SECTION A – Multiple-choice questions

Instructions for Section A

Answer all questions in pencil on the answer sheet provided for multiple-choice questions.
Choose the response that is correct or that best answers the question.
A correct answer scores 1; an incorrect answer scores 0.
Marks will not be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.
Unless otherwise indicated, the diagrams in this book are not drawn to scale.
Take the value of g to be $9.8\ m\ s^{-2}$.

Question 1 (A) easy

Magnetic and gravitational forces have a variety of properties.
Which of the following best describes the attraction/repulsion properties of magnetic and gravitational forces?

	Magnetic forces	Gravitational forces
A.	either attract or repel	only attract
B.	only repel	neither attract nor repel
C.	only attract	only attract
D.	either attract or repel	either attract or repel

Big mass objects attract small mass object.

Question 2 (B) easy

The electric field between two parallel plates that are 1.0×10^{-2} m apart is $2.0 \times 10^{-4}\ N\ C^{-1}$.
Which one of the following is closest to the voltage between the plates?

A. 2.0×10^{-8} V
B. 2.0×10^{-6} V
C. 2.0×10^{-4} V
D. 1.0×10^{-2} V

$V = E \cdot \Delta d$
$= 2.0 \times 10^{-4} \times 1.0 \times 10^{-2}$
$= 2.0 \times 10^{-6}$

Question 3 (A)

Three charges (–Q, +2Q, –2Q) are placed at the vertices of an isosceles triangle, as shown below.

$+2Q - 2Q = 0$
–ve direction is to the left

Which one of the following arrows best represents the direction of the net force on the charge –Q?

Question 4 (D)

The magnitude of the acceleration due to gravity at Earth's surface is g.
Planet Y has twice the mass and half the radius of Earth. Both planets are modelled as uniform spheres.
Which one of the following best gives the magnitude of the acceleration due to gravity on the surface of Planet Y?

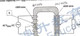
A. $\frac{1}{2}g$
B. $1g$
C. $4g$
D. $8g$

$g = g_E = \frac{GM}{R^2}$ (VCAA formula sheet)

$g_Y = \frac{G(2M)}{(\frac{R}{2})^2}$
$= \frac{2GM}{\frac{R^2}{4}}$
$= \frac{8GM}{R^2}$
$= 8g_E$

Use the following information to answer Questions 5 and 6.

A 40 V_{RMS} AC generator and an ideal transformer are used to supply power. The diagram below shows the generator and the transformer supplying 240 V_{RMS} to a resistor with a resistance of 1200 Ω.



Question 5

Which of the following correctly identifies the parts labelled X and Y, and the function of the transformer?

	Part X	Part Y	Function of transformer
A.	primary coil	secondary coil	step-down
B.	primary coil	secondary coil	step-up
C.	secondary coil	primary coil	step-down
D.	secondary coil	primary coil	step-up

Question 6

Which one of the following is closest to the RMS current in the primary circuit?

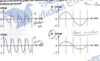
A. 0.04 A
B. 0.20 A
C. 1.20 A
D. 1.50 A

Question 7

The coil of an AC generator completes 50 revolutions per second.

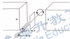
A graph of output voltage versus time for this generator is shown below.

Which one of the following graphs best represents the output voltage if the rate of rotation is changed to 25 revolutions per second?



Question 8

An electrical generator is shown in the diagram below. The generator is turning clockwise.



The voltage between P and Q and the magnetic flux through the loop are both graphed as a function of time, with voltage versus time shown as a solid line and magnetic flux versus time shown as a dashed line.

Which one of the following graphs best shows the relationships for this electrical generator?

A.

B.

C.

D.

Question 9

A monochromatic light ray passes through three different media, as shown in the diagram below.

Assume that v_1 is the speed of light in Medium 1, v_2 is the speed of light in Medium 2 and v_3 is the speed of light in Medium 3.

Which one of the following would best represent the relative speeds in the media?

A. $v_1 > v_2 > v_3$
B. $v_1 > v_3 > v_2$
C. $v_3 > v_2 > v_1$
D. $v_3 > v_1 > v_2$

Question 10

The horizontal face of a glass block is covered with a film of liquid, as shown below.

A monochromatic light ray is incident on the glass–liquid boundary with an angle of incidence of 62.0°.

