SYDNEY GRAMMAR SCHOOL

CANDIDATE NUMBER

NAME

2021
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

Section I - Multiple Choice

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ☒ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word *correct* and drawing an arrow as follows.

correct

A ☒ B ☒ C ○ D ○

Start Here →

1.	A ○	B ○	C ○	D ○	**11.**	A ○	B ○	C ○	D ○
2.	A ○	B ○	C ○	D ○	**12.**	A ○	B ○	C ○	D ○
3.	A ○	B ○	C ○	D ○	**13.**	A ○	B ○	C ○	D ○
4.	A ○	B ○	C ○	D ○	**14.**	A ○	B ○	C ○	D ○
5.	A ○	B ○	C ○	D ○	**15.**	A ○	B ○	C ○	D ○
6.	A ○	B ○	C ○	D ○	**16.**	A ○	B ○	C ○	D ○
7.	A ○	B ○	C ○	D ○	**17.**	A ○	B ○	C ○	D ○
8.	A ○	B ○	C ○	D ○	**18.**	A ○	B ○	C ○	D ○
9.	A ○	B ○	C ○	D ○	**19.**	A ○	B ○	C ○	D ○
10.	A ○	B ○	C ○	D ○	**20.**	A ○	B ○	C ○	D ○

SYDNEY GRAMMAR SCHOOL

2021
TRIAL EXAMINATION

PHYSICS

Form VI

STRUCTURE OF PAPER

SECTION I

Multiple Choice — 20 marks

Allow about 30 minutes for this section.

SECTION II

Parts A-D — 80 marks

Allow about 2 hours and 30 minutes for this section.

EXAMINATION

DATE:	Thu 19th August 8.40 AM
DURATION:	3 hours (+5min reading)
MARKS:	100

CHECKLIST

Each boy should have the following:

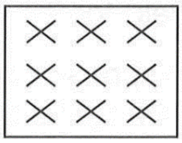
- Examination Paper (including)
  - Examination sections
  - Extra Writing sheets
  - Data/Formula sheets
  - Multiple-Choice Answer Sheet

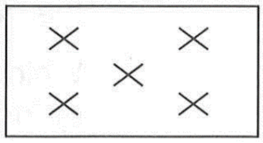
EXAM INSTRUCTIONS

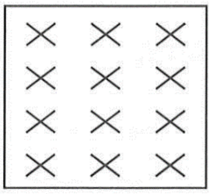
- Remove the centre staple and hand in all parts of the examination in a neat bundle.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATED PART OF THE PAPER.
- Responses requiring more writing space than provided should be clearly be marked **CONTINUED**. When the response is continued on extra writing paper it should clearly indicate the question number.
- There is a Data/Formula sheet included at the end of the paper.

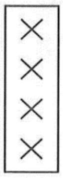
Authors: DGB, SRW, AAH, PCK Master in charge: PCK

1 Which of the following areas contains the largest magnetic flux?

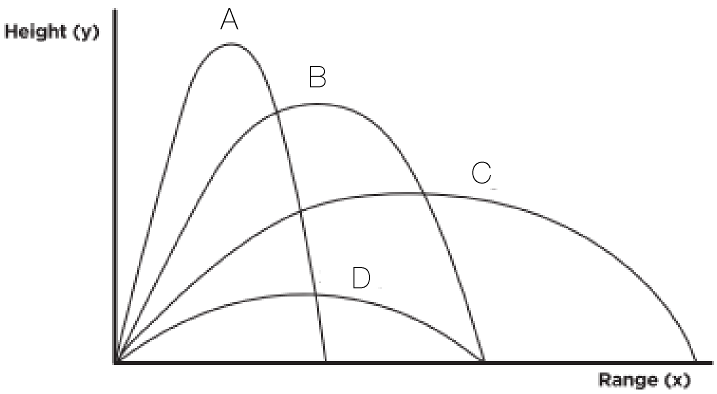
(A) 

(B) 

(C) 

(D) 

2 Below is a diagram of several projectiles launched at the same speed and different angles.



Which trajectory has the longest time-of-flight?

(A) Trajectory A

(B) Trajectory B

(C) Trajectory C

(D) Trajectory D

3 Which of the following pairs of comparisons is correct between a circular low Earth orbit satellite and a geostationary orbit satellite.

	Low Earth Orbit	Geostationary Orbit
(A)	Shorter orbital period	Lower orbital radius
(B)	Higher orbital velocity	Smaller acceleration
(C)	Longer orbital period	Fixed orbital radius
(D)	Always equatorial	Lower orbital velocity

4 Christian Huygens considering light to be waves. Newton considered light to be particles. Which of the following could Newton not account for using his model?

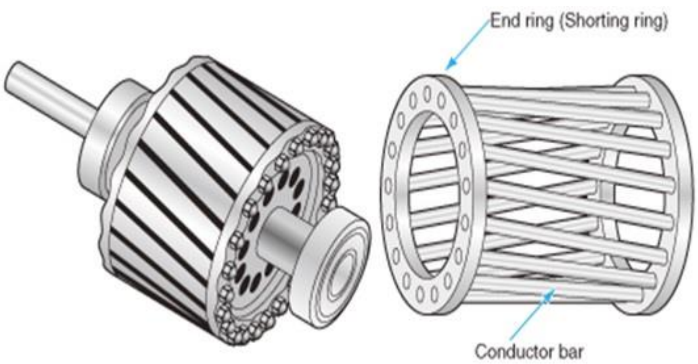
(A) Refraction.

(B) Diffraction.

(C) Reflection.

(D) How white light was made of different colours.

5 In what sort of device would you see the following two examples of this component?



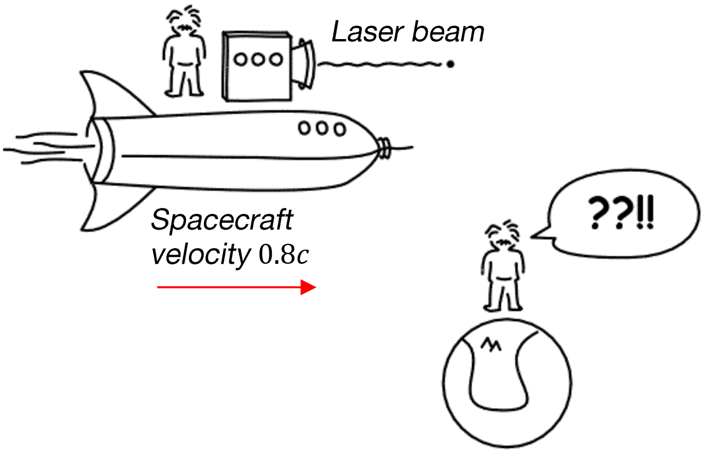
(A) DC Motor

(B) DC generator

(C) AC generator

(D) Induction motor

6 A spacecraft flying past Earth at a speed of $0.8c$, as shown in the diagram below, fires a laser beam forwards at the speed of light.



What is the speed of the laser beam, as measured by a scientist on Earth?

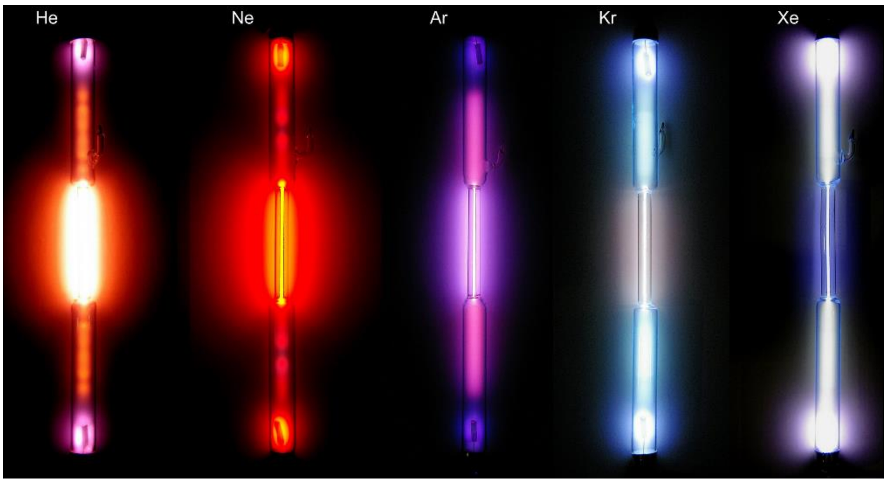
(A) 0.2c

(B) 0.8c

(C) 1.0c

(D) 1.8c

7 The diagram below depicts a series of discharge tubes. When the light from each tube is passed through a diffraction grating you would expect to see what type of spectrum?



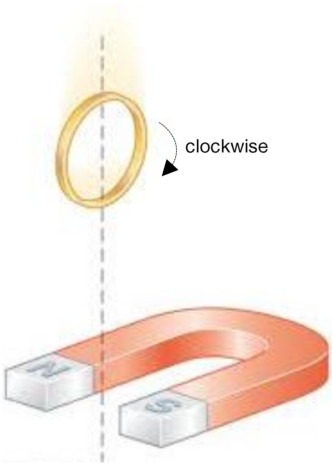
(A) Emission Spectrum

(B) Continuous spectrum

(C) Absorption Spectrum

(D) Scattering Spectrum

8 A conductive ring is dropped between the poles of a horseshoe magnet as shown below.



Which of the following describes the direction (with respect to the picture) of induced current in the ring as it falls between the poles of the magnet?

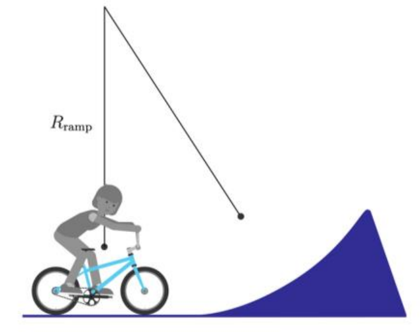
(A) The current is clockwise.

(B) The current is anticlockwise.

(C) The current is first clockwise then anticlockwise.

(D) The current is first anticlockwise then clockwise.

9 When a bike travels up a circular ramp. As the cyclist goes up the ramp, they apply a force parallel to the ramp to maintain a constant speed.



Which of the follow statements is correct when the bike is on the ramp?

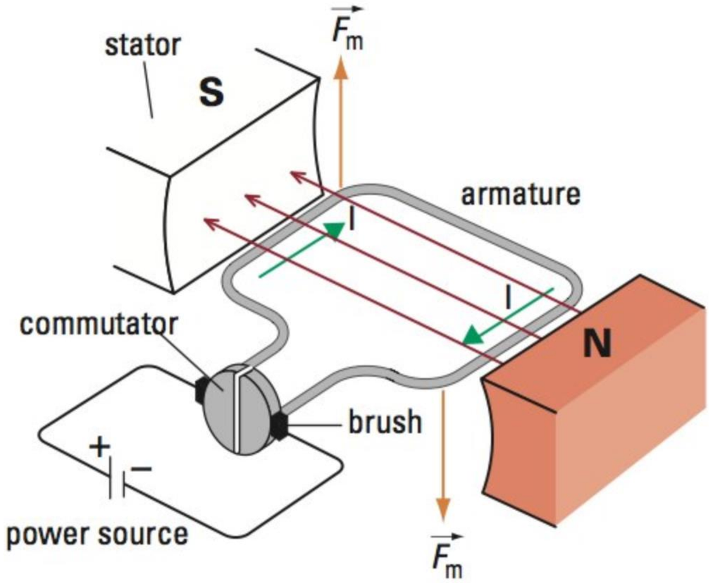
(A) The magnitude of the normal force on the bike is constant.

(B) The normal force on the bike is the bikes centripetal force.

(C) The normal force on the bike is equal in magnitude to the bikes weight force.

(D) The direction of the net force on the bike is toward the centre of the circle.

10 Consider the diagram below of a DC motor.



What happens to the magnitude of the force $\vec{F}_m$ which acts on the wire as the coil rotates clockwise 60° from its current position to a vertical position?

(A) It initially increases and then stays constant.

(B) It decreases to zero.

(C) It increases from zero to its maximum.

