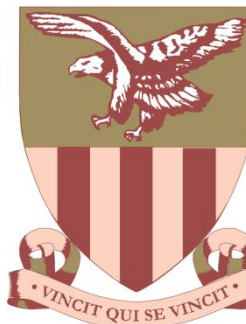


Student Number: _____



North Sydney Boys High School
Science Faculty
Year 12 Physics 2020
Assessment 3

General Instructions:

Reading time – 5 minutes

Working time – 2 hours 15 minutes (135 minutes)

- Write your student number at the top of this page
- Write using black or blue pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- This paper has three sections
- Attempt all questions
- A NESA data sheet will be provided

Total Marks - 75

Section A: Multiple Choice

- Questions 1 to 20
- 20 marks

**Section B: Written Response
(Knowledge and Understanding)**

- Questions 21 to 27
- 30 marks

**Section C: Written Response
(Working Scientifically)**

- Questions 28 to 30
- 25 marks

Section A	/ 20	
Section B	/ 30	
Section C	/ 25	
Total Marks	/ 75	

This paper MUST NOT BE REMOVED from the examination room

Section A – Multiple Choice (20 marks):

Attempt questions 1 - 20

Use the answer grid to record your answer.

Question 1.

Unpolarised light reflected from water is horizontally polarised. The windshield of a speed boat is polarised at 30° to the vertical.

What is the percentage reduction in the reflected light intensity seen by the boat's driver?

- (A) 75 %
- (B) 37.5 %
- (C) 62.5 %
- (D) 25 %

Malus's Law $I = \cos^2 \theta I_0$

angle = $0 - 30 = 60^\circ$

$I = 0.25 \times I_0$

So reduction is 75%

Question 2.

Hole 12 at the local golf course is on a circular green, surrounded by a small lake and a sand trap. The golf course publishes a map (see figure 1) which shows the distance to the hole from the tee off position which are both at the same elevation.

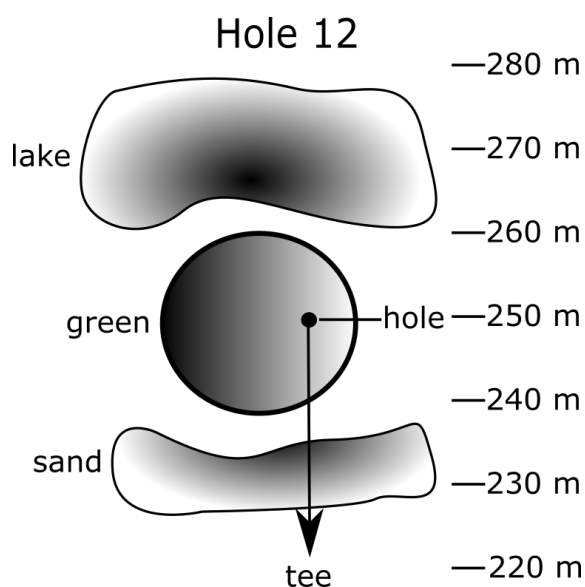


Figure 1.

A golfer hits the golf ball in line with the hole with a velocity of 47.8 ms^{-1} at an angle of 42.5° above the ground.

Where does the golf ball land?

- (A) in the sand.
- (B) in the lake

- (C) on the green
(D) in the hole

velocity 47.8 ms^{-1} at 42.5° above ground

$$v_x = v \cos \theta = 35.2 \text{ ms}^{-1}$$

$$v_y = v \sin \theta = 32.3 \text{ ms}^{-1}$$

$$\text{peak } v^2 = u^2 + 2as \Rightarrow s = v_y^2 / 2a$$

$$\text{peak} = 53.2 \text{ m}$$

$$\text{time to peak } s = \frac{1}{2} at^2 \Rightarrow t = \sqrt{2s/a}$$

$$\text{time to peak} = 3.295 \text{ s}$$

$$\text{time of flight} = 2 \times \text{time to peak} = 6.59 \text{ s}$$

$$\text{range } s = v_x t$$

$$\text{range} = 232 \text{ m}$$

lands in the sand

Question 3.

Some data for the Earth and the Moon is shown in table 1.

Object	Radius of orbit (m)	Radius (m)	Mass (kg)
Moon	3.84×10^8	1.74×10^6	7.34×10^{22}
Earth	1.49×10^{11}	6.37×10^6	5.98×10^{24}

Table 1.

At what distance will a lunar spacecraft be from the centre of the Earth when it experiences no net gravitational force from the Earth and Moon?

- (A) $3.49 \times 10^8 \text{ m}$
(B) $3.46 \times 10^8 \text{ m}$
 (C) $3.42 \times 10^8 \text{ m}$
 (D) $3.15 \times 10^8 \text{ m}$

$$F_E = GM_E m / r_E^2 = F_M = GM_M m / r_M^2$$

$$M_M / r_M^2 = M_E / r_E^2$$

$$r_E^2 / r_M^2 = M_M / M_E$$

$$r_E / r_M = 9.03$$

$$r_E = 3.84 \times 10^8 \times 9.03 / 10.03 = 3.46 \times 10^8 \text{ m}$$

Question 4.

A rectangular coil of wire with sides 2.0 cm and 5.0 cm lies on a plane at 30° to a magnetic field of 20.0 T as shown in figure 2.

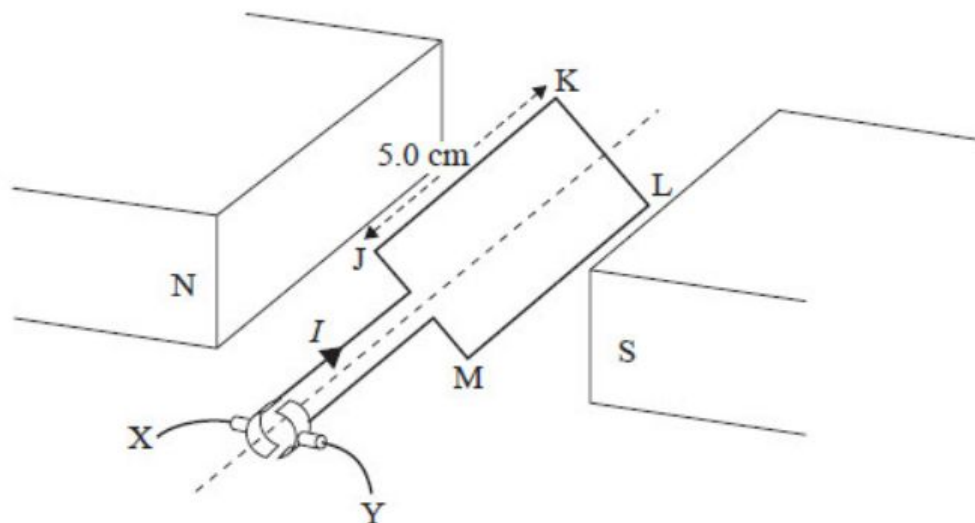


Figure 2.