The minimum value of the liquid's refractive index, so that some light will just cross the interface into the liquid, is closest to

A. 1.33
B. 1.55
C. 1.88
D. 1.98

Question 11

An ultralight aeroplane of mass 500 kg flies in a horizontal straight line at a constant speed of 100 m s^{-1}.
The horizontal resistance force acting on the aeroplane is 1500 N.
Which one of the following best describes the magnitude of the forward horizontal thrust on the aeroplane?

A. 1500 N
B. slightly less than 1500 N
C. slightly more than 1500 N
D. 5000 N

Question 12

A small ball is rolling at constant speed along a horizontal table. It rolls off the edge of the table and follows the parabolic path shown in the diagram below. Ignore air resistance.

Which one of the following statements about the motion of the ball as it falls is correct?

A. The ball's speed increases at a constant rate.
B. The momentum of the ball is conserved.
C. The acceleration of the ball is constant.
D. The ball travels at constant speed.

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Question 13

Joanna is an observer in Spaceship A, watching Spaceship B fly past at a relative speed of 0.94c (γ = 3.00). She measures the length of Spaceship B from her frame of reference to be 150 m.

Which one of the following is closest to the proper length of Spaceship B?

A. 50 m
B. 150 m
C. 450 m
D. 900 m

Question 14

Electrons of mass 9.1×10^{-31} kg are accelerated in an electron gun to a speed of 1.0×10^{7} m s^{-1}.
The best estimate of the de Broglie wavelength of these electrons is

A. 4.5×10^{-8} m
B. 7.3×10^{-8} m
C. 7.3×10^{-11} m
D. 4.5×10^{-12} m

Question 15

Electrons pass through a fine metal grid, forming a diffraction pattern.
If the speed of the electrons was doubled using the same metal grid, what would be the effect on the fringe spacing?

A. The fringe spacing would increase.
B. The fringe spacing would decrease.
C. The fringe spacing would not change.
D. The fringe spacing cannot be determined from the information given.

Question 16

Students are conducting a photoelectric effect experiment. They shine light of known frequency onto a metal and measure the maximum kinetic energy of the emitted photoelectrons.

The students increase the intensity of the incident light.

The effect of this increase would most likely be

A. fewer maximum kinetic energy of the emitted photoelectrons.
B. higher maximum kinetic energy of the emitted photoelectrons.
C. fewer emitted photoelectrons but of higher maximum kinetic energy.
D. more emitted photoelectrons but of the same maximum kinetic energy.

Question 17

Which one of the following is true when incandescent light is compared to laser light?

A. Laser light has a very wide spectrum; incandescent light has a very narrow spectrum.
B. Both laser light and incandescent light have a very narrow spectrum.
C. Laser light is incoherent; incandescent light is coherent.
D. Laser light is coherent; incandescent light is incoherent.

Use the following information to answer Questions 18 and 19.

As part of an experimental investigation, Physics students use a pendulum, as shown below, to indirectly measure the magnitude of Earth's gravitational field at their location.

The students use a constant mass and a constant amplitude of swing, changing only the length of the pendulum and then measuring the time for five oscillations. They obtain four different time readings for four different lengths of the pendulum.

By using the relationship

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where T is the period and l is the length of the pendulum, the students obtain four values for the magnitude of Earth's gravitational field.

Question 18

Which of the following best identifies the independent, dependent and controlled variables in the students' experimental investigation?

	Independent	Dependent	Controlled
A.	length	time	mass, amplitude
B.	time	length	mass, amplitude
C.	mass	time	length, amplitude
D.	amplitude	length	time, mass

Question 19

Which one of the following best explains why the students measured the time for five oscillations rather than the time for one oscillation?

A. One oscillation is too quick to see.
B. Five oscillations reduce the effect of air friction.
C. Five oscillations reduce the uncertainty of the measured period.
D. Five oscillations reduce the uncertainty of the measured length.

Question 20

As part of their Physics course, Anna, Bianca, Chris and Darshiree investigate the physics of car crashes. On an internet site that describes what happens during car crashes, they find the following statement.

> It happens in a flash: your car goes from driving to impacting … As the vehicle crashes into something, it stops or slows very abruptly, and at the point of impact the car's structure will bend or break. That crumpling action works to absorb some of the initial crash forces, protecting the passenger compartment to some degree.

Source: Kathleen Poling, 'Crash Dynamics for Dummies', Car Seats for the Littles, 3 January 2018, <https://csftl.org/crash-dynamics-dummies/>

The students disagree about the use of the word 'forces' in the statement, 'That crumpling action works to absorb some of the initial crash forces, protecting the passenger compartment to some degree'.