(D) It stays the same

11 The four diagrams below each represent the visible light emitted by an object.

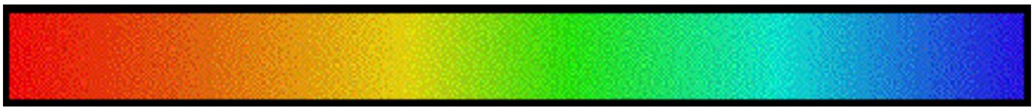
Which of these spectra is most likely to have been emitted by a star?

(A)

(B)

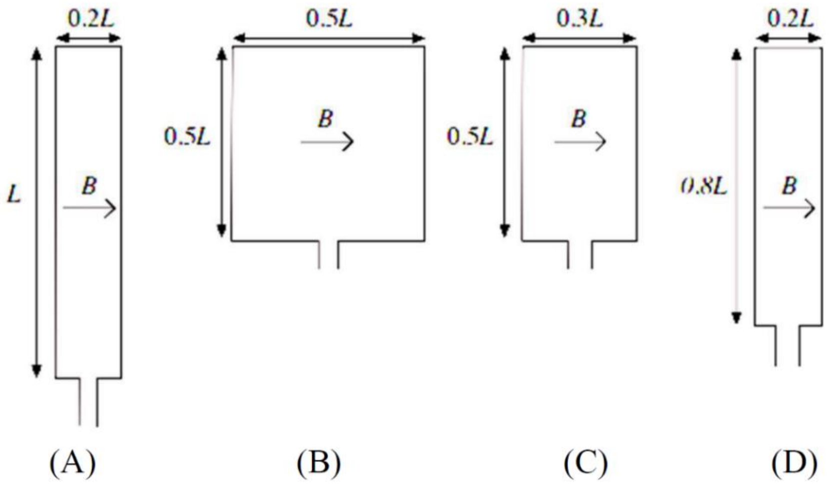
(C)

(D)



12 Four rectangular single loops of wire A, B, C and D are each placed in a uniform magnetic field of the same flux density B. The direction of the magnetic field is parallel to the plane of the loops as shown. When a current of 1.0 A is passed through each of the loops, magnetic forces act on them. The lengths of the sides of the loops are as shown.

Which loop experiences the largest torque?



13 Charged particles of mass m and charge q, travel at a constant speed in a circle of radius r in a uniform magnetic field of flux density B.

Which expression gives the period of rotation of a particle in the beam?

(A) $\frac{\pi m}{qB}$

(B) $\frac{m}{qB}$

(C) $\frac{m}{2\pi qB}$

(D) $\frac{2\pi m}{qB}$

14 Unpolarised light of intensity I is passed through two polarising filters with their polarising axes at an angle of 30° to one another. The intensity of the light passing through the second filter is:

(A) $0.375I$

(B) $0.43I$

(C) $0.5I$

(D) $0.75I$

15 In a science fiction novel, a scientist invents a machine that converts matter into energy with 100% efficiency, in accordance with the Special Theory of Relativity. Unfortunately, his curious cat – large tabby of mass 4.6 kg - falls into the machine while it is being tested, generating a burst of energy and destroying his laboratory in the process.

How much energy does the unlucky cat generate?

(A) 1.4×10^{9} J

(B) 2.0×10^{16} J

(C) 4.1×10^{17} J

(D) 1.9×10^{18} J

16 Two cars, A and B, go around the same curved road (radius of curvature r). They both have the same maximum traction force between the road and the tyres. Car A has 1.5 times the mass of car B.

If the maximum speed that car A can go around the curve is v, then what is the maximum speed that car B can go around the curve?

(A) $0.81v$

(B) $1.2v$

(C) $1.5v$

(D) $2.25v$

17 A laser produces 1.50×10^{-3} W of green light with a wavelength of 5.30×10^{-7} m.

Calculate the number of photons it emits every second.

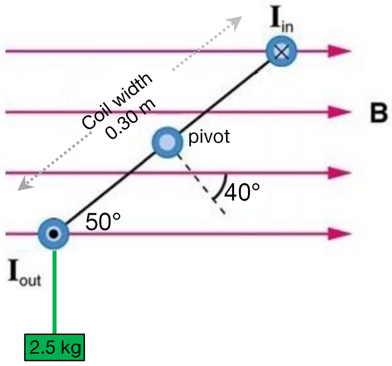
(A) 4.0×10^{15}

(B) 2.7×10^{18}

(C) 1.2×10^{24}

(D) 4.3×10^{36}

18 A mass of 2.5 kg is attached to one side of a coil in a magnetic field. In its current position, the coil is stationary. This is shown in the cross-sectional diagram below. The width of the coil is 0.30 m.



Determine the magnitude of the torque on the coil due to the magnetic field.

(A) 2.4 N m

(B) 2.8 N m

(C) 3.7 N m

(D) 4.7 N m

19 Ganymede and Europa are both moons of Jupiter. Ganymede orbits Jupiter every 7.2 days. Europa's orbital radius is 63% of Ganymede's.

The orbital period of Europa is?

(A) 1.8 days.

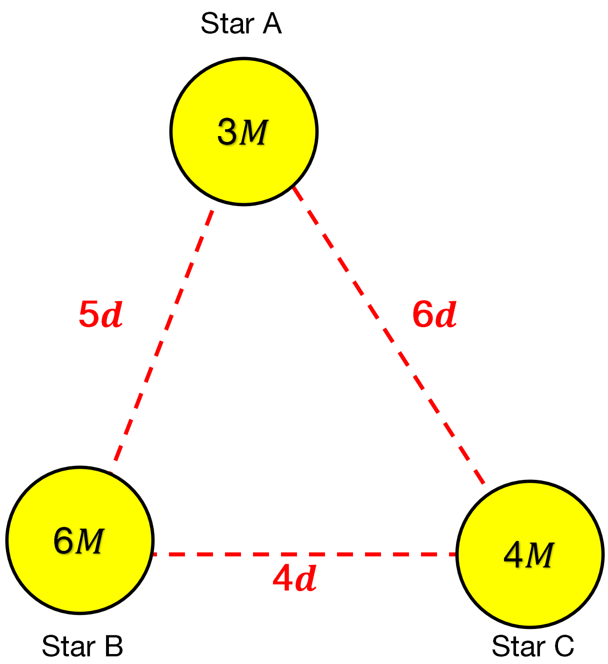
(B) 3.6 days.

(C) 5.7 days.

(D) 14.4 days.

20 There are 3 stars in a trinary star system. Their relative masses and relative distances from their centre of masses are shown below.

Not to scale



How much greater is the magnitude of the gravitational force between Stars B and C compared to the force between stars A and C.

(A) 0.22 times

(B) 1.67 times

(C) 2.16 times

(D) 4.50 times

SECTION II: Part A (20 Marks)

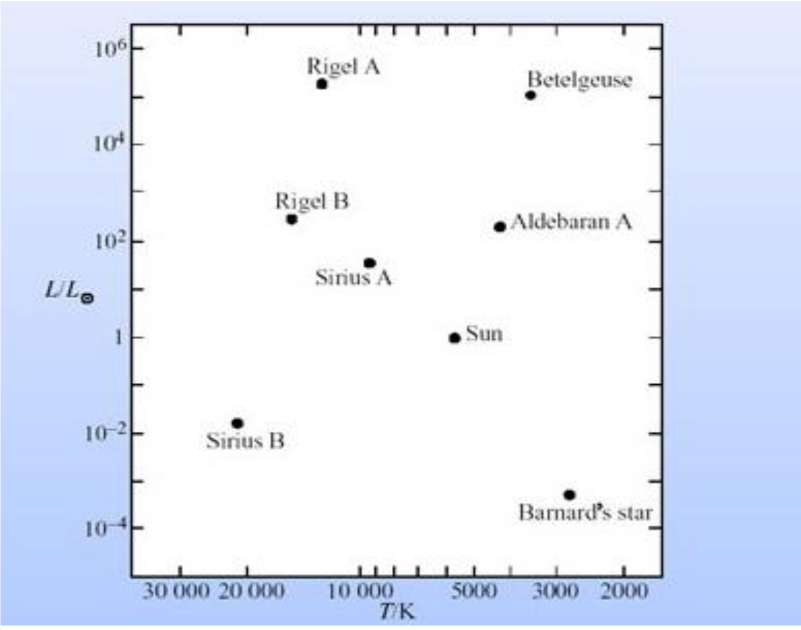
CANDIDATE NUMBER

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

NAME

Question 21 (3 marks) **Marks**

Below is a Hertzsprung-Russel diagram containing some notable stars.



(a) Identify ONE star that is only fusing hydrogen to helium in its core.

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(b) Identify ONE star where CNO cycle fusion is predominant in the core of the star.

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(c) Which star, if it replaced the sun, would be the brightest when viewed from the Earth.

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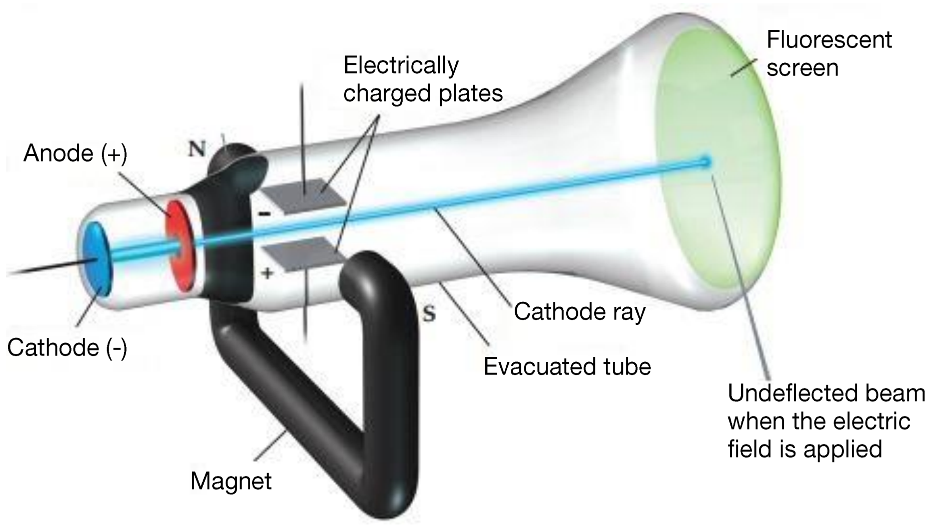
Question 22 (6 marks) **Marks**

The diagram below shows a variation of the experiment used by J.J. Thomson in 1897 to measure the charge to mass ratio, e/m, of the electron. In this scenario a beam of cathode rays is constantly subjected to a magnetic field of 5.0×10^{-3} T and an electric field that can be turned off.



(a) Using information from the data sheet, calculate the charge to mass ratio e/m for cathode rays.

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(b) When the electric field is switched off it is found that the cathode rays move in a circular path of radius 6.5×10^{-3} m.

i. Determine the direction that the magnetic field will deflect the cathode rays on the fluorescent screen from its undeflected position.

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ii. Given that you know the value of e/m, calculate the velocity of the cathode rays in this experiment.

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Question 22 continued on next page.

Question 22 continued **Marks**

(c) When the electric field is turned on, it is adjusted until the cathode ray beam is undeflected (as depicted in the diagram).

Determine the magnitude of the electric field required for the cathode rays to be undeflected.

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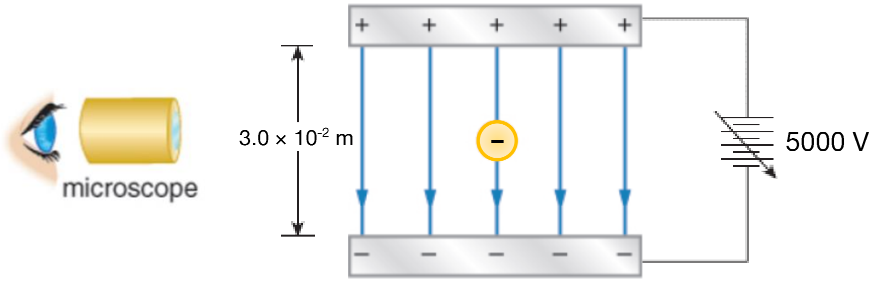
Question 23 (5 marks)

Marks

The diagram below shows a simplified version of the experiment performed by Robert Millikan in 1909 to determine the charge on an electron. In the experiment shown below, a small, negatively charged drop of oil, of mass 5.4×10^{-15} kg, is levitated by an electric field, until it is at rest between two metal plates. The voltage is 5000 V and the vertical separation of the plates is 3.0×10^{-2} m.



