the frequency of light does; 1

Marker's comment: "stopping voltage" as synonymous with "energy" was also accepted. Answers based on experimental evidence (and so using experimental language to answer the question) which did not support the wave model of light were accepted.

(b) (i) the threshold frequency is found from the frequency axis intercept; 1
to be 3.8 (±0.2) × 10^{14} Hz; 1

(ii) a value of the Planck constant is obtained from the slope; 1
to be 6.5 (±0.2) × 10^{-34} J s; 1
*(Award **[0]** for copied answer of 6.625 × 10^{-34} J s from data sheet. Answers must show evidence of rise/run calculations)*

Marker's comment: " 5.2 and 5.8 was NOT accepted. 4.054 × 10^{-15} eVs with gradient and working was accepted. No marks were deducted for missing units.

(iii) the work function of the surface is found from the intercept with the vertical axis; 1
to be 1.5 (±0.1) eV; 1

Marker's comment: For full marks 1.5 eV and evidence that the graph was used. 1 mark for showing extrapolation on the graph as evidence of using the graph to answer the question. If only calculations and 1.5 eV, then 1 mark. If only calculations and not 1.5 eV than no marks. If negative 1.5 eV then 1 mark. 1 mark for using the data from the previous question. 1.7 eV not accepted. 1.59 eV accepted.

(c) straight-line parallel to the first; 1
intersecting the frequency axis at 8.0 × 10^{14} Hz; 1

[10]

18. Gravitation

(a) centripetal force is provided by the gravitational force; 1

(must include an explanation other than just the equation)

$\frac{mv^2}{R} = \frac{GMm}{R^2}$; to give $GM = Rv^2$ 1

(b) (i) $6.67 \times 10^{-11} \times 5.69 \times 10^{26} = (1.36 \times 10^8) \times v^2$

$v = 1.67 \times 10^4 \text{ms}^{-1}$; 1

$T = \frac{2\pi r}{v}$; 1

$T = 5.1 \times 10^4$ s; 1

(c) is the speed of an object at the surface of a planet so that object may move to infinity or escape the gravitational field of the planet; 1

(Need to be clear that the object escapes the gravitational field of the body. Escaping orbit is not the same thing, ie. if an orbiting body's velocity drops to zero, it will escape orbit.)

(d) loss in kinetic energy = gain in gravitational potential energy; 1

(potential energy = mgh is not appropriate in this situation)

$\frac{1}{2}mv^2 = \frac{GMm}{R}$; 1

but $g = \frac{GM}{R^2}$; hence $v_{es} = \sqrt{(2gR)}$. 1

assumption: *eg* planet is isolated / no friction / no atmosphere, *etc*; 1

(e) $v_{es} = \sqrt{\left(2 \times 1.6 \times 1.7 \times 10^6\right)}$; 1

$= 2.3 \times 10^3 \text{ms}^{-1}$; 1

[12]

19. (a) *pos1*: the speed of light in a vacuum is an absolute constant (or similar); 1

pos2: all inertial frames of reference are equivalent (or similar); 1

(b) (i) $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - 0.8^2}} = \frac{10}{6}$ (=1.7); 1

interval on earth = γ × interval on spacecraft; 1

interval on earth $\frac{10}{6}$ × 6 years = 10 years; 1

(Note: some of the above calculations may be combined)

(ii) both observers are inertial observers; 1

and both are equally valid and correct in their measurements; 1

(iii) the spacecraft has been travelling for 10 years as far as the Earth observers are concerned; 1

so the distance travelled according to the Earth observers is

$x = vt = 0.8c \times 10$ years = 8.0 light years ($= 7.57 \times 10^{16}$ m); 1

(iv) Earth moves away at 0.80 *c* and so is at a distance of $6 \times 0.80\ c = 4.8$ ly when signal is emitted; 1

signal reaches earth in time *T* (years) where $cT = 4.8\ c + 0.80\ cT$; 1

correct answer $T = 24$ years; 1

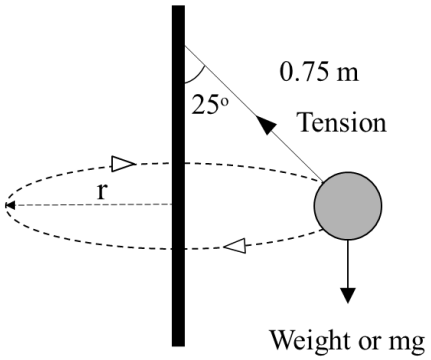
or (alternative answer)

the signal arrives on Earth after $\frac{(10 \times 0.80c)}{c}$ = 8 years, *ie* 18 years

after departure according to Earth clocks; (1)
the events "Earth and spacecraft coincide" and "signal arrives on Earth" occur at the same place according to Earth and so 18 years is a proper time interval; (1)
spacecraft clocks show $\gamma \times 18 = 30$ years *ie* 24 years after sending the signal; (1)

[12]

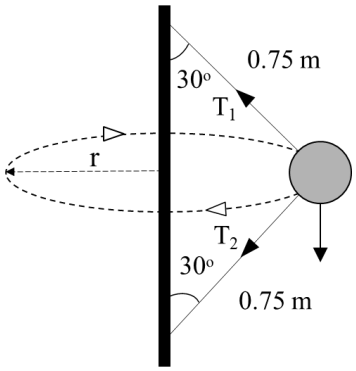
20. a)



Correct direction and label for Tension 1
Correct direction and label for Weight or mg 1
(Award 0 marks if centripetal force is shown as a physical force)

(b) $T\cos\theta = mg$ and $T\sin\theta = mv^2/r$; 1
combining both equations, $\tan\theta = v^2/gr$ or $v^2 = gr\tan\theta$; 1
$v^2 = 9.8 \times 0.75\sin25 \times \tan25$, $v = 1.2$ ms^{-1} (correct substitution and answer); 1

(c)



$T_1\cos\theta - T_2\cos\theta - mg = 0$ or $T_1\cos\theta = T_2\cos\theta + mg$; (vertical resolution of forces) 1
$T_1\sin\theta + T_2\sin\theta = mv^2/r$; (horizontal resolution of forces) 1
$T_1\cos30 = T_2\cos30 + 1.8 \times 9.8$ and $T_1\sin30 + T_2\sin30 = 1.8 \times 3^2/(0.75\sin30)$
(correct substitutions of values and simplification of equations); 1
$T_1 = 53.4$ N (correct answer); 1
$T_2 = 33.0$ N (correct answer); 1

[10]

21. (Any four of the following five paragraphs, yielding 1 mark each for a total of 4 marks. Words may vary but intent should be clear)

i. The diagram shows alternating electric and magnetic fields oscillating perpendicular to each other relating to Maxwell's prediction of mutual inductance, that a changing electric field induces a changing magnetic field and vice versa.

ii. The diagram shows Maxwell's prediction that the electric and magnetic fields are in phase with each other, and that at any point, they both reach their maximum value at

the same time.

iii. The diagram shows Maxwell's prediction that the electromagnetic wave will propagate in a direction perpendicular to both the electric and magnetic fields with velocity c.

iv. The diagram shows electromagnetic waves relating to Maxwell's prediction of a range of waves with different wavelengths, all travelling at the same speed given by:

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}.$$

v. The diagram also shows an electromagnetic wave emanating from an oscillating charge. This is consistent with Maxwell's prediction that an oscillating electric charge produces a changing electric field and magnetic field.

[4]