Which one of the following students best identifies the physics of how the crumpling action protects the passengers?

A.	Anna	'… to absorb some of the initial crash speed, protecting …'
B.	Bianca	'… to absorb some of the initial crash kinetic energy, protecting …'
C.	Chris	'… to absorb some of the initial crash momentum, protecting …'
D.	Darshiree	'… to absorb some of the initial crash forces, protecting …'

SECTION B

Instructions for Section B

Answer all questions in the spaces provided. Write using blue or black pen.
Where an answer box is provided, write your final answer in the box.
If an answer box has a unit printed in it, give your answer in that unit.
In questions where more than one mark is available, appropriate working **must** be shown.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1 (3 marks)

A particle of mass m and charge q travelling at velocity v enters a uniform magnetic field B, as shown in Figure 1.

Figure 1

a. Is the charge q positive or negative? Give a reason for your answer. 1 mark

Negative

(A1) mention "cross product" or "right hand rule"

Using cross product, only if the particle ... a Lorentz force pointing to the centre.

b. Explain why the path of the particle is an arc of a circle while the particle is in the magnetic field.

The force experienced by this -ve particle is given by $\vec{F} = q(\vec{E} + \vec{v}\times\vec{B})$. Since $\vec{E}$ is absent, we only analyse $\vec{v}\times\vec{B}$. With $\vec{v}$ perpendicular to the Lorentz force, a circular motion is maintained within the magnetic field B. Immediately before the -ve particle exits $\vec{B}$, the speed is the same and without $\vec{B}$, $\vec{F}_{Lorentz}$ disappears and thus q will exit the field $\vec{B}$ instantaneously along the tangential direction.

(A1) why arc? explained (A1) why not arc? explained

SECTION B – continued

Question 2 (2 marks)

Figure 2 shows two equal positive stationary point charges placed near each other.

(A1) (A1)

Figure 2

Note: the no. of field lines should be the same and they must look symmetrical

Sketch on Figure 2 the shape and direction of the electric field lines. Use at least eight field lines.

磁场中
有安培力 $\vec{F} = q(\vec{E} + \vec{v}\times\vec{B})$，E为0
该力垂直于动速度
形成圆周运动(弧)
出磁场一瞬间安培力消失，圆周运动结束
则带电粒子沿圆弧末端切线方向飞出。

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SECTION B – continued

Question 3 (6 marks)

Figure 3 shows a schematic diagram of a DC motor. The motor has a coil, JKLM, consisting of 100 turns. The permanent magnets provide a uniform magnetic field of 0.45 T. The commutator connectors, X and Y, provide a constant DC current, I, to the coil. The length of the side JK is 5.0 cm.

The current I flows in the direction shown in the diagram.

$\vec{F} = ILB$ (VCAA formula sheet)

Figure 3

a. Which terminal of the commutator is connected to the positive terminal of the current supply? 1 mark

Terminal X (A1) answer

b. Draw an arrow on Figure 3 to indicate the direction of the magnetic force acting on the side JK. 1 mark

↓F (A1)

c. Explain the role of the commutator in the operation of the DC motor. 2 marks

(A1) Definition (A1) detailed explanation

The commutator is to ensure that the force acting on the coil's armature is always in the same direction, because the commutator turns on and off to control the electromagnetic field is pointing.

On one side of the coil where the electricity should always flows away; on the other side, electricity flows "towards". switch direction

Without a commutator, the coil only rotate 180° and

$I = 6.0$

d. A current of 6.0 A flows through the 100 turns of the coil JKLM. The side JK is 5.0 cm in length.

$n = 100$, $\ell = 0.05$ $B = 0.45\,T$

Calculate the size of the magnetic force on the side JK in the orientation shown in Figure 3. Show your working. 2 marks

$|\vec{F}| = nILB$ (VCAA formula sheet)

substitution (M1) $= 100 \times 5 \times 0.05 \times 0.45$

$= 11.25$

11.25 N

(A1)

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Question 4 (5 marks)

Assume that a journey from approximately 2 Earth radii ($2R_E$) down to the centre of Earth is possible. The radius of Earth (R_E) is 6.37×10^6 m. Assume that Earth is a sphere of constant density.

A graph of gravitational field strength versus distance from the centre of Earth is shown in Figure 4.