(a) Calculate the charge of the oil drop.

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(b) Explain how the results of Millikan's original experiment allowed him to determine the charge on an electron.

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Question 24 (6 marks) **Marks**

In an experiment, light of wavelength 4.20×10^{-7} m is shone on a rubidium surface which has a work function of 2.20 eV.

The observations are:

1. Electrons are emitted from the rubidium surface.
2. When the light intensity is increased the number of electrons emitted from the rubidium surface also increases.
3. The emitted electrons are measured to have a maximum kinetic energy of 0.75 eV, which does not change when the intensity of light is varied.

How did Einstein explain these observations? Support your answer with appropriate calculations.

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Question 24 continued on next page.

Question 24 continued

Marks

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SECTION II: Part B (20 Marks)

CANDIDATE NUMBER

NAME

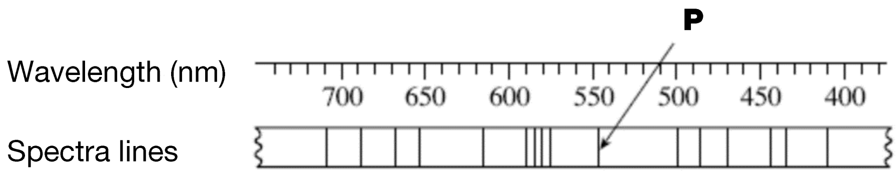
Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 25 (2 marks) **Marks**

For a diffraction grating the equation for just the first order maximum is

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

A light source produces a spectrum as shown below.



The diffraction grating used to obtain the spectrum has 300 slits per mm which is $\frac{1}{300}$ mm between slits.

Calculate the angle of diffraction of the first-order line P in the figure above.

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Question 26 (4 marks) **Marks**

Outline the predictions made by Maxwell concerning the nature of light.

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Question 27 (4 marks) **Marks**

A proton in a particle accelerator has a speed of 2.0×10^8 m s^{-1}.

(a) Calculate the relativistic momentum of the proton at this speed.

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(b) Referring to your answer in Part (a), explain why the Special Theory of Relativity provides an upper limit to the speed of all matter.

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Question 28 (4 marks)

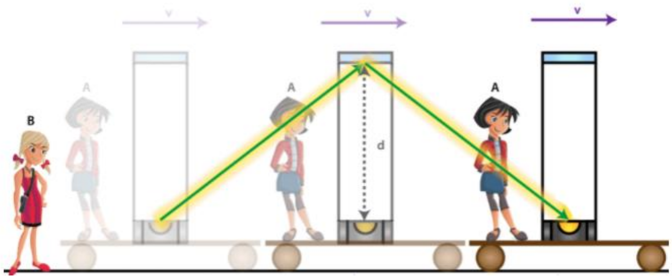
Marks

Two observers (A and B) observe a light beam travel from the bottom of a box to a mirror at the top and back to the bottom where a clock measures the time taken.

Observer A's Frame of Reference

According to observer A the light travels distance $2d$ and the clock measures that it takes time t.

Observer B's Frame of Reference

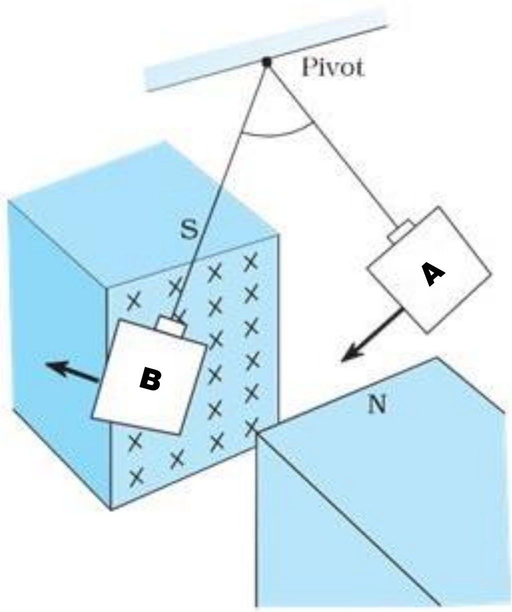


Using the diagrams above explain why Einstein concluded that the measurement of the time it takes for the light to complete its journey depends on the frame of reference of the observer. (A full quantitative derivation is not required)

4

Question 29 (6 marks) **Marks**

A sheet of copper is mounted on a string which is allowed to swing from a pivot. After being released at position A it enters a magnetic field. In position B it is half in and half out of the field.



(a) Using correct physics explain the motion of the sheet of copper.

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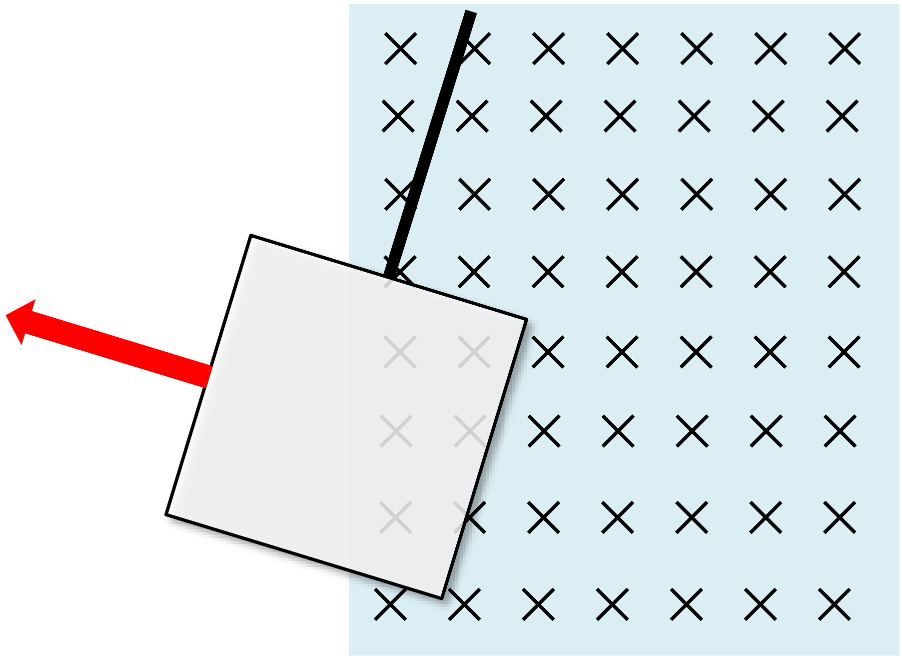
Question 29 continued on next page.

Question 29 continued

Marks

(b) Draw on the metal plate the currents in the sheet at position B when moving as indicated.



2

SECTION II: Part C (17 Marks)

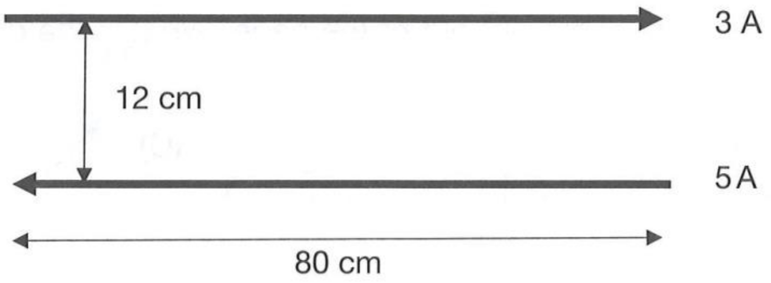
CANDIDATE NUMBER

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

NAME

Question 30 (3 marks) **Marks**

Consider two parallel current-carrying conductors shown below. Each conductor is 80 cm long.



(a) Determine the direction of the force on the wire carrying 3 A of current.

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(b) Calculate the force per unit length between the wires.

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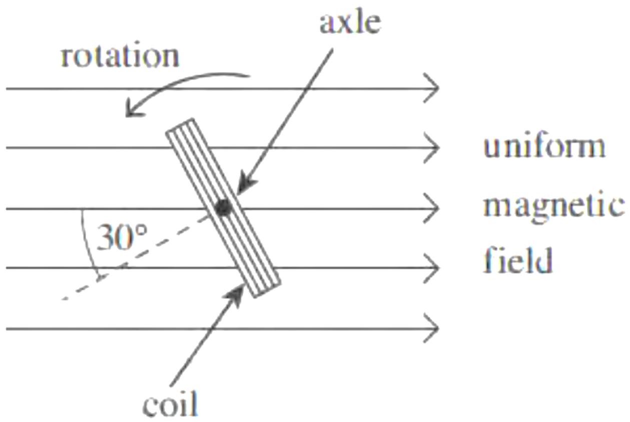
Question 31 (6 marks) **Marks**

A rectangular coil is freely rotating anticlockwise at constant angular speed with its axle at right angles to a uniform magnetic field. The diagram below shows an side on view of the coil at a particular instant.



At the instant shown the angle between the normal to the plane of the coil and the direction of the magnetic field is 30°. The coil contains 20 turns of wire and has an area of 1.96×10^{-3} m^2. The magnetic field strength is 2.7 T.

(a) Determine the flux through the coil.

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(b) As the coil rotates, at what angle will the emf induced in the coil first reach a maximum?

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Question 31 continued on next page.

Question 31 continued

Marks

(c) The coil is connected to an external circuit containing a light bulb. When the light bulb is connected, the coil's angular speed is observed to change.

Account for this observation.

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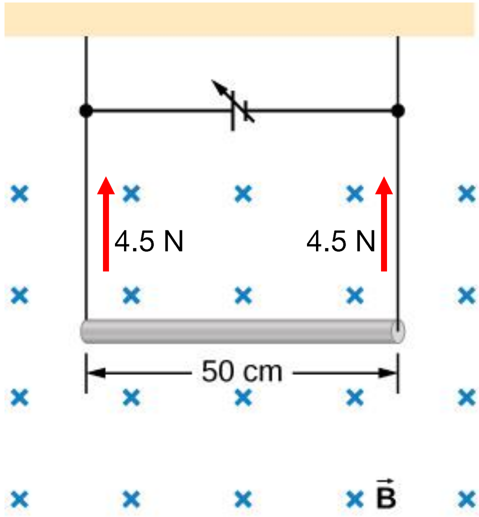
Question 32 (3 marks) **Marks**

A rod of length 0.50 m has a 1.3 A current flowing through it and sits in a uniform external magnetic field of 2.3 T that points into the page. The two wires holding the rod each exert a tension force on the rod of 4.5 N at each end.



(a) In which direction is the force on the rod due to the magnetic field?

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(b) Determine the mass of the rod?

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Question 33 (5 marks) **Marks**

A transformer has a primary coil with 1200 loops and secondary coil with 900 loops. The current in the primary coil is 4.0 A.

(a) Assuming this transformer is ideal, determine the current in the secondary coil.

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(b) Not all transformers are ideal. Describe how and where energy is lost in a transformer and state how its efficiency can be improved.

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SECTION II: Part D (23 Marks)

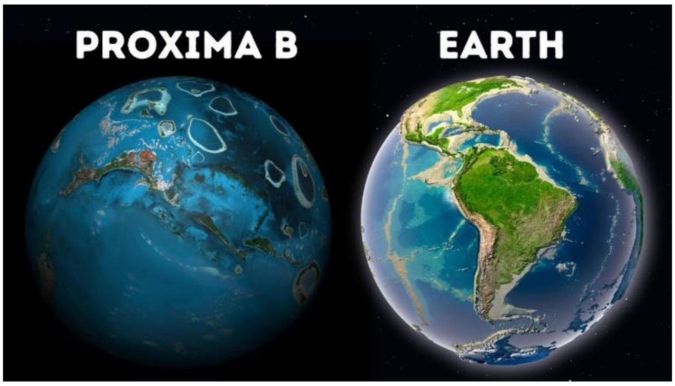
CANDIDATE NUMBER

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

NAME

Question 34 (8 marks) **Marks**

Proxima Centauri is small dim red dwarf star that is the closest star to our solar system. In 2016 it was determined that there is a planet around this star which was named Proxima B. Its mass is estimated to be 1.2 times that of Earth and its radius is estimated to be 1.3 times the radius of the Earth. It has an orbital radius of 7.5×10^9 m from Proxima Centauri and an orbital period of 11.2 Earth Days around it.