What is the flux through the coil?

- (A) 100 W
- (B) 20 mW
- (C) 17 mW
- (D) 10 mW

$$\text{Area} = 0.05 \times 0.02 = 0.001 \text{ m}^2$$

$$\phi = BA \cos \theta$$

Note: θ is the angle between the magnetic field B and the normal to the area A

so $\theta = 60^\circ$

$$\text{Flux} = 20 \times 0.001 \times \cos 60$$

$$\text{Flux} = 0.010 \text{ W} = 10 \text{ mW}$$

Question 5.

A stream of electrons is generated in a vacuum tube as shown in figure 3.

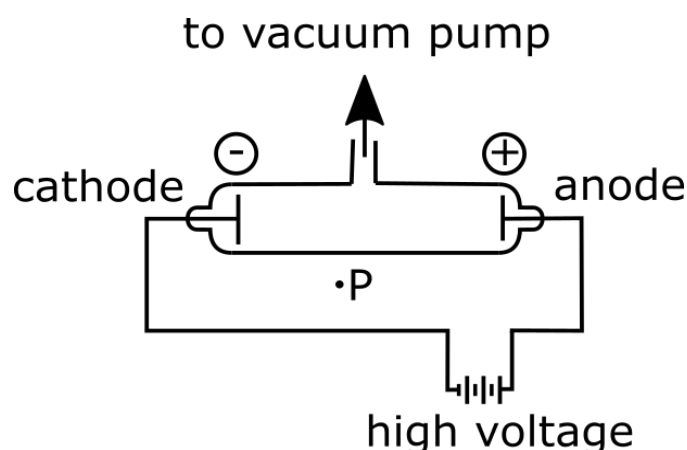


Figure 3.

What is the direction of the magnetic field at point P ?

- (A) To the right

- (B) Down the page
- (C) Into the page
- (D) Out of the page**

electrons have negative charge

Question 6.

When an aeroplane is at an altitude of 500 m and moving horizontally at a speed of 160 ms^{-1} , a small object falls from it. In the period of time after the object falls until it hits the ground, which of the following describes the effect of including and excluding air resistance?

- (A) Time of flight will be longer and its horizontal displacement will be shorter with air resistance included**
- (B) Time of flight will be shorter and its horizontal displacement will be shorter with air resistance included
- (C) Its horizontal displacement will be longer and vertical acceleration will be smaller with air resistance included
- (D) Its vertical displacement will be shorter and vertical acceleration will be smaller with air resistance included

**vertical acceleration will be less than g so time of flight will be longer
horizontal velocity will decrease so horizontal displacement will be shorter
vertical displacement stays the same**

Question 7.

Two satellites (LSat_A3 and KSat_D7) are in circular orbits around the Earth. LSat_A3 is R metres from the centre of the Earth and has an orbital velocity of V. KSat_D7 is 4R metres from the centre of the Earth.

What is the orbital velocity of KSat_D7?

- (A) $V/4$
- (B) $4V$
- (C) $V/2$**
- (D) $2V$

$$r_A^3/T_A^2 = GM/4\pi^2 \text{ and } r_B^3/T_B^2 = GM/4\pi^2$$

$$r_A^3/T_A^2 = r_B^3/T_B^2$$

$$v_A = 2\pi r_A/T_A \text{ and } v_B = 2\pi r_B/T_B$$

$$T_A = 2\pi r_A/v_A \text{ and } T_B = 2\pi r_B/v_B$$

$$r_A^3/(2\pi r_A/v_A)^2 = r_B^3/(2\pi r_B/v_B)^2$$

$$r_A/v_A^2 = r_B/v_B^2$$

$$v_B^2 = v_A^2 \times r_A/r_B$$

$$v_B = v_A \times \sqrt{r_A/r_B}$$

$$v_B = \frac{1}{2} v_A$$

Question 8.

A sphere falling in a viscous fluid reaches a terminal velocity v_t at which point the retarding force and the buoyancy force balance the weight of the sphere. The terminal velocity depends on the variables shown in table 2.

r	The radius of the sphere
η	The viscosity of the fluid
g	The Earth's gravitational field strength
ρ	The density of the sphere
ρ'	The density of the fluid

Table 2.

The unit for viscosity (η) is $\text{kg m}^{-1} \text{s}^{-1}$

Use this information to determine which of the following relations is correct:

- (A) $v_t = \frac{2rg}{9\eta^2}(\rho - \rho')$
 (B) $v_t = \frac{2rg^2}{9\eta}(\rho - \rho')$
(C) $v_t = \frac{2r^2g}{9\eta}(\rho - \rho')$
 (D) $v_t = \frac{2rg}{9\eta}(\rho - \rho')$

- A. $\text{ms}^{-1} \neq \text{m ms}^{-2} \text{kg}^{-2} \text{m}^2 \text{s}^2 \text{kgm}^{-3} = \text{m s}^{-1} \text{kg}^{-1}$
 B. $\text{ms}^{-1} \neq \text{m m}^2 \text{s}^{-4} \text{kg}^{-1} \text{ms kgm}^{-3} = \text{m}$
 C. $\text{ms}^{-1} = \text{m}^2 \text{ms}^{-2} \text{kg}^{-1} \text{ms kgm}^{-3} = \text{m s}^{-1}$
 D. $\text{ms}^{-1} \neq \text{m ms}^{-2} \text{kg}^{-1} \text{ms kgm}^{-3} = \text{s}^{-1}$

Question 9.

How much work is done on a proton being accelerated between two charged plates with a voltage difference of 1 kV?

- (A) $8.0 \times 10^{-17} \text{ J}$
(B) $1.6 \times 10^{-16} \text{ J}$
 (C) $1.7 \times 10^{-24} \text{ J}$
 (D) $8.0 \times 10^{-18} \text{ J}$

$$W = qV$$

$$\text{Work} = 1.602 \times 10^{-19} \times 1000 = 1.602 \times 10^{-16} \text{ J}$$

Question 10.