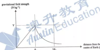

Figure 4

a. What is the numerical value of Y? 1 mark

9.8 N kg⁻¹ (A1)

b. Explain why gravitational field strength is 0 N kg⁻¹ at the centre of Earth. 2 marks

Using the formula $g = \frac{GM}{R^2}$ R = 0

Taking one diameter as example:

By symmetry, if the earth is uniformly distributed sphere then, $\vec{F}_{XR} = -\vec{F}_{YR}$ so does every other directions.

(A1) diagram or theory
(A1) "all forces cancelled out" articulated

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c. Calculate the increase in potential energy for a 75 kg person hypothetically moving from the centre of Earth to the surface of Earth. Show your working. 2 marks

$R = 6.37 \times 10^6$ m, $M = 75$ kg, $g = 9.8$ N/kg

$\Delta GPE = \int_0^{R_E} \frac{75g}{R_E} \cdot x \, dx = \left[\frac{1}{2} 75g \cdot \frac{1}{R_E} \cdot x^2\right]_0^{R_E}$

~~2340975000~~

2.34×10^9 J (A1) (A1)

Question 5 (5 marks)

Navigation in vehicles or on mobile phones uses a network of global positioning systems (GPS) satellites. The GPS consists of 31 satellites that orbit Earth.

In December 2018, one satellite of mass 2270 kg, from the GPS Block IIIA series, was launched into a circular orbit at an altitude of 20000 km above Earth's surface.

a. Identify the type(s) of force(s) acting on the satellite and the direction(s) in which the force(s) must act to keep the satellite orbiting Earth. 2 marks

The gravitational attraction/force from the satellite towards the centre of Earth is the centripetal force that maintains constant speed and circular trajectory of the satellite (A1) (A1)

b. Calculate the period of the satellite to three significant figures. You may use data from the table below in your calculations. Show your working. 3 marks

Data

mass of satellite	2.27×10^3 kg
mass of Earth	5.98×10^{24} kg
radius of Earth	6.37×10^6 m
altitude of satellite above Earth's surface	2.00×10^7 m
gravitational constant	6.67×10^{-11} N m^2 kg^{-2}

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

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

Kepler's 3rd Law: $a = R_E + h = 6.37\times10^6 + 2.00\times10^7 = 2.637\times10^7$ m

$T = \frac{2\pi a^{\frac{3}{2}}}{\sqrt{GM}}$ (M1)

$= \frac{2\pi \times (2.637\times10^7)^{\frac{3}{2}}}{\sqrt{6.67\times10^{-11}\times5.98\times10^{24}}}$ (M1)

$= 42602.15362...$ s

4.26×10⁴ s (A1)

Question 6 (7 marks)

A home owner on a large property creates a backyard entertainment area. The entertainment area has a low-voltage lighting system. To operate correctly, the lighting system requires a voltage of 12 V_{RMS}. The lighting system has a resistance of 12 Ω.

a. Calculate the power drawn by the lighting system. 1 mark

$P = \frac{V^2}{R} = \frac{12^2}{12} = 12$ Watts

12 W (A1)

To operate the lighting system, the home owner installs an ideal transformer at the house to reduce the voltage from 240 V_{RMS} to 12 V_{RMS}. The home owner then runs a 200 m long heavy-duty outdoor extension lead, which has a total resistance of 3 Ω, from the transformer to the entertainment area.

b. The lights are a little dimmer than expected in the entertainment area.

Give one possible reason for this and support your answer with calculations. 4 marks

One possible reason could be the power loss along the lines transmitting electricity from the transformer to the area (A1)

Thus we have $I = \frac{V}{R+r} = \frac{12}{12+3} = \frac{4}{5}$ (A) (A1)

So $V_{loss} = I \times R_{loss}$

$= 0.8 \times 3 = 2.4$ Volts (A1)

Due to extra resistance in the circuit, this power loss will make the light dimmer (C1)

c. Using the same equipment, what changes could the home owner make to improve the brightness of the lights? Explain your answer. 2 marks

- Supply higher voltage to compensate the power loss i.e. If V = 15 Volts $I = \frac{15}{15} = 1$ A.
- Change a light bulb with smaller resistance so that the total resistance drops and light will be brighter
- Put a indoor transformer to increase the power supply indoor.