(a) For the planet Proxima B:

i. Calculate the surface gravity on Proxima B.

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ii. Calculate the escape velocity from Proxima B's surface.

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Question 34 continued on next page.

Question 34 continued **Marks**

(b) For the star Proxima Centauri:

i. Determine the mass of the star Proxima Centauri

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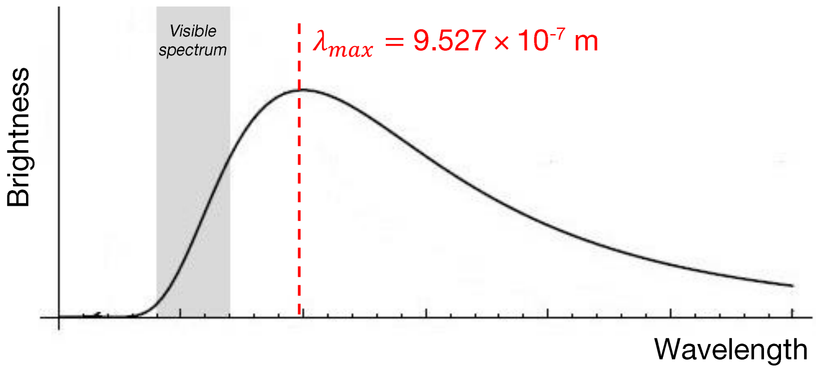
ii. When analysing the spectrum of Proxima Centauri it is found that it is emitting the most amount of light at a wavelength of $\lambda_{max} = 9.527 \times 10^{-7}$ m



Determine the surface temperature of the star.

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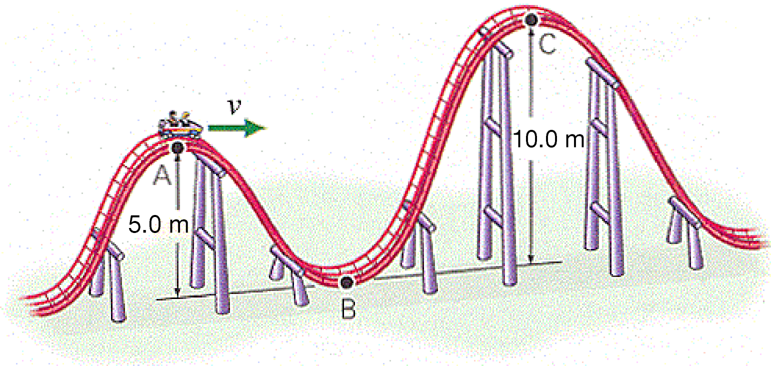
Question 35 (4 marks) **Marks**

In an amusement park a rollercoaster track is being designed for a rollercoaster car of mass 540 kg.



The rollercoaster car needs a certain velocity at point A to make it over point C (with a minimum speed of 1.4 m s^{-1} for safety). Using conservation of kinetic and gravitational potential energy, the predicted speed at points A and B can be calculated. The following table provides information about the track at each point and the predicted speed at each point.

	Point A	Point B	Point C
Vertical Height (m)	5.0	0	10.0
Radius of Curvature (m)	7.5	8.0	6.2
Predicted Speed (m s^{-1})	10	14.1	1.4

(a) Determine the magnitude of the Normal force on the rollercoaster car at point B at the predicted speed given.

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(b) Determine the maximum speed, v, that the rollercoaster can go at point A, before it leaves the tracks and assess if the predicted speed of 10 m s^{-1} is too high.

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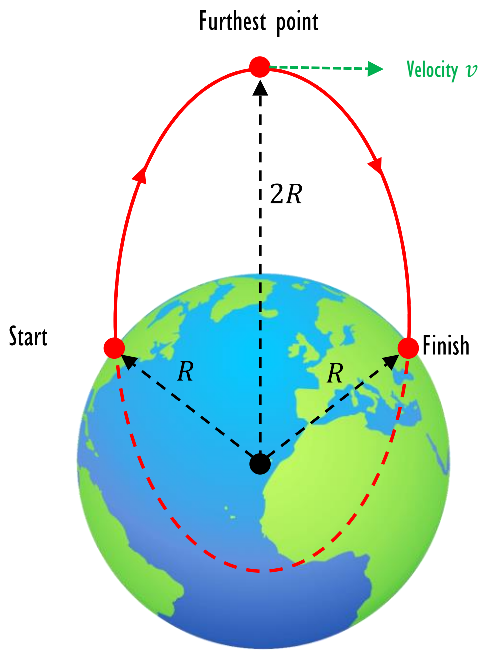
Question 36 (4 marks)

Marks

A projectile is launched from one point of the Earth to a point on the other side. The trajectory of this projectile (ignoring all atmospheric friction) has the shape of an elliptical orbit with the centre of the Earth as a focus. This is depicted below.



When launched it has an initial speed of 8200 m s^{-1} at a distance of R from the centre of the Earth and reaches a maximum distance from the centre of the Earth of $2R$ which is the furthest distance from the Earth's surface.

Using the law of conservation of energy, determine the speed, v, of the projectile when it is furthest from the Earth's surface. (Assume there is no air resistance acting on the projectile.)

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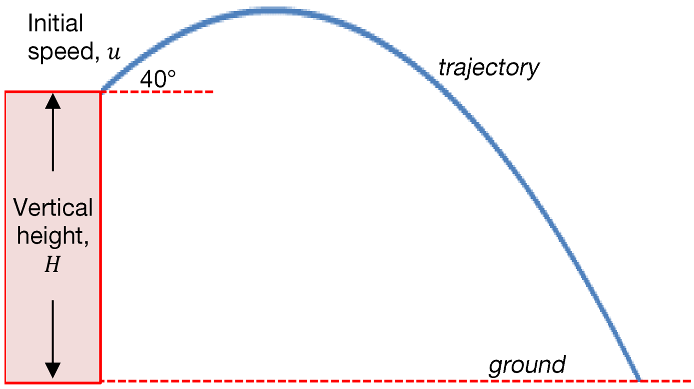
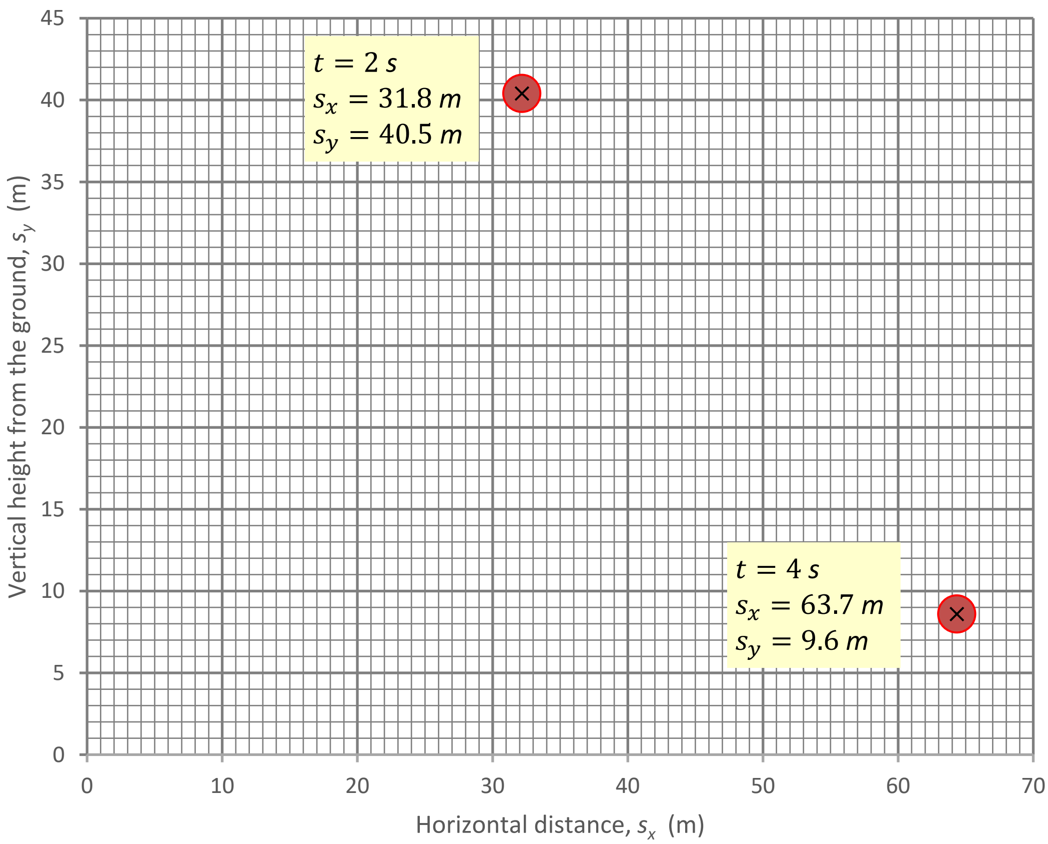
Question 37 (7 marks) **Marks**

A projectile is launched at an initial speed u from a vertical height H from the ground, at an angle to the horizontal of $\theta = 40°$. Its trajectory is recorded with a camera that has, unfortunately, a slow capture time and can only take a picture of the projectile every 2 seconds. The graph below shows the camera recording the position of the projectile at times $t = 2$ and 4 seconds.





Question 37 continued on next page.

Question 37 continued

Marks

(a) Determine the initial horizontal speed of the projectile from this graph.

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(b) Determine the initial speed u of the projectile.

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(c) Use the points on the graph to calculate the vertical velocity of the projectile at time $t = 2$ s.

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(d) Determine the initial vertical height H that the projectile was launched from.

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END OF EXAMINATION

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Physics

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	$3.00 \times 10^{8} \text{ m s}^{-1}$
Electric permittivity constant, ε_0	$8.854 \times 10^{-12} \text{ A}^2 \text{ s}^4 \text{ kg}^{-1} \text{ m}^{-3}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7} \text{ N A}^{-2}$
Universal gravitational constant, G	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
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)	$1.097 \times 10^{7} \text{ m}^{-1}$
Atomic mass unit, u	1.661×10^{-27} kg $931.5 \text{ MeV}/c^2$
1 eV	1.602×10^{-19} J
Density of water, ρ	$1.00 \times 10^{3} \text{ kg m}^{-3}$
Specific heat capacity of water	$4.18 \times 10^{3} \text{ J kg}^{-1} \text{ K}^{-1}$
Wein's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

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

$v = u + at$

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

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

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

$\Delta U = mg\Delta h$

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

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

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

$\sum \frac{1}{2}mv_{\text{before}}^2 = \sum \frac{1}{2}mv_{\text{after}}^2$

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

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

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

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

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

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

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

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

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

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

Waves and thermodynamics

$v = f\lambda$

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

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

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

$d\sin\theta = m\lambda$

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

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

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

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

$I_1r_1^2 = I_2r_2^2$

$Q = mc\Delta T$

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

Electricity and magnetism

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

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

$$W = qV$$

$$W = qEd$$

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

$$B = \frac{\mu_0 N I}{L}$$

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

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

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

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

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

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

$$V = IR$$

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

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

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

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

$$V_p I_p = V_s I_s$$

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	79
Symbol	Au
Standard Atomic Weight	197.0
Name	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

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

SYDNEY GRAMMAR SCHOOL

2021
TRIAL EXAMINATION

PHYSICS

CRIB

Form VI

STRUCTURE OF PAPER

SECTION I

Multiple Choice 20 marks

Allow about 30 minutes for this section.

SECTION II

Parts A-D 80 marks

Allow about 2 hours and 30 minutes for this section.