A satellite of mass $6.30 \times 10^3 \text{ kg}$ is orbiting the Earth at an altitude of $1.88 \times 10^4 \text{ km}$.

The potential energy of the satellite is closest to:

(A) $-1.00 \times 10^{11} \text{ J}$

(B) $-1.00 \times 10^{14} \text{ J}$

(C) $-3.95 \times 10^{11} \text{ J}$

(D) $-1.34 \times 10^{14} \text{ J}$

$$U = -GMm/r$$

$$U = -6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 6.3 \times 10^3 \times (1.88 \times 10^7 + 6.371 \times 10^6)$$

$$U = -1.00 \times 10^{11} \text{ J}$$

Question 11.

5 cm of a conductor, carrying a current of 0.35 A, runs through a magnetic field of 1.3 T as shown in figure 4.

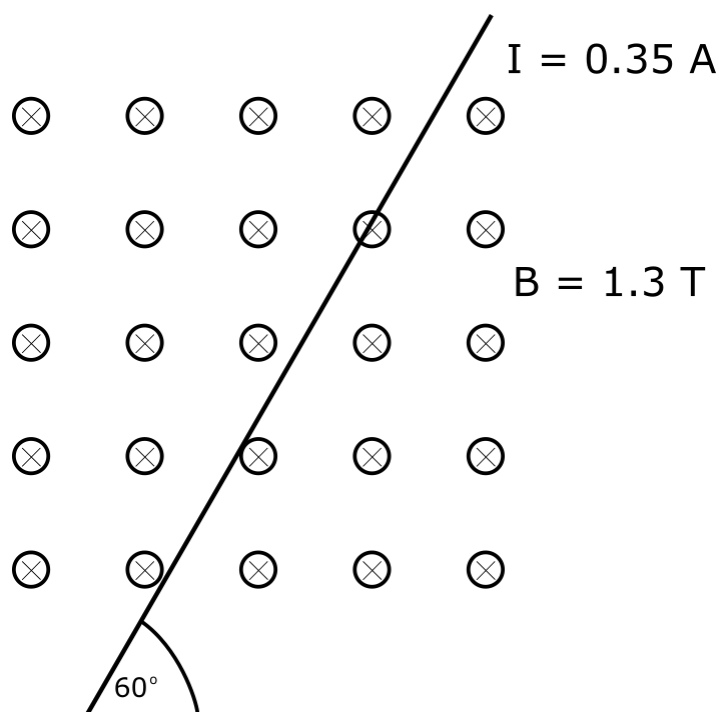


Figure 4.

What is the magnitude of the force on the conductor?

(A) 0.020 N

(B) 0.023 N

(C) 0.011 N

(D) 0.046 N

$$F = ilB \sin \theta$$

Note: conductor is perpendicular to the field

$$F = 0.35 \times 0.05 \times 1.3 \times 1$$

$$F = 0.023 \text{ N}$$

Question 12.

The hydrogen α line in the Balmer series occurs at 656.3 nm. When the spectrum from a star is analysed, the hydrogen α line is recorded at 686.2 nm.

Which of the following is true?

- (A) The star is blue-shifted and moving away from Earth
- (B) The star is blue-shifted and moving towards Earth
- (C) The star is red-shifted and moving towards Earth
- (D) The star is red-shifted and moving away from Earth

longer wavelength = red shift, object is moving away

Question 13.

The trace of a sine wave from an oscilloscope is shown in figure 5.

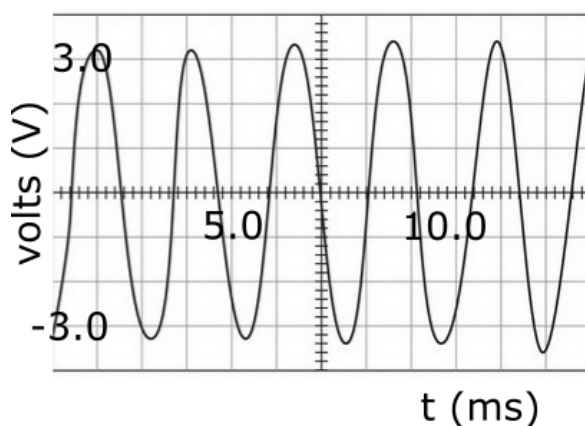


Figure 5.

What is the frequency of the wave?

- (A) 440 Hz
- (B) 22 Hz
- (C) 44 Hz
- (D) 2.2 Hz

4 cycles in 9 ms
frequency = $4/9 \times 10^{-3}$
f = 440 Hz

Question 14.

A spacecraft with an outer radius of 48.6 m is constructed with a doughnut shape so that it can rotate to provide artificial gravity for the occupants while in deep space as shown in figure 6.

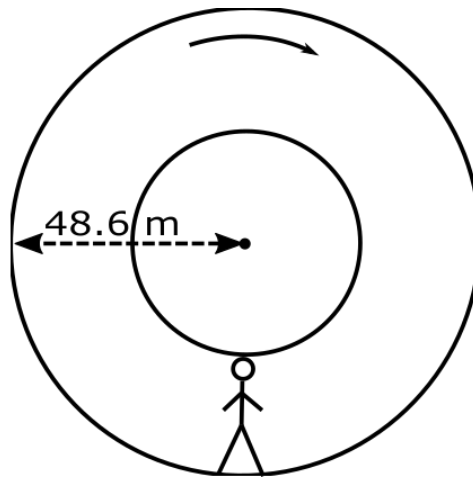


Figure 6.

What period of rotation of the spacecraft is required to provide an artificial gravity of 9.8 ms^{-2} ?

- (A) 28.0s
- (B) 12.8 s
- (C) 14.0 s**
- (D) 25.6 s

radius = 48.6 m

acceleration = 9.8 ms^{-2}

$a = v^2/r$

$v = \sqrt{ar} = 21.8 \text{ ms}^{-1}$

circumference = $2\pi r = 2 \times \pi \times 48.6 = 305 \text{ m}$

so period = $305 / 21.8 = 14 \text{ s}$

Question 15.

The transformer in a laptop charger has 2400 turns in the primary coil and 400 turns in the secondary coil. The laptop draws a current of 4.2 A when charging.

What is the current in the primary coil?

- (A) 25.2 A
- (B) 0.70 A**
- (C) 40.0 A
- (D) 0.35 A

$N_p = 2400$

$N_s = 400$

$I_p = N_s/N_p \times I_s$

$I_p = 400/2400 \times 4.2 = 0.7 \text{ A}$

Question 16.