(A1) + (A1) two of the ones mentioned

Question 7 (11 marks)

Students in a Physics practical class investigate the piece of electrical equipment shown in Figure 5. It consists of a single rectangular loop of wire that can be rotated within a uniform magnetic field. The loop has dimensions 0.50 m × 0.25 m and is connected to the output terminals with slip rings. The loop is in a uniform magnetic field of strength 0.40 T.

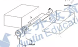

Figure 5

a. Circle the name that best describes the piece of electrical equipment shown in Figure 5. (A1) 1 mark

(alternator) DC generator DC motor AC motor

b.

i. What is the magnitude of the flux through the loop when it is in the position shown in Figure 5? 1 mark

0	Wb

$\Phi = B_{\perp} A$. $B_{\perp} = 0$, N∥ 90° (A1)

ii. Explain your answer to part b.i. 1 mark

$\vec{B} = \vec{B_{\parallel}} + \vec{B_{\perp}}$

When the $\vec{B}$ field is parallel to the loop area, there is no perpendicular component, $\Phi = 0$. (A1)

The students connect the output terminals of the piece of electrical equipment to an oscilloscope. One student rotates the loop at a constant rate of 20 revolutions per second.

c. Calculate the period of rotation of the loop. 1 mark

$P = \frac{1}{20}$ (A1)

$\frac{1}{20}$	s

0.05 ✓ $\frac{1}{20}$ ✓

d. Calculate the maximum flux through the loop. Show your working. 2 marks

0.40 × 0.50 × 0.25 when θ = 90°

= 0.05 (A1)

0.05	Wb

e. The loop starts in the position shown in Figure 5.

What is the average voltage measured across the output terminals for the first quarter turn? Show your working. 2 marks

$\mathcal{E} = -N\frac{d\Phi}{dt} = -N\frac{\Phi_t - \Phi_0}{\frac{1}{4}(0.05)} = -1 \times \frac{0.05 - 0}{\frac{1}{4} \times 0.05}$

$= -4$

(A1) could be "4 V" It doesn't say "magnitude"

−4	V

f. State two ways that the amplitude of the voltage across the output terminals can be increased. 2 marks

- Increase the rotor speed so that the number of turns will increase (A1)
- Change another two magnets with stronger field, so B↑, Φ_{max}↑ (A1)
- Or change another loop that is larger (in area)

5. Figure 6 shows the output voltage graph shown on the oscilloscope for two cycles.

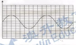

Figure 6

The students now replace the slip rings in Figure 5 with a split-ring commutator.

On Figure 7, sketch with a solid line the output that the students will now observe on the oscilloscope. Show two complete revolutions. The original output is shown with a dashed line. 1 mark

(A1) all correct

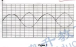

Figure 7

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Question 8 (9 marks)

A 250 g toy car performs a loop in the apparatus shown in Figure 8.

Figure 8

The car starts from rest at point A and travels along the track without any air resistance or retarding frictional forces. The radius of the car's path in the loop is 0.20 m. When the car reaches point B it is travelling at a speed of 3.0 m s^{-1}.

a. Calculate the value of *h*. Show your working. 3 marks

at point A: $E_{total} = mgh = 0.25 \times 9.8h$ (A1) Datum ✓

at point B: $E_{total} = \frac{1}{2}mv^2 + mg(2r) = 0.25(\frac{1}{2} \times 3^2 + 9.8 \times 0.4)$

Using conservation of energy: $0.25 \times 9.8h = 0.25 \times (\frac{1}{2} \times 3^2 + 9.8 \times 0.4)$ (M1)

$\therefore h = \frac{\frac{1}{2} \times 3^2 + 9.8 \times 0.4}{9.8}$

$\frac{421}{490}$ m or 0.86 (2 sig figs) (A1)

b. Calculate the magnitude of the normal reaction force on the car by the track when it is at point B. Show your working. 3 marks

$\sum F = N + mg = m\frac{v^2}{r}$ (M1)

$N = m\frac{v^2}{r} - mg$ (A1)

$= 0.25\left(\frac{3^2}{0.2} - 9.8\right)$

$\frac{44}{5}$ N or 8.8 (N)

c. Explain why the car does not fall from the track at point B, when it is upside down. 3 marks

Because the car is travelling very fast (greater than 1.4 m/s)

During the motion, by travelling at high speed the car remains contact with the track surface and the sum of normal reaction force and weight force acts on the car as the force pointing to the centre of the motion. As circular motion, the car won't fall from the track.