EXAMINATION

DATE:	Thu 19th August 8.40 AM
DURATION:	3 hours (+5min reading)
MARKS:	100

CHECKLIST

Each boy should have the following:

- ☐ Examination Paper (including)
  - Examination sections
  - Extra Writing sheets
  - Data/Formula sheets
  - Multiple-Choice Answer Sheet

EXAM INSTRUCTIONS

- Remove the centre staple and hand in all parts of the examination in a neat bundle.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATED PART OF THE PAPER.
- Responses requiring more writing space than provided should be clearly be marked **CONTINUED**. When the response is continued on extra writing paper it should clearly indicate the question number.
- There is a Data/Formula sheet included at the end of the paper.

Authors: DGB, SRW, AAH, PCK Master in charge: PCK

SYDNEY GRAMMAR SCHOOL

CANDIDATE NUMBER

NAME

2021

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

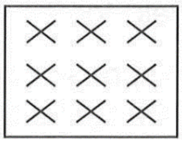
CRIB

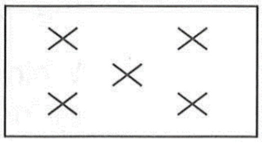
Question	Answer
1	C
2	A
3	B
4	B
5	D
6	C
7	A
8	C
9	D
10	D
11	A
12	B
13	D
14	A
15	C
16	B
17	A
18	A
19	D
20	D

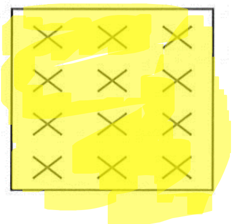
SECTION I: MULTIPLE CHOICE (20 marks)

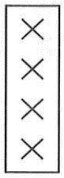
Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 Which of the following areas contains the largest magnetic flux?

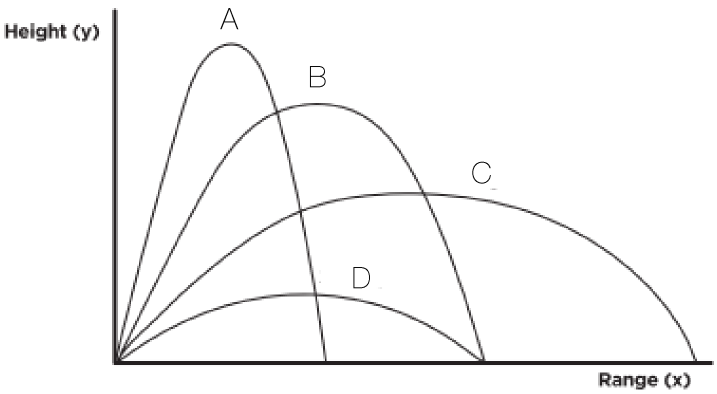
(A) 

(B) 

(C) 

(D) 

2 Below is a diagram of several projectiles launched at the same speed and different angles.



Which trajectory has the longest time-of-flight?

(A) Trajectory A

(B) Trajectory B

(C) Trajectory C

(D) Trajectory D

3 Which of the following pairs of comparisons is correct between a circular low Earth orbit satellite and a geostationary orbit satellite.

	Low Earth Orbit	Geostationary Orbit
(A)	Shorter orbital period	Lower orbital radius
(B)	Higher orbital velocity	Smaller acceleration
(C)	Longer orbital period	Fixed orbital radius
(D)	Always equatorial	Lower orbital velocity

4 Christian Huygens considering light to be waves. Newton considered light to be particles. Which of the following could Newton not account for using his model?

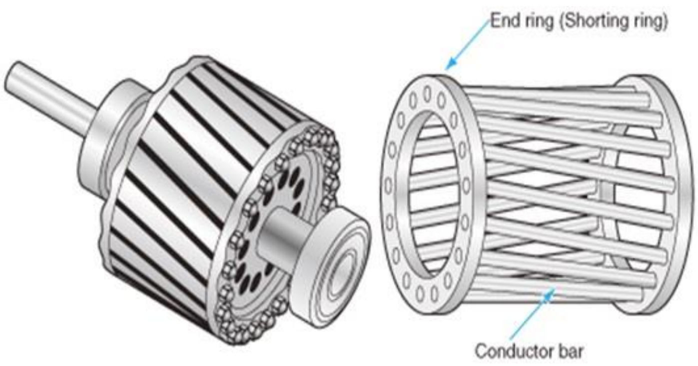
(A) Refraction. – Newton could account for refraction, but it required light to travel faster in a medium (later shown to be false)

(B) Diffraction.

(C) Reflection.

(D) How white light was made of different colours.

5 In what sort of device would you see the following two examples of this component?



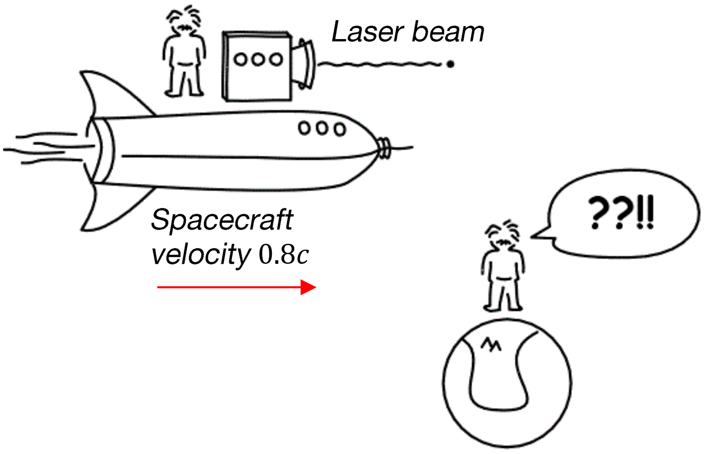
(A) DC Motor

(B) DC generator

(C) AC generator

(D) Induction motor

6 A spacecraft flying past Earth at a speed of $0.8c$, as shown in the diagram below, fires a laser beam forwards at the speed of light.



What is the speed of the laser beam, as measured by a scientist on Earth?

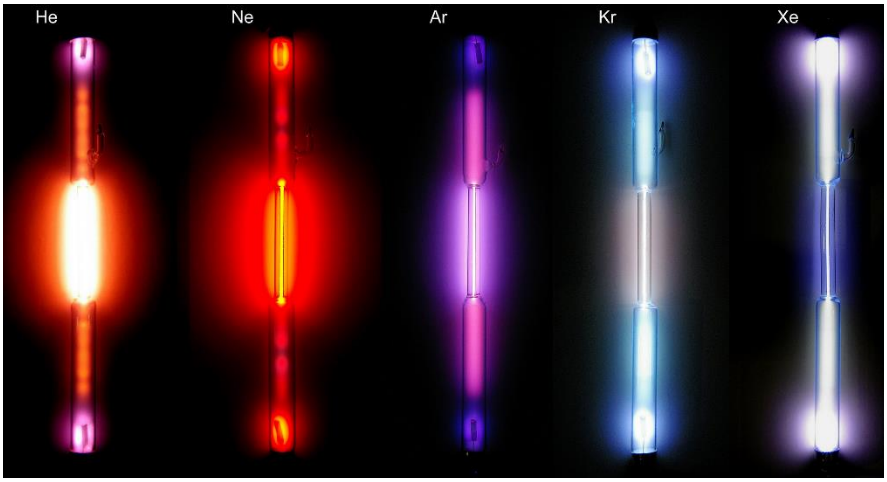
(A) 0.2c

(B) 0.8c

(C) 1.0c

(D) 1.8c

7 The diagram below depicts a series of discharge tubes. When the light from each tube is passed through a diffraction grating you would expect to see what type of spectrum?



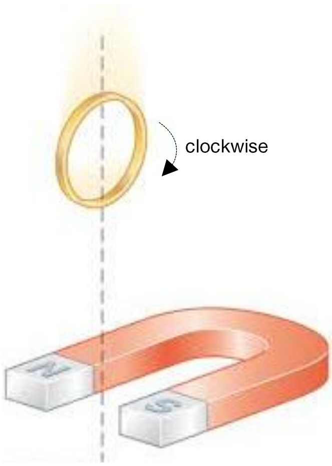
(A) Emission Spectrum ✓

(B) Continuous spectrum ✗

(C) Absorption Spectrum ✗

(D) Scattering Spectrum ✗

8 A conductive ring is dropped between the poles of a horseshoe magnet as shown below.



Which of the following describes the direction (with respect to the picture) of induced current in the ring as it falls between the poles of the magnet?

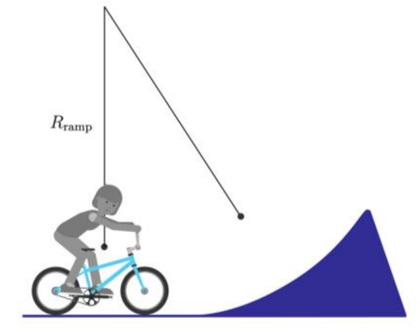
(A) The current is clockwise.

(B) The current is anticlockwise.

(C) The current is first clockwise then anticlockwise.

(D) The current is first anticlockwise then clockwise.

9 When a bike travels up a circular ramp. As the cyclist goes up the ramp, they apply a force parallel to the ramp to maintain a constant speed.



Which of the follow statements is correct when the bike is on the ramp?

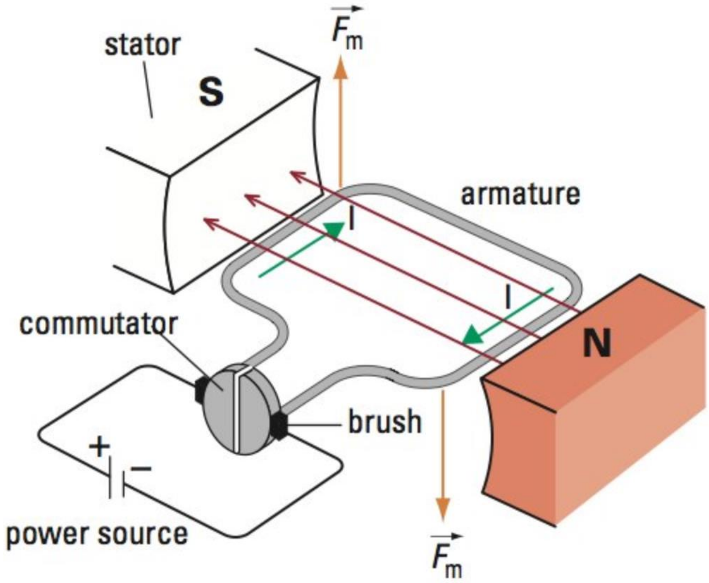
(A) The magnitude of the normal force on the bike is constant.

(B) The normal force on the bike is the bikes centripetal force.

(C) The normal force on the bike is equal in magnitude to the bikes weight force.

(D) The direction of the net force on the bike is toward the centre of the circle.

10 Consider the diagram below of a DC motor.



What happens to the magnitude of the force $\vec{F}_m$ which acts on the wire as the coil rotates clockwise 60° from its current position?

(A) It initially increases and then stays constant.

(B) It decreases to zero.

(C) It increases from zero to its maximum.

(D) It stays the same

$F = BIl\sin\theta \quad \theta = 90^\circ$

the force remains constant

11 The four diagrams below each represent the visible light emitted by an object.

Which of these spectra is most likely to have been emitted by a star?