A laser with a wavelength of 536 nm is pointed through a card that has a pair of small slits cut into it. A wall 5.54 m away is used as a screen to record the pattern of bright spots, which are measured to be 3.3 cm apart.

What is the separation between the slits in the card?

- (A) 900 μm
- (B) 341 μm
- (C) 31.9 μm
- (D) 90 μm

wavelength (λ) = 536 nm
distance to screen (L) = 5.54 m
maxima separation (y) = 0.033 m
 $d \sin \theta = m\lambda \Rightarrow dy/L = m\lambda$
for distance between 2 maxima, $(m+1) - m = 1$
 $d = \lambda L / y$
 $d = 536 \times 10^{-9} \times 5.54 / 0.033 = 9.0 \times 10^{-5}$
 $d = 90 \times 10^{-6} \text{ m} = 90 \mu\text{m}$

Question 17.

The spaceship shown in figure 7 has a proper length of 86.0 m and is observed from Earth to be travelling at $2.7 \times 10^8 \text{ ms}^{-1}$.

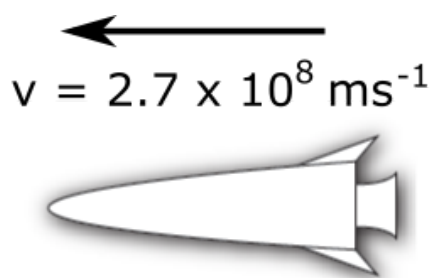


Figure 7.

What is the length of the spaceship measured by the observer on Earth?

- (A) 16.3 m
- (B) 37.5 m
- (C) 197 ms
- (D) 86.0 m

$l = l_0 \sqrt{1 - v^2/c^2}$
 $l = 86 \times \sqrt{1 - (2.7 \times 10^8)^2 / (3 \times 10^8)^2}$
 $l = 86 \times \sqrt{1 - (2.7 \times 10^8)^2 / (3 \times 10^8)^2}$
 $l = 37.4 \text{ m}$

Question 18.

The magnitude of the acceleration due to gravity on the Earth's surface is g . A newly discovered planet has three times the mass and twice the radius of Earth.

Which of the following describes the acceleration due to gravity on the surface of this planet?

- (A) $3g$
- (B) $2g$
- (C) $1.5g$
- (D) $0.75g$**

$$g_E = GM_E/r_E^2$$

$$g_X = G(3M_E)/(2r_E)^2$$

$$g_X = \frac{3}{4} g_E$$

Question 19.

Michelson and Morley performed an experiment to detect the movement of the Earth through the luminiferous aether. The result of this experiment showed:

- (A) The Earth was moving at a constant speed through the aether
- (B) The existence of the aether could not be confirmed**
- (C) The Earth was not moving through the aether
- (D) The aether did not exist

Null result did not support their hypothesis

Question 20.

A magnet is dropped down a copper pipe with the North end of the magnet facing down, the acceleration of the magnet is recorded as it travels through the pipe.

The magnet is then dropped down the same pipe, but with the South end of the magnet facing down and the acceleration of the magnet is again recorded.

Which of the following best describes the acceleration of the magnet in each orientation?

	Acceleration North pole down	Acceleration South pole down
(A)	g	g
(B)	$> g$	$> g$
(C)	$< g$	$< g$
(D)	$< g$	$> g$

acceleration of magnet will be less than g in both cases

Part B – Written Response - Knowledge and Understanding (30 marks):**Attempt questions 21 - 27.****Use the space provided to answer the following questions.****Question 21 (7 marks)**

- (a) A parked car exerts a force of 18,250 N on the roadway. Calculate the mass of the car.

2

Criteria	Marks
Correct application of formula, correct working AND correct answer	2
Error in working OR incorrect answer	1
Sample: $g = 9.8 \text{ ms}^{-2}$ $F = 18250 \text{ N}$ $F = mg$ $m = F/g = 18250/9.8$ $m = 1862 \text{ kg}$	

- (b) The car is driven around a curve of radius 25.0 m at a constant speed of 20 ms^{-1} . Calculate the acceleration of the car.

3

Criteria	Marks
Correct application of formula, correct working AND correct answer	3
One error in working OR incorrect answer	2
Multiple errors, some relevant information	1
Sample: $r = 25.0 \text{ m}$ $v = 20 \text{ ms}^{-1}$ $a = v^2/r$ $a = 20 \times 20 / 25$ $a = 16 \text{ ms}^{-1}$	

- (c) If the driver has a mass of 68 kg, calculate the net force on the driver.

2

Criteria	Marks
Correct application of formula, working AND correct answer	2
Error in working OR incorrect answer (carried error from parts a,b)	1

Sample:
 $F = ma$
 $a = 16 \text{ ms}^{-2}$
 $m = 68 \text{ kg}$
 $F = 16 \times 68 = 1088 \text{ N}$

Question 22 (8 marks)

In a Young's double slit experiment, two slits, each of $100 \mu\text{m}$ width and a separation of $600 \mu\text{m}$ were arranged in front of a blue laser with a wavelength of 380 nm . A screen was placed at a distance of 2.4 m and the interference pattern was observed.

- (a) Calculate the spacing between the Fraunhofer diffraction minima.

2

Criteria	Marks
Correct application of formula, working AND correct answer	2
Error in working OR incorrect answer (carried error from parts a,b)	1
<p>Sample: width of slit $w = 100 \mu\text{m}$ distance to screen $L = 2.4 \text{ m}$ wavelength $= 380 \text{ nm}$</p> <p>single slit (Fraunhofer) diffraction minima $w \sin \theta = m\lambda$, and $\sin \theta \approx y/L$ $y = m\lambda L/w$</p> <p>$y = 380 \times 10^{-9} \times 2.4 / 100 \times 10^{-6}$ $y = 9.12 \times 10^{-3} \text{ m}$</p>	

- (b) Calculate the number of interference maxima that will be visible within the central diffraction maxima.

3

Criteria	Marks
Correct application of formula, working AND correct answer	3
One error in working	2
Multiple errors, some relevant information	1
<p>Sample: distance between slits $= 600 \mu\text{m}$ distance to screen $L = 2.4 \text{ m}$ wavelength $= 380 \text{ nm}$</p>	

Double slit interference maxima

$$d \sin \theta = m\lambda, \text{ and } \sin \theta \approx y/L$$

$$y = m\lambda L/d$$

$$y = 380 \times 10^{-9} \times 2.4 / 600 \times 10^{-6}$$

$$y = 1.52 \times 10^{-3} \text{ m}$$

So $m = 6$ maxima coincides with Fraunhofer minima ($m = 6$ is therefore not visible)
so -5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5 maxima visible for a total of 11

- (c) Describe any changes that would be observed if the blue laser was replaced with a red laser.