Limiting case: when $N \to 0$

$mg = m\frac{v^2}{r}$

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

$9.8 \times 0.2 = v^2$

$v = \sqrt{9.8 \times 0.2}$

$= \frac{7}{5}$ (A1)

at B, $v = 3$ m/s $> \frac{7}{5}$

$\therefore$ The car is able to remain circular motion

(A1) calculation

(A1) comparison & explanation

Question 9 (3 marks)

A proton in an accelerator detector collides head-on with a stationary alpha particle, as shown in Figure 9a and Figure 9b. After the collision, the alpha particle travels at a speed of 4.0×10^6 m s^{-1}. The proton rebounds at 6.0×10^6 m s^{-1}.

+ve direction →

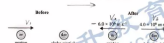


Figure 9a   Figure 9b

Find the speed of the proton before the collision, modelling the mass of the alpha particle, 4m, to be equal to four times the mass of the proton, m. Show your working. Ignore relativistic effects.

Using conservation of momentum

$m \cdot V_1 = mV_2 + (4m)V_3$ LHS ✓ (A1)

$m \cdot V_1 = m(V_2 + 4V_3)$ RHS ✓ (A1)

$V_1 = V_2 + 4V_3$

$V_1 = -6.0 \times 10^6 + 4(4.0 \times 10^6)$

$= 16 \times 10^6 - 6 \times 10^6$

$= 10^7$

10^7 m s^{-1} (A1)

Question 10 (4 marks)

A projectile is launched from the ground at an angle of 39° and at a speed of 25 m s^{-1}, as shown in Figure 10. The maximum height that the projectile reaches above the ground is labelled *h*.

Figure 10

a. Ignoring air resistance, show that the projectile's time of flight from the launch to the highest point is equal to 1.6 s. Give your answer to two significant figures. Show your working and indicate your reasoning. 2 marks

$y = 25\sin(39°) \cdot t - 4.9t^2$ (M1)

$y = 0,\ 25\sin(39°)t - 4.9t^2 = 0$

$t(25\sin(39°) - 4.9t) = 0$

$t = 0,\ t = \frac{25\sin(39°)}{4.9}$ (A1)

By symmetry (R1)

$T_{highest} = \frac{1}{2} \times \frac{25\sin(39°)}{4.9}$

$= 1.6s$

b. Calculate the range, *R*, of the projectile. Show your working. 2 marks

$R = V\cos(39°) \cdot t$

$= 25\cos(39°) \cdot \frac{25\sin(39°)}{4.9}$ (M1)

$= 62.38186229...$

62.38186 m (62 m, correct to 2 sig figs) (A1)

Question 11 (3 marks)

What is the second postulate of Einstein's theory of special relativity regarding the speed of light? Explain how the second postulate differs from the concept of the speed of light in classical physics.

(A1) According to Einstein, the speed of light c is a constant, independent of the relative motion of the source.

(A1) There was a contradiction between this postulate and Newton's classic physics laws, in which velocities add like vectors.

(A1) If the latter was true, then two observers moving at different speeds would see light travelling at different speeds.

Question 12 (3 marks)

A sinusoidal wave of wavelength 1.40 m is travelling along a stretched string with constant speed v, as shown in Figure 11. The time taken for point P on the string to move from maximum displacement to zero is 0.120 s.

Figure 11

Calculate the speed of the wave, v. Give your answer correct to three significant figures. Show your working.

One quarter period $= \frac{1}{4}T = 0.120$ s, $T = 0.480$ s (A1) obtain correct period

$v = \frac{\lambda}{T} = \frac{1.4}{0.48} = \frac{35}{12} = 2.91\dot{6}$

(A1) show calculation

2.92 m s⁻¹ (A1)

Question 13 (3 marks)

In an experimental set-up used to investigate standing waves, a 6.0 m length of string is fixed at both ends, as shown in Figure 12. The string is under constant tension, ensuring that the speed of the wave pulses created is a constant 40 m s⁻¹.

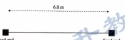


Figure 12

In an initial experiment, a continuous transverse wave of frequency 7.5 Hz is generated along the string.

a. Determine the wavelength of the transverse wave travelling along the string. 1 mark

$v = \lambda \cdot f$ & $\lambda = \frac{v}{f} = \frac{40}{7.5} = \frac{16}{3}$

$\frac{16}{3}$ m or $5.\dot{3}$ (A1) exact value preferred..

b. Will a standing wave form? Give a reason for your answer. 2 marks

(A1) No.