(A)

Red Green Violet

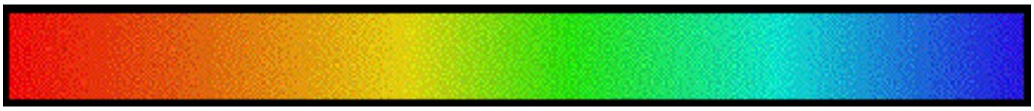
(B)

Red Green Violet

(C)

Red Green Violet

(D)

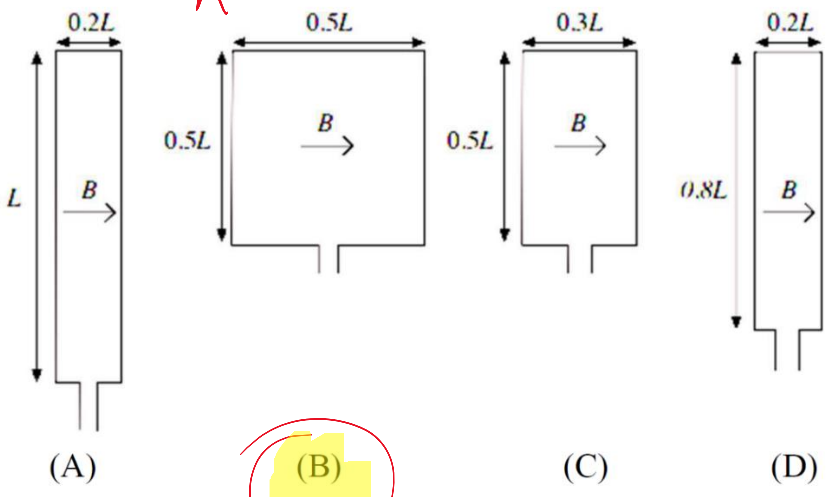


Red Green Violet

12 Four rectangular single loops of wire A, B, C and D are each placed in a uniform magnetic field of the same flux density B. The direction of the magnetic field is parallel to the plane of the loops as shown. When a current of 1.0 A is passed through each of the loops, magnetic forces act on them. The lengths of the sides of the loops are as shown.

Which loop experiences the largest torque?

$A = 0.2L^2$ $A = 0.25L^2$ $A = 0.15L^2$ $A = 0.16L^2$



13 Charged particles of mass m and charge q, travel at a constant speed in a circle of radius r in a uniform magnetic field of flux density B.

Which expression gives the period of rotation of a particle in the beam?

(A) $\frac{\pi m}{qB}$

(B) $\frac{m}{qB}$

(C) $\frac{m}{2\pi qB}$

(D) $\frac{2\pi m}{qB}$

$qvB = \frac{mv^2}{r}$ | $qB = \frac{mv}{r}$

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

$qB = \frac{m2\pi \cancel{r}}{\cancel{r}T}$

$T = \frac{2\pi m}{qB}$

14 Unpolarised light of intensity I is passed through two polarising filters with their polarising axes at an angle of 30° to one another. The intensity of the light passing through the second filter is:

(A) $0.375I$

(B) $0.43I$

(C) $0.5I$

(D) $0.75I$

$I_2 = I_1 \cos^2 30° = I_1(0.86)^2$

unpolarised to polarised $I_1 = \frac{I_0}{2}$

$I_2 = \frac{I_0}{2}(0.75)$

15 In a science fiction novel, a scientist invents a machine that converts matter into energy with 100% efficiency, in accordance with the Special Theory of Relativity. Unfortunately, his curious cat – large tabby of mass 4.6 kg - falls into the machine while it is being tested, generating a burst of energy and destroying his laboratory in the process.

How much energy does the unlucky cat generate?

(A) 1.4×10^9 J

(B) 2.0×10^{16} J

(C) 4.1×10^{17} J

(D) 1.9×10^{18} J

$E = mc^2$
$= 4.6 \times 9 \times 10^{16}$
$= 4.14 \times 10^{17}$ J

16 Two cars, A and B, go around the same curved road (radius of curvature r). They both have the same maximum traction force between the road and the tyres. Car A has 1.5 times the mass of car B.

If the maximum speed that car A can go around the curve is v, then what is the maximum speed that car B can go around the curve?

(A) $0.81v$

(B) $1.2v$

(C) $1.5v$

(D) $2.25v$

$\frac{m_A V_A^2}{r} = \frac{m_B V_B^2}{r}$

$m_A = 1.5 m_B$

$V_A = V$

$\frac{1.5 \cancel{m_B} V^2}{\cancel{r}} = \frac{\cancel{m_B} V_B^2}{\cancel{r}}$

$V_B^2 = 1.5 V^2$
$V_B = \sqrt{1.5}\, V$

17 A laser produces 1.50×10^{-3} W of green light with a wavelength of 5.30×10^{-7} m.

Calculate the number of photons it emits every second.

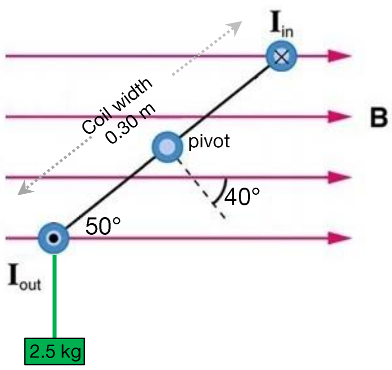
(A) 4.0×10^{15}
(B) 2.7×10^{18}
(C) 1.2×10^{24}
(D) 4.3×10^{36}

Power $P = \frac{nE}{t} = \frac{nhf}{t} = \frac{nhc}{t\lambda}$

When $t = 1s$

$n = \frac{P\lambda}{hc} = \frac{1.5\times10^{-3} \times 5.3\times10^{-7}}{6.626\times10^{-34} \times 3\times10^{8}}$

18 A mass of 2.5 kg is attached to one side of a coil in a magnetic field. In its current position, the coil is stationary. This is shown in the cross-sectional diagram below. The width of the coil is 0.30 m.



Determine the magnitude of the torque on the coil due to the magnetic field.

(A) 2.4 N m
(B) 2.8 N m
(C) 3.7 N m
(D) 4.7 N m

When in balance
Torque of coil = torque by mass

$\tau = rF\sin\theta$, $F = mg$
$= \left(\frac{0.30}{2}\right) \times 2.5 \times 9.8 \times \sin(50+90^\circ)$

19 Ganymede and Europa are both moons of Jupiter. Ganymede orbits Jupiter every 7.2 days. Europa's orbital radius is 63% of Ganymede's.

The orbital period of Europa is?

(A) 1.8 days.

(B) 3.6 days.

(C) 5.7 days.

(D) 14.4 days.

$T_G = 7.2$ days

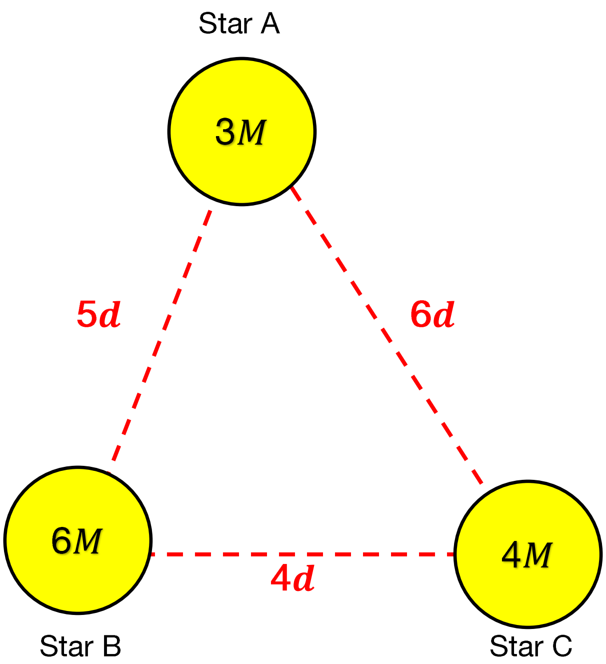
$r_E = 0.63\, r_G$

$\frac{T_G^2}{r_G^3} = \frac{T_E^2}{r_E^3}$ or $T_E = T_G\sqrt{\frac{r_E^3}{r_G^3}}$

$T_E = 7.2\sqrt{0.63^3} = 3.6$

20 There are 3 stars in a trinary star system. Their relative masses and relative distances from their centre of masses are shown below.

Not to scale



How much greater is the magnitude of the gravitational force between Stars B and C compared to the force between stars A and C.

(A) 0.22 times

(B) 1.67 times

(C) 2.16 times

(D) 4.50 times

$$\frac{F_{BC}}{F_{AC}} = \frac{\frac{G(6\cancel{m})(4\cancel{m})}{(4\cancel{d})^2}}{\frac{\cancel{G}(3\cancel{m})(4\cancel{m})}{(6\cancel{d})^2}} = \frac{\left(\frac{6\times4}{4^2}\right)}{\left(\frac{3\times4}{6^2}\right)} = \frac{\frac{3}{2}}{\frac{1}{3}} = 4\frac{1}{2}$$

SECTION II: Part A (20 Marks)

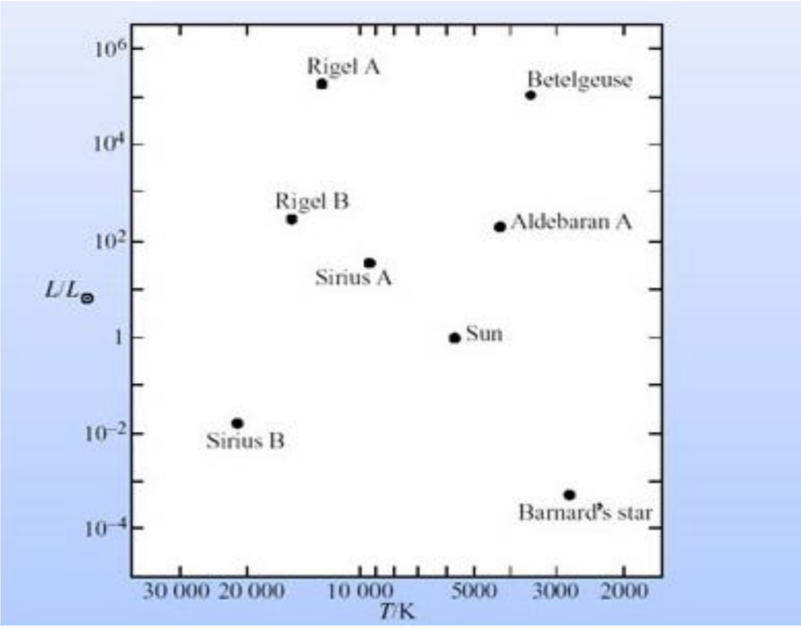
CANDIDATE NUMBER

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

NAME

Question 21 (3 marks) — Marks

Below is a Hertzsprung-Russel diagram containing some notable stars.



(a) Identify ONE star that is only fusing hydrogen to helium in its core.

Rigel B, Sirius A, Sun, Barnards Star

For Any one of the Above — 1

(b) Identify ONE star where CNO cycle fusion is predominant in the core of the star.

Rigel B or Sirius A — For Either

(transition is 1·3 - 1·5 solar masses on main sequence) — 1

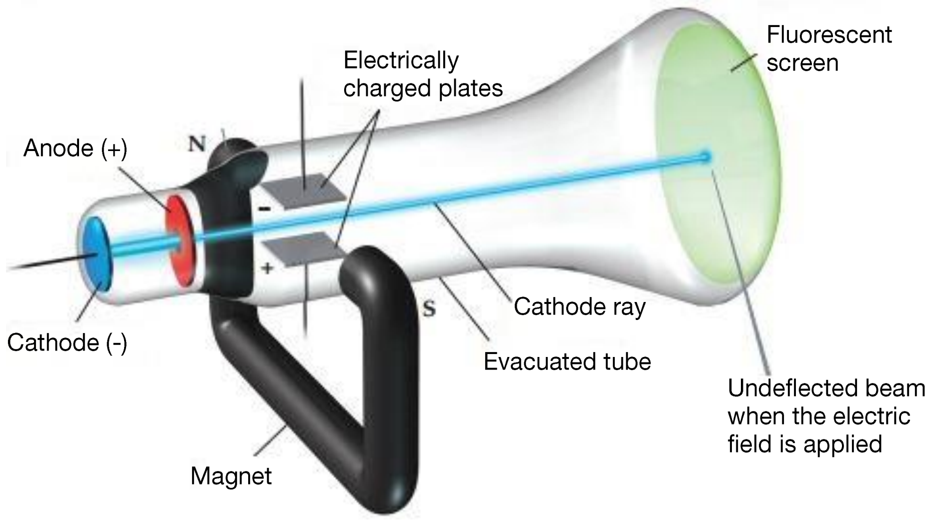
(c) Which star, if it replaced the sun, would be the brightest when viewed from the Earth.