3

Criteria	Marks
Identify that red laser has longer wavelength AND describe effect on Fraunhofer diffraction minima AND describe effect on double slit interference pattern AND identify that number of interference fringes within diffraction maxima will stay the same	3
Identify that red laser has longer wavelength AND describe effect on Fraunhofer diffraction minima OR describe effect on double slit interference pattern OR identify that number of interference fringes within diffraction maxima will stay the same	2
Some relevant information	1
Red laser has longer wavelength Single slit (Fraunhofer) diffraction minima $y = m\lambda L/w$ so as wavelength increases, distance between minima will increase Double slit interference maxima $y = m\lambda L/d$ so as wavelength increases, distance between maxima will increase The pattern will however be the same as the number of interference maxima within the diffraction maxima will stay the same since it depends on the ratio of the distance between the slits and the slit width which remains constant	

Question 23 (5 marks)

A particle velocity selector consists of a parallel plate electric field (E) inside a magnetic field (B) as shown in figure 8. A charged particle entering the velocity selector will experience both electric and magnetic forces. When the forces are balanced, the particle will continue straight through.

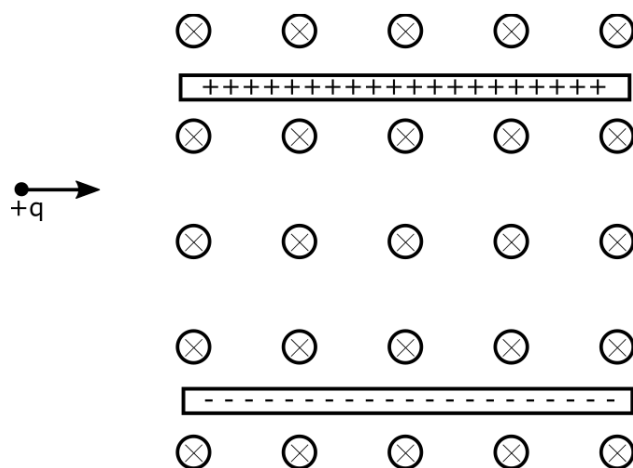


Figure 8.

- (a) Derive an expression for the velocity of a particle that will pass straight through the velocity selector. 3

Criteria	Marks
Correct application of formulae to derive correct expression	3
One error in working	2
Multiple errors	1
Force from electric field $F = Eq$ Force from magnetic field $F = qvB \sin \theta$ ($\theta = 90^\circ$, so $\sin \theta = 1$) $Eq = qvB$ $v = E/B$	

- (b) A particle with the same properties except for a negative charge is now sent into the velocity selector with the same magnetic and electric fields. 2
Describe the effect of these fields on the path of this particle.

Criteria	Marks
Correctly describes (no) effect.	2
Multiple errors	1
Since $v = E/B$ does not depend on charge, particle with positive or negative charge will follow the same path, ie. straight through. Deflection from each field will be in the opposite direction and they will still cancel each other out. A number of students described the direction of the forces beautifully, however did not describe the effect on the path of the particle.	

Question 24 (3 marks)

A ray of sunlight hits a rectangular piece of glass at an angle of incidence of 55° . The refracted light is split into a rainbow. The blue ray has a speed of $2.71 \times 10^8 \text{ ms}^{-1}$ and the red ray a speed of $2.78 \times 10^8 \text{ ms}^{-1}$.

Calculate the angular separation between the red and blue rays.

Criteria	Marks
Correct application of formulae AND correct answer	3
One error in working	2
Multiple errors	1
$n_1 \sin \theta_1 = n_2 \sin \theta_2$ $\text{and } n = c/v$ $\sin \theta_2 = \sin \theta_1 v_2/v_1$ Angle for red $\sin \theta = \sin(55^\circ) \times 2.78 \times 10^8 / 3 \times 10^8$ angle = 49.38° Angle for blue $\sin \theta = \sin(55^\circ) \times 2.71 \times 10^8 / 3 \times 10^8$ angle = 47.73° Angular separation = $49.38 - 47.72 = 1.65^\circ$ It is better to stay in decimals for angles rather than convert to degrees:minutes.	

Question 25 (10 marks)

An astronaut is doing maintenance on a spaceship which is in orbit above the Earth. They are using a spanner with a 45 cm shaft to tighten a nut holding a solar array, which requires a torque of 5.0 Nm to be fully tightened.

- (a) Calculate the force required to fully tighten the nut if the astronaut is able to apply a force perpendicular to the spanner shaft.

2

Criteria	Marks
Correct application of formulae AND correct answer	2
An error in working OR incorrect result	1
$\tau = rF \sin \theta$ $F = \tau / r \sin \theta$ $\text{where } \theta = 90^\circ \text{ so } \sin \theta = 1$ $\tau = 5 \text{ Nm}$ $r = 0.45 \text{ m}$ $F = 5 / 0.45 = 11.1$ $\text{Force} = 11.1 \text{ N}$	

- (b) If the same force as in part (a) was applied at 75° to the spanner shaft, how much torque would be applied to the nut?

2

Criteria	Marks
Correct application of formulae AND correct answer	2
An error in working OR incorrect result	1
<p>Sample:</p> $\tau = rF \sin \theta$ $r = 0.45 \text{ m}$ $F = 11.1 \text{ N}$ $\tau = rF \sin \theta \text{ where } \theta = 75^\circ$ $\tau = 0.45 \times 11.1 \times 0.966$ $\text{Torque} = 4.82 \text{ Nm}$	

- (c) Describe the changes in kinetic and potential energy as the spaceship fires its engines to move to a higher orbit.