Standing wave must have integer solution.... for example: ... $\frac{3\lambda}{2}$, $\frac{\lambda}{2}$, λ, ...

(R1) reason or calculation

$y = 2A\sin\left(\frac{2\pi x}{\lambda}\right)\cdot\cos(\omega t)$

$L = 6$ m, $v = 40$, $f = 7.5$, $\lambda = \frac{16}{3}$

$y = 2A\sin\left(\frac{2\pi x}{\frac{16}{3}}\right)\cos(\omega t)$

$= 2A\sin\left(\frac{3}{8}\pi x\right)\cos(\omega t)$

…tion 14 (6 marks)

…nts have set up a double-slit experiment using microwaves. The beam of microwaves passes through …al barrier with two slits, shown as S_1 and S_2 in Figure 13. The students measure the intensity of the …ing beam at points along the line shown. They determine the positions of maximum intensity to be at …oints labelled P_0, P_1, P_2 and P_3. Take the speed of electromagnetic radiation to be 3.00×10^8 m s^{-1}.

Figure 13

…istance from S_1 to P_3 is 72.3 cm and the distance from S_2 to P_3 is 80.6 cm.

What is the frequency of the microwaves transmitted through the slits? Show your working. 2 marks

$d = 80.6 - 72.3 = 8.3 = 3\lambda \quad \lambda = \frac{8.3}{3}$ (M)

$f = \frac{v}{\lambda} = \frac{3.00 \times 10^8}{\frac{8.3}{3}}$ = 1084337349…

1.08×10^{8} Hz (M) (3 sig fig)

The signal strength is at a minimum approximately midway between points P_0 and P_1.

Explain the reason why the signal strength would be a minimum at this location. 2 marks

At the midway position, i.e. $\frac{\lambda}{2}$, the effect of (A1)

superposition between two waves is destructive (A1)

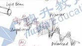
∴ it's the minimum.

c. The microwaves from the source are polarised.

Explain what is meant by the term 'polarised'. You may use a diagram in your answer. 2 marks

Polarisation is a property applying to transverse waves that specifies the geometrical orientation of oscillations.

(A1) definition



(A1) Diagram & explanation

tion 15 (4 marks)

dent sets up an experiment involving a source of white light, a glass prism and a screen. The path of a ray of white light when it travels through the prism and onto the screen is shown in Figure 14.

Figure 14

ctrum of colours is observed by the student on the screen, which is positioned to the right of the prism.

Name and explain the effect observed by the student. 3 marks

The effect observed is dispersive polarisation of the single white light through a prism. The prism bends lights. The degree of bending of the light's path depends on the angle that incident beam of the light makes with the surface. According to Snell's law, the colour observed along XY varies with different wavelengths.

Points X and Y on Figure 14 represent either end of the visible spectrum observed by the student.

Identify the two visible colours observed at point X and at point Y. 1 mark

Point X Red Point Y Violet/purple

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…stion 17 (7 marks)

…ents are comparing the diffraction patterns produced by electrons and X-rays, in which the same …ing of bands is observed in the patterns, as shown schematically in Figure 18. Note that both patterns …re to the same scale.

Figure 18

This is the energy E. Holistic marking applies

…electron diffraction pattern is produced by 3.0×10^3 eV electrons. (Particle-wave duality)

Explain why electrons can produce the same spacing of bands in a diffraction pattern as X-rays. 3 marks

- The e⁻s have the same (de Broglie) λ as X-rays.
- Electrons can produce the same slit widths as X-rays in terms of their diffraction patterns.
- Therefore, the same spacing of bands are observed.

Calculate the frequency of X-rays that would produce the same spacing of bands in a diffraction pattern as for the electrons. Show your working. 4 marks

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 3.0 \times 10^{3} \times 1.6 \times 10^{-19}}}$

$= 2.24344327 \times 10^{-11}$ metres

$f = \frac{v}{\lambda} = \frac{3.0 \times 10^{8}}{2.24\ldots \times 10^{-11}} = 1.3374408 \times 10^{19}$ Hz

1.34E19 Hz (3 sig figs)

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Question 18 (5 marks)

The energy level diagram for a hydrogen atom is shown in Figure 19.

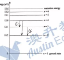

Figure 19

a. A hydrogen atom in the ground state is excited to the $n = 4$ state.