Rigel A. — 1

Question 22 (6 marks)

Marks

The diagram below shows a variation of the experiment used by J.J. Thomson in 1897 to measure the charge to mass ratio, e/m, of the electron. In this scenario a beam of cathode rays is constantly subjected to a magnetic field of 5.0×10^{-3} T and an electric field that can be turned off.



(a) Using information from the data sheet, calculate the charge to mass ratio e/m for cathode rays.

$e/m_e = 1.76 \times 10^{11}$ C/kg   UNITS NOT REQUIRED   1

(b) When the electric field is switched off it is found that the cathode rays move in a circular path of radius 6.5×10^{-3} m.

i. Determine the direction that the magnetic field will deflect the cathode rays on the fluorescent screen from its undeflected position.

up   1

ii. Given that you know the value of e/m, calculate the velocity of the cathode rays in this experiment.

$\frac{mv^2}{r} = qvB$ $v = \frac{rqB}{m} = \left(\frac{e}{m}\right) rB$

(1) RECOGNISES CORRECT PHYSICS.

$= 1.76 \times 10^{11} \times 6.5 \times 10^{-3} \times 5 \times 10^{-3}$ T

$= 5.72 \times 10^{6}$ m/s   (2)

2

Question 22 continued on next page.

Question 22 continued

Marks

(c) When the electric field is turned on, it is adjusted until the cathode ray beam is undeflected (as depicted in the diagram).

Determine the magnitude of the electric field required for the cathode rays to be undeflected.

when undeflected $v = \frac{E}{B}$ $\boxed{E = vB}$ ① or similar

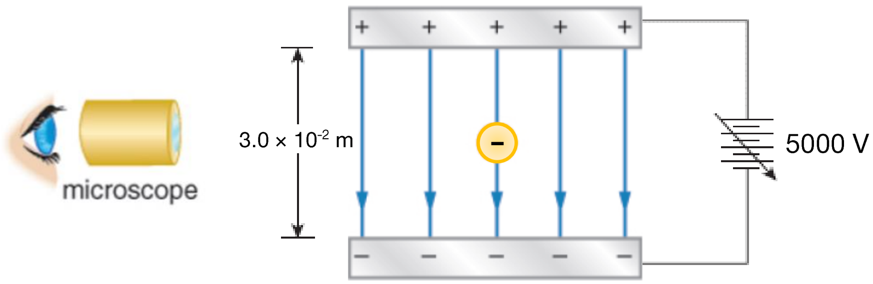
cf. $= 5.72 \times 10^{6} \times 5 \times 10^{-3}$

$= \boxed{2.86 \times 10^{4}}$ V/m ②

2

Question 23 (5 marks) **Marks**

The diagram below shows a simplified version of the experiment performed by Robert Millikan in 1909 to determine the charge on an electron. In the experiment shown below, a small, negatively charged drop of oil, of mass 5.4×10^{-15} kg, is levitated by an electric field, until it is at rest between two metal plates. The voltage is 5000 V and the vertical separation of the plates is 3.0×10^{-2} m.



(a) Calculate the charge of the oil drop.

1   $qE = mg \qquad q = \frac{mg}{E} = \frac{mgd}{V}$

$q = \frac{9.8 \times 5.4 \times 10^{-15} \times 3 \times 10^{-2}}{5000}$

$= 3.1752 \times 10^{-19}$ C   2

2

(b) Explain how the results of Millikan's original experiment allowed him to determine the charge on an electron.

Criteria	Mark
For each of the three points below.	3
For two of the points below	2
For some relevant, correct information.	1

Millikan repeated the experiment for many oils drops.
The results he obtained were consistently an integer multiple of a common factor: 1.6×10^{-19}c
He inferred that this must be the charge on an electron.

NB1: pupils who scored 2 usually did not make the link between the common factor and the charge on the electron explicit.

NB2: many pupils went into great detail about the *method* he used. This is not what the question asks, and is unnecessary: you were not asked to describe his method but to "explain how the results…". (This was not penalised in an otherwise correct answer, but it was a waste of time.)

3

Question 24 (6 marks) **Marks**

In an experiment, light of wavelength 4.20×10^{-7} m is shone on a rubidium surface which has a work function of 2.20 eV.

The observations are:

1. Electrons are emitted from the rubidium surface.
2. When the light intensity is increased the number of electrons emitted from the rubidium surface also increases.
3. The emitted electrons are measured to have a maximum kinetic energy of 0.75 eV, which does not change when the intensity of light is varied.

How did Einstein explain these observations? Support your answer with appropriate calculations.

Criteria	Mark
For a very good answer that addresses the following points: • Identifies this phenomenon as the photoelectric effect. • Outlines the photon model of light. • Explains the concept of the work function • Explains the importance of the equation $KE = hc/\lambda - \phi$ • Relates intensity to the number of photons and uses this to explain observations 2 and 3 • Supports their answer with suitable calculations: e.g. calculates the energy of the photons and shows the KE of the electrons = 0.75 eV. • Demonstrates a good understanding of the concepts by structuring their answer	6
For a good answer that addresses nearly all the points above.	5
For a fair answer that addresses most of the points above.	4
For a reasonable answer that addresses some of the points above.	3
For weaker answers, depending on the number of valid points made.	1-2

Relevant Calculations:
$E_{photon} = hc/\lambda = 4.73 \times 10^{-19}$ J = 2.95 eV
$KE_{electron} = 2.95 - 2.20 = 0.75$ eV
Threshold Frequency = $\phi/h = 2.20 * 1.6 \times 10^{-19} / 6.6 \times 10^{-34} = 5.3 \times 10^{15}$ Hz

NB1: the most common reasons for pupils losing marks on this question were:
- Not providing an ***appropriate context***: beginning their answers with the equation $KE = hc/\lambda - \phi$ without explaining where it comes from or relating it to any information in the question.
- Not making the ***one-to-one interaction*** between photons and electrons explicit.
- Not making clear the relationship between ***light intensity and the number of photons***, or how this relates to the number of electrons emitted.

NB2: In ***any*** question of the photoelectric effect, you must:
- Identify what the photoelectric effect is.
- Outline the photon model of light, referring to ***photons*** and using the equation ***E = hf*** or ***E= hc/λ***

Question 24 continued on next page.

Question 24 continued **Marks**

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SECTION II: Part B (20 Marks)

CANDIDATE NUMBER

NAME

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 25 (2 marks) **Marks**

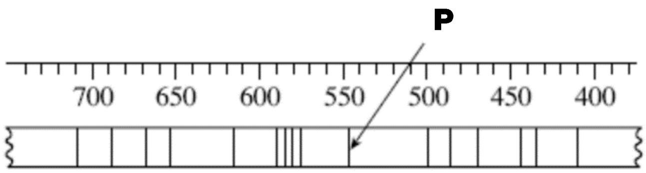
For a diffraction grating the equation for just the first order maximum is

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

A light source produces a spectrum as shown below.

Wavelength (nm)

Spectra lines



The diffraction grating used to obtain the spectrum has 300 slits per mm which is $\frac{1}{300}$ mm between slits.

Calculate the angle of diffraction of the first-order line P in the figure above.

$d \sin\theta = n\lambda$, $n = 1$

unit conversion $\lambda = 550\text{ nm}$ (roughly)

$\sin\theta = \frac{\lambda}{d} = \frac{550 \times 10^{-9}}{\frac{1}{300} \times 10^{-3}}$ $d = \frac{1}{300} \times 10^{-3}\ \text{m}$ ✓ unit conversion

$\sin\theta = 0.165$, $\theta = 9.5°$ 2

Question 26 (4 marks) **Marks**

Outline the predictions made by Maxwell concerning the nature of light.

Answers would include most of the following elements

Maxwell used his 4 equations to make the following predictions about light.

1. Light is an electromagnetic wave,
2. It is comprised of both transverse E and B fields.
3. The E and B fields are perpendicular to each other
4. The wave is self-propagating i.e. A changing E-field produced a changing B-field which produced a changing E-field, etc
5. This wave travelled at a constant speed of 3 x 10^8 m s^{-1} in a vacuum which he calculated from the following electric and magnetic constants. $c = 1/\sqrt{\varepsilon_0\mu_0}$
6. Predicted that EM waves could be created by accelerating charges (later verified by Hertz)

Could also add

- If c was a constant, then there existed (by $c = f\lambda$) an entire spectrum of EM waves beyond the visible spectrum.

Criteria	Mark
Answer contains a COMPREHENSIVE amount of detail as listed above	4
Answer contains a GOOD amount of detail as listed above	3
Answer contains SOME of the above points	2
Answer contains relevant information	1

4

Question 27 (4 marks) **Marks**

A proton in a particle accelerator has a speed of 2.0 x 10^8 m s^{-1}.

(a) Calculate the relativistic momentum of the proton at this speed.

$$p_v = \frac{mv}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1.673\times10^{-27}\times2.0\times10^{8}}{\sqrt{1-\left(\frac{2}{3}\right)^2}}$$

$$= \frac{3.346\times10^{-19}}{\sqrt{1-\frac{4}{9}}} = 4.48\times10^{-19}\ \text{kg m s}^{-1}$$

2

(b) Referring to your answer in Part (a), explain why the Special Theory of Relativity provides an upper limit to the speed of all matter.

An Impulse needs to be applied to an object to change its momentum.

$$I = \Delta p$$

If momentum is $p_v = \frac{mv}{\sqrt{1-\frac{v^2}{c^2}}}$ then as $v \to c$, $p_v \to \infty$.

This means that to make any object with mass travel at the speed of light would require an infinite impulse. (since $I = Ft$ this either requires an infinite force in a finite time or a fixed force in an infinite amount of time). Applying an infinite impulse would require an infinite amount of work energy ($W = Fs$) to achieve.

Criteria	Mark
Able to use physics to 'explain' why the speed of light cannot be reached or exceeded.	2
Provides some relevant detail about the limit of the speed of light.	1

2

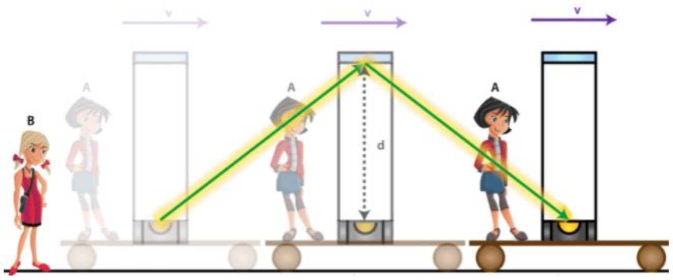
Question 28 (4 marks) **Marks**

Two observers (A and B) observe a light beam travel from the bottom of a box to a mirror at the top and back to the bottom where a clock measures the time taken.

Observer A's Frame of Reference

According to observer A the light travels distance $2d$ and the clock measures that it takes time t.

Observer B's Frame of Reference



Using the diagrams above explain why Einstein concluded that the measurement of the time it takes for the light to complete its journey depends on the frame of reference of the observer. (A full quantitative derivation is not required)

Answers should include the following elements

1. Einstein postulated that the speed of light for both observers is a constant c.
2. According to observer A the time taken is $2d/c$
3. For observer B, in the time it takes light to reach the mirror and back the train has moved forward some distance ($L = vt$) as well as the vertical distance $2d$.
4. Hence from observer B's perspective the light has travelling a longer distance (the two hypotenuse lines depicted).
5. Since to observer B the light has travelled a longer distance and is travelling at the same speed c, then it must have taken a longer time.

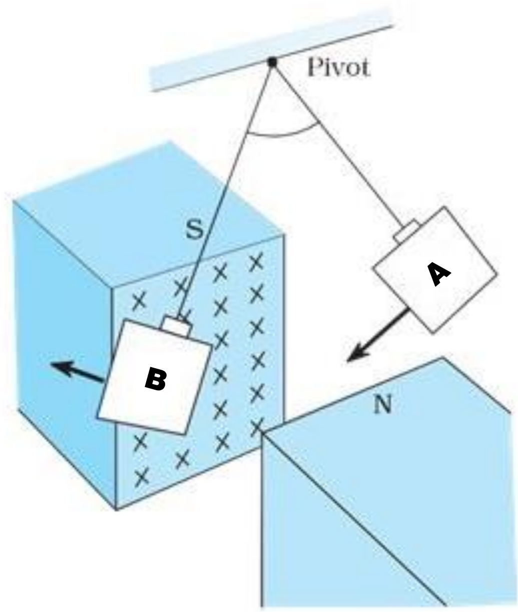
Therefore, Einstein was able to demonstrate that if his postulates were true then the time taken for the light depends on the observers frame of reference.