2

Criteria	Marks
Describes increase in gravitational potential energy AND decrease in kinetic energy at higher orbit AND explains engines do work against gravity	2
As above, missing some detail	1
<p>Sample:</p> <p>As the spaceship fires its engines, work is done against gravity to increase gravitational potential energy as it moves to a higher orbit (equation). At a higher altitude kinetic energy reduces to stay in orbit (equation). Maybe sketch spaceship Ek and U as altitude increases.</p> <p>Note:</p> <p>Conservation of energy refers to the combined Earth-satellite system.</p> $E_{\text{total (satellite)}} = E_{\text{ks}} + U_s$ $E_{\text{k (satellite)}} = \frac{1}{2} mv^2 = \frac{1}{2} F_c r = \frac{1}{2} GM_e m / r^2 = \frac{1}{2} GM_e m / r$ $U_{\text{satellite}} = -GM_e m / r$ $E_{\text{total (satellite)}} = \frac{1}{2} GM_e m / r - GM_e m / r = -\frac{1}{2} GM_e m / r$ <p>so going from say $r = R$ to $2R$</p> $\Delta E_{\text{k (satellite)}} = \frac{1}{2} GM_e m / 2R - \frac{1}{2} GM_e m / R$ $\Delta E_{\text{k (satellite)}} = -GM_e m / R$ <p>as expected higher orbit is slower hence lower kinetic energy</p> $\Delta U_{\text{satellite}} = -GM_e m / 2R + GM_e m / R$ $\Delta U_{\text{satellite}} = GM_e m / 2R$ <p>as expected higher orbit has higher gravitational potential energy</p>	

But, the total energy for the satellite is NOT conserved
Only half of the change in kinetic energy goes to changing the gravitational potential of the satellite. Where does the other half go?

- (d) Distinguish between escape velocity and orbital velocity, include formulae for both velocities in your answer.

4

Criteria	Marks
Describes both escape and orbital velocities AND provides both equations AND includes consideration of kinetic and potential energy	4
As for 4, missing one element	3
As for 4, missing two elements	2
Some relevant information	1
<p>Sample: orbital velocity $v_o = \sqrt{GM/r}$ velocity where an object is bound in orbit about another object, centripetal acceleration due to gravity enables object to follow a circular path (at v_o)</p> <p>escape velocity $v_e = \sqrt{2GM/r}$ velocity where object is not bound, ie potential $\rightarrow 0$ (and $E_k \rightarrow 0$), object has enough velocity to "leave" the gravitational field (at ∞)</p> <p>when $v_o < v < v_e$ object will follow elliptical orbit</p>	

Question 26 (11 marks)

An electron is accelerated to 0.9999 c in a particle accelerator.

- (a) Calculate its relativistic mass.

2

Criteria	Marks
Correct working AND correct answer	2
An error in working OR incorrect answer	1
<p>Sample: $m_0 = 9.109 \times 10^{-31} \text{ kg}$ $v = 0.9999 \text{ c}$ $m = m_0 / \sqrt{1 - v^2/c^2}$</p>	

$$m = 9.109 \times 10^{-31} / (1 - 0.9999^2)$$

$$m = 6.44 \times 10^{-29} \text{ kg}$$

- (b) Calculate the electron's relativistic momentum. 1

Criteria	Marks
Correct working AND correct answer	1
Sample: $m = 6.44 \times 10^{-29} \text{ kg}$ $p = mv$ $p = 6.44 \times 10^{-29} \times 0.9999 \times 3 \times 10^8$ $p = 1.93 \times 10^{-20} \text{ kg ms}^{-1}$	

- (c) A positron is the antiparticle of the electron which has the same properties except for a charge of +1. When a positron collides with an electron they annihilate each other and produce electromagnetic radiation as two photons. 2
- Calculate how much energy is released in this collision.

Criteria	Marks
Correct working AND correct answer	2
An error in working OR incorrect answer	1
Sample: $m_0 = 9.109 \times 10^{-31} \text{ kg}$ $E = mc^2$ $E = 2 \times 9.109 \times 10^{-31} \times (3 \times 10^8)^2$ $E = 1.64 \times 10^{-13} \text{ J}$ or $E = 1.02 \text{ MeV}$	

- (d) Justify how Einstein's mass energy equivalence equation can be used to explain such phenomena as the energy produced by the Sun. 3

Criteria	Marks
States mass energy equivalence equation AND relates to fusion of nuclei in the Sun to produce energy AND describes mechanism of mass defect	3

as for 3 with error or omission	2
some relevant information	1
<p>Sample:</p> <p>Einstein's mass energy equivalence states that mass is able to be converted into energy and vice versa according to the equation $E = mc^2$. Because of the large value for c, this means that a small mass will be converted into very large amounts of energy.</p> <p>In the Sun, nuclei are fused (eg. $H + H \rightarrow He$) and the mass of the He nucleus is smaller than the sum of the H nuclei masses. This is the mass defect, and is converted into energy according to Einstein's equation. A large number of fusion reactions occur in the Sun and provide all of the radiated energy coming from it.</p>	

- (e) Outline one piece of evidence to support Einstein's theory of special relativity.

3

Criteria	Marks
Identifies one piece of evidence AND outlines thoroughly how it supports Einstein's special theory of relativity	3
Identifies one piece of evidence AND outlines basically how it supports Einstein's special theory of relativity	2
provides relevant information	1
<p>Sample:</p> <p>One piece of evidence is the decay lifetime of the muon in the Earth's atmosphere. The muon has a proper decay lifetime of $2.2 \mu s$. They are created by the collision of cosmic rays with the particles of the upper atmosphere and travel close to the speed of light. At that speed, they should not reach the surface of the Earth before they decay. However, it is found that they can reach the surface of the Earth because of time dilation of the muon decay lifetime. An experiment was performed by Frisch & Smith in 1963 to measure the number of muons detected at sea level and it agreed with the number predicted by Einstein's theory of special relativity.</p> <p>Note:</p> <p>The muon has a mean lifetime of $2.2 \mu s$ after which it decays. Radioactive decay (α, β or γ) is measured in half life, which is the time for half of the nuclei to decay. Don't mix up these terms.</p>	

Question 27 (6 marks)

A wireless charger can be used to provide energy to recharge the battery in a mobile phone. A diagram of this arrangement is shown in figure 9.