Explain how the hydrogen atom could be excited to the $n = 4$ state in one step. 2 marks

If the energy absorbed by H is 12.8 eV, it can be directed excited from ground state.

b. List the possible photon energies that could be emitted as the atom goes from the $n = 4$ state to the $n = 2$ state. 3 marks

n=4 → n=3

① : 12.8 − 12.1 = 0.7 eV emission; followed by ② n=3 → n=2: 12.1 − 10.2 = 1.9 eV emission

③ : n=4 → n=2

12.8 − 10.2 = 2.6 eV emission

estion 19 (18 marks)

part of their practical investigation, some students investigate a spring system consisting of two springs, A and B, d a top platform, as shown in Figure 20. The students place various masses on the top platform. Assume that the platform has negligible mass.

Figure 20

th no masses on the top platform of the spring system, the distance between the uncompressed Spring A and the of Spring B is 60 mm.

e students place various masses on the top platform of the spring system and note the vertical compression, Δx, of spring system.

ey use a ruler with millimetre gradations to take readings of the compression of the spring(s), Δx, with an certainty of ±2 mm.

e results of their investigation are shown in Table 1 below.

ble 1

Mass (g)	Compression, Δx (mm)
0	0
300	21
600	40
900	60
1300	68
1700	75
1900	80

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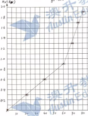
The students plot a force (F) versus compression (Δx) graph for the spring system and use $g = 10\ N\ kg^{-1}$ for the value of the magnitude of the gravitational field strength.

a. On the axes provided below:

- plot a graph of force (F) versus compression (Δx) for the spring system
- include scales and units on each axis
- insert appropriate uncertainty bars for the compression values on the graph
- draw lines that best fit the data for:
  - the effect of Spring A alone
  - the effect of Spring A and Spring B

6 marks



b. i. Determine the spring constant for Spring A, k_A. Show your working. 2 marks

$F_A = k_A \cdot x \quad k_A = \frac{0.3 \times 9.8}{20 \times 10^{-3}} = 147$ (M1)

| 147 $N\,m^{-1}$ | (A1)

ii. Determine the spring constant for Spring B, k_B. Show your working. 2 marks

from $x = 60 \times 10^{-3}\,m$, $F = 0.9 \times 9.8\,N$ to $x = 80 \times 10^{-3}\,m$, $F = 1.9 \times 9.8\,N$

| 343 $N\,m^{-1}$ | (A1)

$F_B = k_B \cdot x + C$

$1.9 \times 9.8 = 80 \times 10^{-3} k_B + C$

$0.9 \times 9.8 = 60 \times 10^{-3} k_B + C$

$k_{A+B} = 490$

Both springs (M1)

$k_{A+B} = k_A + k_B$

$490 = 147 + k_B$

$k_B = 343$

c. Using the area under the force (F) versus compression (Δx) graph, or otherwise, determine

i. the potential energy (PE_A) stored in Spring A when the spring system is compressed by 80 mm. Show your working 2 marks

$PE_A = \frac{1}{2} k_A \times (\Delta x)^2 = \frac{1}{2} \times 147 \times (0.08)^2$ (M1)

| 0.47 J | (A1) consequential on part bi

ii. the potential energy (PE_{A+B}) stored in the spring system when the spring system is compressed by 80 mm. Show your working 2 marks

$PE_B = \frac{1}{2} k_B (\Delta x)^2 = \frac{1}{2} \times 343 \times \left((80-60) \times 10^{-3}\right)^2 = 0.0686\,J$ (M1)

| 0.5386 J | (A1) $(0.47 + 0.0686)\,J$

iii. the work done to compress Spring B when the spring system is compressed by 80 mm. Show your working. 2 marks

Work, $W = PE_B = \frac{1}{2} \times 350 \times (20 \times 10^{-3})^2 = 0.0686\,J$ (M1)

| 0.0686 J | (A1) consequential on part bii

d. Explain how this type of spring system could be used in car spring suspension systems to enable the car to negotiate small bumps and more severe bumps in the road. 2 marks

Since the double spring system has dual displacements, it can be flexible with small bumps & big bumps. For small bumps, the Δx can be handled by compressing the first 60 mm of the spring. For big bumps, the Δx can be handled by the Δx using both springs and they absorb the energy more effectively than only 1.

(A1) (A1)