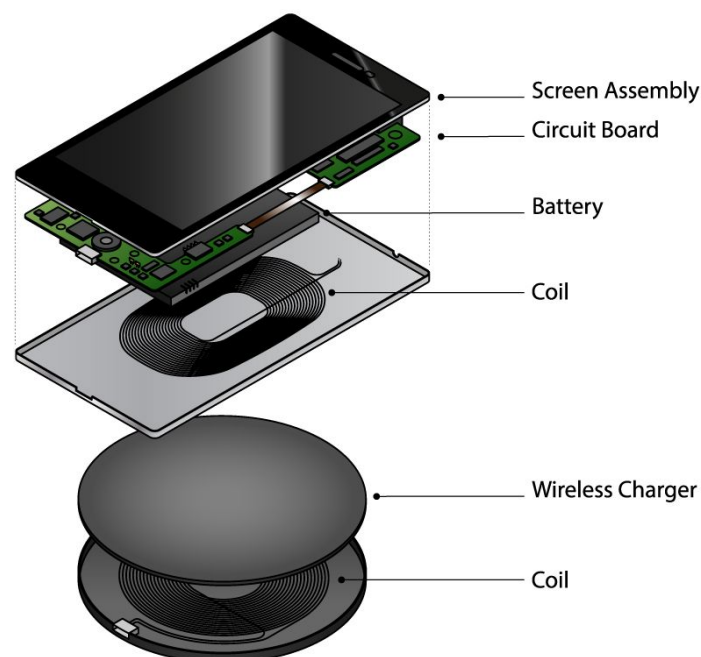


Figure 9.

Explain the operation of the mobile phone charger when charging the phone.

Criteria	Marks
Describes all components of arrangement AND explains thoroughly how energy is transferred from the charger to the phone AND demonstrates extensive knowledge of magnetic induction	6
Describes all components of arrangement AND explains how energy is transferred from the charger to the phone AND demonstrates extensive knowledge of magnetic induction	5
Describes some components of arrangement AND explains how energy is transferred from the charger to the phone AND demonstrates sound knowledge of magnetic induction	4
Describes some components of arrangement OR explains how energy is transferred from the charger to the phone AND demonstrates sound knowledge of magnetic induction	3
Describes some components of arrangement OR explains how energy is transferred from the charger to the phone OR demonstrates basic knowledge of magnetic induction	2
some relevant information	1
<p>Sample:</p> <p>Better answers included appropriate formulae (and clearly identified where they were applicable).</p> <ul style="list-style-type: none"> • Ampere's Law $B = \mu_0 I / 2\pi r$ $B = \mu_0 NI / L$ • Faraday's Law of Induction $\varepsilon = -N\Delta\phi / \Delta t$ • Transformer law $V_s / V_p = N_s / N_p$ $V_s I_s = V_p I_p$ 	

Operation requires a varying (AC) current in the charger coil
 Current induced in the phone (secondary coil) will also be AC, which needs to be converted to DC to charge the phone battery.
 Some students identified issues with eddy currents, problems of air core coupling, flux leakage between the coils or other energy losses.

Section C – Written Response - Working Scientifically (25 marks):

Attempt questions 28 - 30.

Use the space provided to answer the following questions.

Question 28 (12 marks)

A simple device for investigating the photoelectric effect is shown in figure 10.

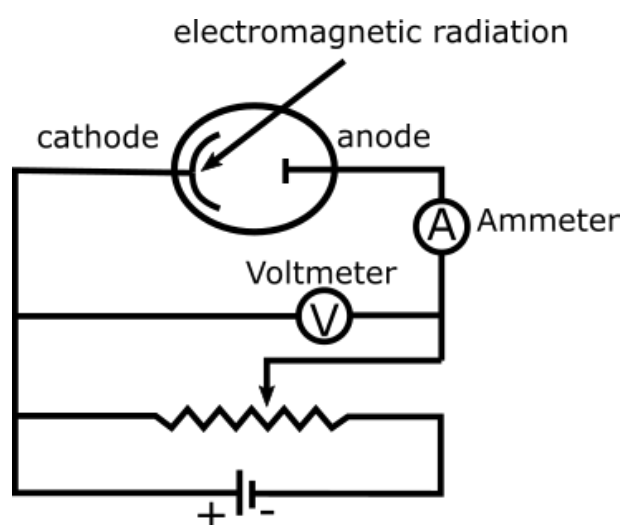


Figure 10.

When light of sufficient energy hits the cathode electrons are ejected towards the anode. The voltage of the power supply can be varied until no current is measured at the ammeter, this is the stopping voltage.

- (a) Calculate the initial velocity of the electrons as they leave the cathode if the stopping voltage is 4.9 V.

2

Criteria	Marks
correct working AND correct answer	2
error in working OR incorrect answer	1
Sample: Work done = E_k (at stopping voltage) $W = qV = \frac{1}{2}mv^2$ $v^2 = 2qV/m$ $v^2 = 2 \times 1.602 \times 10^{-19} \times 4.9 / 9.109 \times 10^{-31} = 1.723 \times 10^{12}$ $v = 1.31 \times 10^6 \text{ ms}^{-1}$	

Most of the students responded well to this question.

- (b) The device was used to investigate the relationship between the type of metal at the cathode and the stopping voltage. 1
Write a suitable hypothesis for this investigation.

Criteria	Marks
Reasonable hypothesis using independent & independent variables.	1
Samples: The stopping voltage will depend on the type of metal. The maximum kinetic energy can be determined by work function. Metals with a higher work function will have a lower stopping voltage.	

The following data was collected for a zinc cathode.

photon frequency (10^{14} Hz)	stopping voltage (V)
1.00	Note 1.
1.25	0.87
1.50	1.90
1.75	2.94
2.00	3.97
2.25	5.01
Note 1. no current was detected	

- (c) Plot this data on the graph paper below. 3

Criteria	Marks
All graph details present	3
minor error or omission	2
multiple errors or omissions	1

Students did well. Only some did not provide the title or incorrectly labelled the axis.

- (d) Using your graph, calculate the work function for zinc. 2

Criteria	Marks
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reads graph to provide accurate frequency AND applies formula to calculate correct answer (margin $\pm 0.05 \times 10^{-20}$ J)	2
poor reading of frequency OR incorrect application of formula OR answer not within margin	1
Sample: $E = hf$ $E = 6.626 \times 10^{-34} \times 1.06 \times 10^{14}$ $E = 7.0 \times 10^{-20} \text{ J}$	

- (e) Explain how the quantum model of light accounts for the results of this experiment.

4

Criteria	Marks
Demonstrates extensive knowledge of the quantum model of light AND establishes relationship (cause & effect) between the model and the results for this experiment	4
Demonstrates thorough knowledge of the quantum model of light AND establishes relationship (cause & effect) between the model and the results for this experiment	3
Demonstrates sound knowledge of the quantum model of light AND relates model to the results for this experiment	2
Demonstrates basic knowledge of the quantum model of light OR relates model to the results for this experiment	1
Sample: The quantum model predicts that the frequency below a threshold value will not have enough energy to eject an electron. This frequency is given by $E = hf = \phi$, which corresponds to the work function. This is demonstrated clearly in the graph where the threshold frequency of ($1.06 \times 10^{14} \text{ Hz}$) corresponds to a work function of ($7.0 \times 10^{-20} \text{ J}$). For frequencies above this value, the electrons will have a kinetic energy equivalent to the total energy of the photon less the work function ($E_k = hf - \phi$). Hence, as the frequency goes up, the stopping voltage goes up with a gradient of h (planck's constant). This is shown on the graph where the straight line increases linearly from the threshold frequency.	

Question 29 (7 marks)

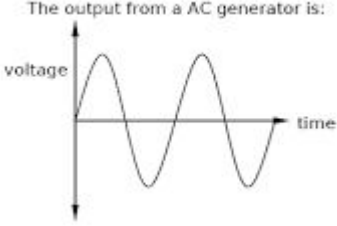
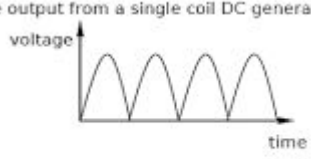
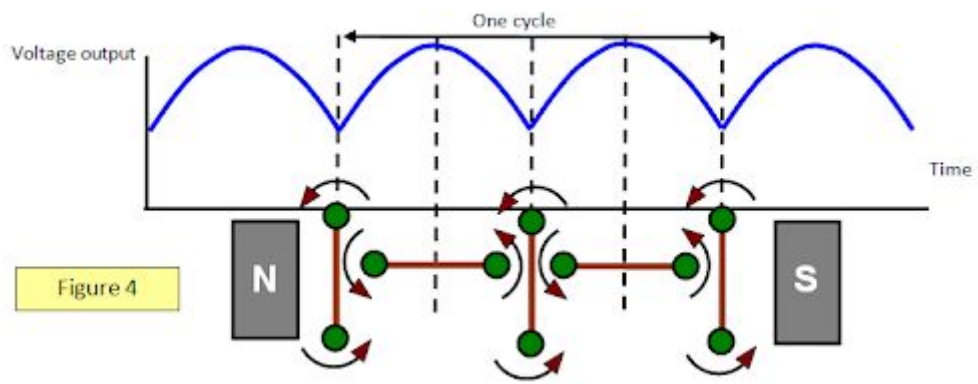
- (a) Using a series of annotated diagrams, show how a small DC motor operates.

4

Criteria	Marks
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Provides multiple, correctly drawn diagrams that show the operation of the DC motor AND annotations demonstrate extensive knowledge of how the motor operates	4
Provides correctly drawn diagram(s) that show the operation of the DC motor AND annotations demonstrate thorough knowledge of how the motor operates	3
Provides diagram(s) that show the operation of the DC motor AND annotations demonstrate basic knowledge of how the motor operates	2
some relevant information	1
Sample:	

- (b) If the shaft of a DC motor is turned by an external torque, it will act as a generator. 3
 Sketch the output voltage of a DC generator against the angle of the shaft for one complete rotation.

Criteria	Marks
sketch shows positive rectified sine wave AND shows full cycle	3
sketch shows positive rectified sine wave AND less than full cycle	2
sketch shows sine wave	1
<p>Sample: shown in figure 4</p> <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;"> <p>The output from a AC generator is:</p>  </div> <div style="text-align: center;"> <p>The output from a single coil DC generator is:</p>  </div> </div> <div style="text-align: center; margin-top: 20px;">  <p>Figure 4</p> </div>	

Question 30 (6 marks)

A simple pendulum consists of a bob (point-mass) m , hanging from a (massless) string of length L , fixed at a pivot point P . When displaced to an initial angle and released, the pendulum will swing back and forth with periodic motion.

A simple pendulum, as shown in figure 11, can be used to estimate the value for the acceleration due to gravity (g) on the Earth's surface.

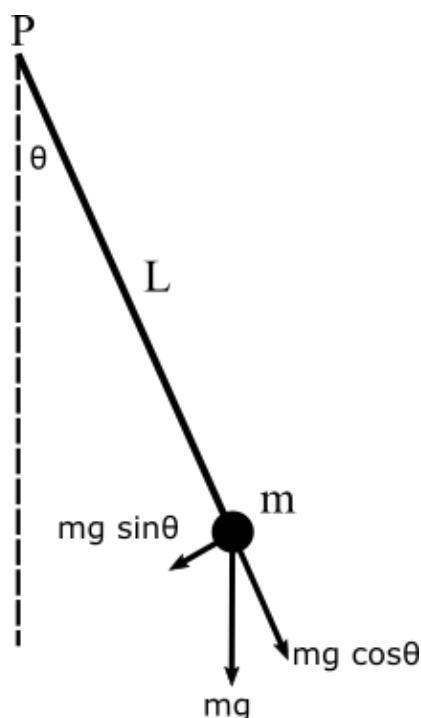


Figure 11.

By applying Newton's second law for rotational systems, the equation of motion for the pendulum may be obtained and the period of the pendulum is then given by the following equation:

$$T = \sqrt{\frac{L}{g}}$$

where:

- T period of the pendulum (s)
- L length of the pendulum (m)
- g acceleration due to gravity (ms^{-2})

An investigation will be performed with the following aim:

Aim:

To obtain an estimate for the value the acceleration due to gravity g , using a simple pendulum and its equation of motion.

- (a) Write a procedure to collect the appropriate data from the pendulum to meet the aim of this investigation.

4

Criteria	Marks
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Reasonable procedure AND multiple swings AND repeats each length AND multiple lengths	4
above missing one element	3
above missing two elements	2
some relevant information	1
<p>Sample:</p> <p>For full marks students should mention the following:</p> <ul style="list-style-type: none"> • Change the length of pendulum • Time multiple (10) oscillations • Measure the period • Period square 	

- (b) Show how the equation of motion for the pendulum can be rearranged to enable you to graphically analyse the data and hence obtain a value for g . 2

Criteria	Marks
Rearranges equation AND explains how to determine value for g from the graph	2
Rearranges equation OR explains how to determine value for g from the graph	1
<p>Sample:</p> $T = \sqrt{\frac{L}{g}}$ $T^2 = \frac{L}{g}$ $T^2 = \frac{1}{g}L$ <p>By plotting T^2 against L the value for g can be determined from the gradient.</p> <p>The question was well understood by students.</p>	

End of Assessment