Criteria	Mark
A comprehensive answer that clearly links Einstein's postulate to both observers seeing the same event taking different amounts of time.	4
A good answer that does not clearly 'explain' why both observers will measure different times	3
Has some of the above information but it is not detailed or logically expressed.	2
Some relevant information addressing the question.	1

4

Question 29 (6 marks) **Marks**

A sheet of copper is mounted on a string which is allowed to swing from a pivot. After being released at position A it enters a magnetic field. In position B it is half in and half out of the field.



(a) Using correct physics explain the motion of the sheet of copper.

Answers should include the following elements

1. The plate experiences a change in flux due to the sheet moving in and out of field.
2. This causes an induced emf/voltage due to Faraday's law.
3. This causes eddy currents to be induced in sheet.
4. By Lenz's Law these currents move in a direction to oppose the flux change that created it.
5. The external magnetic field then acts on these currents producing a force which slows the sheet down bringing it to a stop.

Criteria	Mark
Well connected links between physics of the situation and its effect on the motion of the plate. Both Faraday's law and Lenz's law should be contextually stated.	4
Not fully connecting all elements or using Faraday's or Lenz's laws incompletely	3
Missing critical details in explanation	2
Some relevant details	1

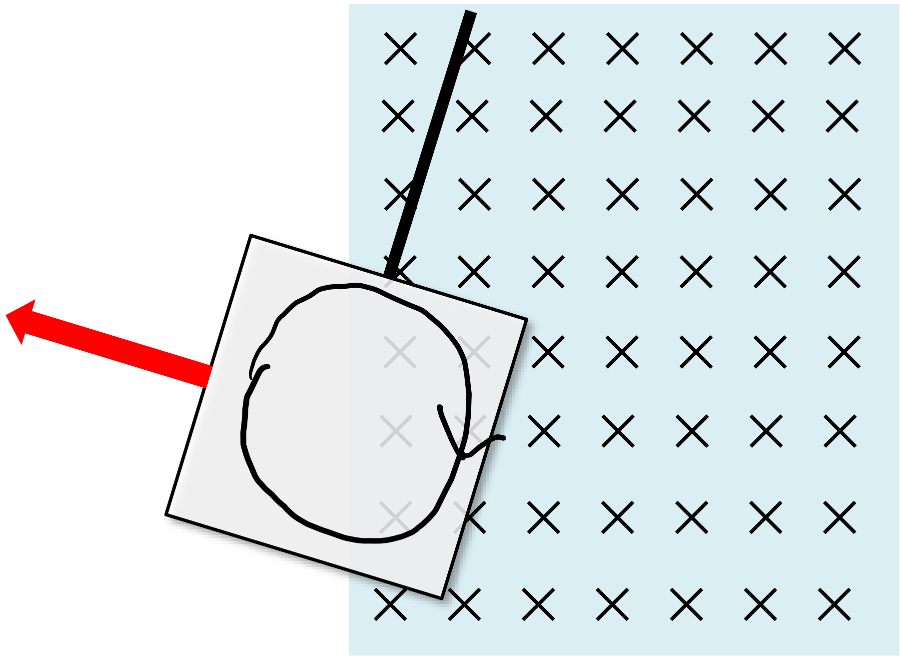
4

Question 29 continued on next page.

Question 29 continued

Marks

(b) Draw on the metal plate the currents in the sheet at position B when moving as indicated.



2

(1) mark - correct placement at edge of magnetic field

(1) mark - correct direction (clockwise)

SECTION II: Part C (17 Marks)

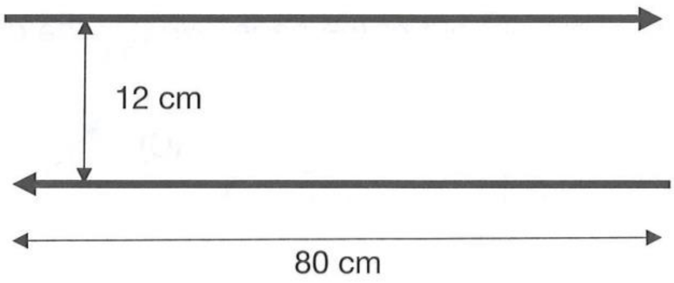
CANDIDATE NUMBER

NAME

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 30 (3 marks) **Marks**

Consider two parallel current-carrying conductors shown below. Each conductor is 80 cm long.



(a) Determine the direction of the force on the wire carrying 3 A of current.

Currents in opposite directions

$\Rightarrow$ repulsion $\Rightarrow$ force on 3A wire is up 1

(b) Calculate the force per unit length between the wires.

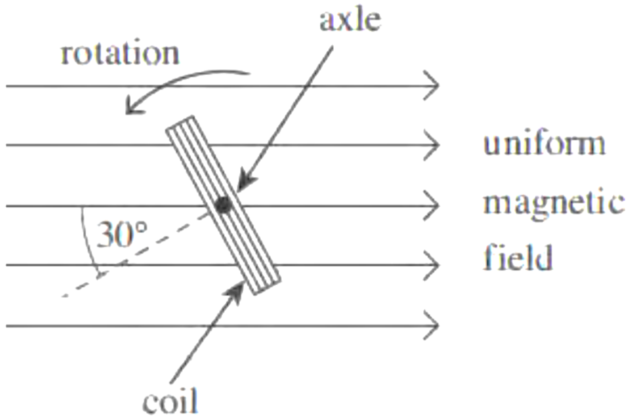
⚠ $\ell = 1m$ 1 mark

$$\underbrace{\frac{F}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi r}}_{1\text{ mark}} = \frac{4\pi \times 10^{-7}}{2\pi \times 0.12} \times 3 \times 5 = 2.5 \times 10^{-5}\ N/m$$

2

Question 31 (6 marks) **Marks**

A rectangular coil is freely rotating anticlockwise at constant angular speed with its axle at right angles to a uniform magnetic field. The diagram below shows a side on view of the coil at a particular instant.



At the instant shown the angle between the normal to the plane of the coil and the direction of the magnetic field is 30°. The coil contains 20 turns of wire and has an area of 1.96×10^{-3} m^2. The magnetic field strength is 2.7 T.

The number of turns is irrelevant here

(a) Determine the flux through the coil. (1 mark)

flux $\Phi = BA\cos\theta = 2.7 \times 1.9 \times 10^{-3} \times \cos 30°$

↳ $\Phi = 4.58 \times 10^{-3}$ Wb (1 mark) 2

(b) As the coil rotates, at what angle will the emf induced in the coil first reach a maximum?

Faraday's Law: induced emf is maximum when magnetic flux is zero therefore when the plane of the coil is parallel to the field lines, i.e. when the angle shown will be 90° (i.e. extra anticlockwise rotation of 60°). 1

Question 31 continued on next page.

Question 31 continued **Marks**

(c) The coil is connected to an external circuit containing a light bulb. When the light bulb is connected, the coil's angular speed is observed to change.

Account for this observation.

When the light bulb is connected to the coil, work must be done by the electrons to illuminate the light bulb. Therefore, part of the energy from the coil (i.e. part of the work done by the magnetic forces making the coil turn) is now transformed into light and heat energy.

There wasn't any current in the coil before, as the circuit was open. Just the emf induced by Faraday's law due to the rotation at constant speed of the coil in the magnetic field.

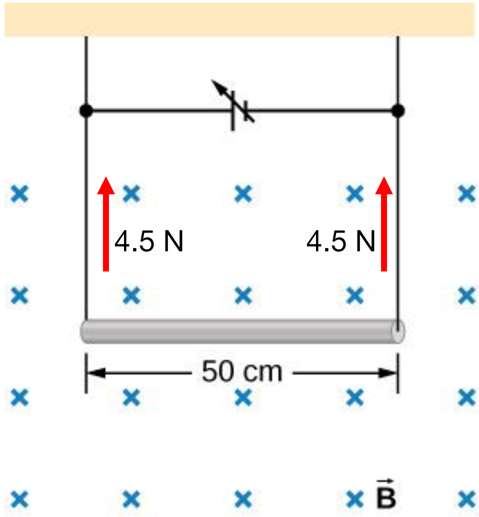
When the light bulb is connected, then a current flows in the circuit and in the coil. The current in the coil is flowing within an external magnetic field and will therefore experience the motor effect ($F = BIl\sin\theta$) and by Lenz's law, the force acting on the coil will oppose its motion, slowing down the rotation of the coil. Therefore, its angular speed will decrease.

Criteria	Mark
For a very good answer that addresses the following points: • Identifies that there was no current in the coil before the light bulb was connected. • Identifies that when the light bulb is connected a current now flows in the coil. • Identifies that part of the energy of the coil now has to be converted into heat and light in the light bulb. • Correctly links the phenomenon to the Motor Effect and Lenz's law. • Correctly deduces that the coil's angular speed decreases. • Demonstrates a good understanding of the concepts by structuring their answer logically.	3
For a good answer that addresses some of the points above.	2
For some relevant, correct information about one of the points above.	1

Most common explanation/error:
"The light bulb adds resistance to the circuit reducing the current flowing in the circuit/coil therefore the coil spins more slowly", as if there was already a current flowing in the coil before the light bulb was connected.

Question 32 (3 marks) **Marks**

A rod of length 0.50 m has a 1.3 A current flowing through it and sits in a uniform external magnetic field of 2.3 T that points into the page. The two wires holding the rod each exert a tension force on the rod of 4.5 N at each end.



(a) In which direction is the force on the rod due to the magnetic field?

RHPR ⇒ force on the rod is upwards

1

(b) Determine the mass of the rod?

1 mark

N2L on rod: $mg = BIL\sin\theta + 2T$ with $\theta = 90°$

$m = \dfrac{BIl\sin\theta + 2T}{g} = \dfrac{2.3 \times 1.3 \times 0.50 \sin 90° + 2 \times 4.5}{9.8}$

$\Rightarrow m = 1.07$ kg (1 mark)

2

Question 33 (5 marks) **Marks**

A transformer has a primary coil with 1200 loops and secondary coil with 900 loops. The current in the primary coil is 4.0 A.

(a) Assuming this transformer is ideal, determine the current in the secondary coil.

(1 mark) $\frac{N_s}{N_p} = \frac{I_p}{I_s} \Rightarrow I_s = \frac{N_p}{N_s} I_p$

$\Rightarrow I_s = \frac{1200}{900} \times 4.0 = \underline{\underline{5.33\ A}}$ (1 mark)

2

(b) Not all transformers are ideal. Describe how and where energy is lost in a transformer and state how its efficiency can be improved.

3

- Incomplete magnetic flux linkage between the primary and the secondary coils.
  Improvement: introduction of a soft iron core to allow more magnetic field lines from the primary coil to thread through the secondary coil.
- Eddy currents in the soft iron core: resistive heating ($P_{lost} = RI^2$).
  Improvement: lamination of the soft iron core (perpendicularly to the plane of the coil) to reduce the size of these eddy currents (reduced surface area) + use of ferrites which reduce the ability to establish eddy currents in the first place.
- Resistive heating also in wires carrying a current ($P_{lost} = RI^2$)
  Improvement: use of thicker wires to reduce their resistance.

Criteria	Mark
For a very good answer that fully and logically addresses the 3 points above (with expression of lost energy). For each source of energy loss, the connection between how and where the energy is lost and how to improve the efficiency must be explicitly stated to gain full marks	3
For a good answer that addresses some of the points above.	2
For some relevant, correct information about one of the points above.	1

Many boys merely only stated sources of energy losses without really connecting any of them to a specific improvement.

SECTION II: Part D (23 Marks)

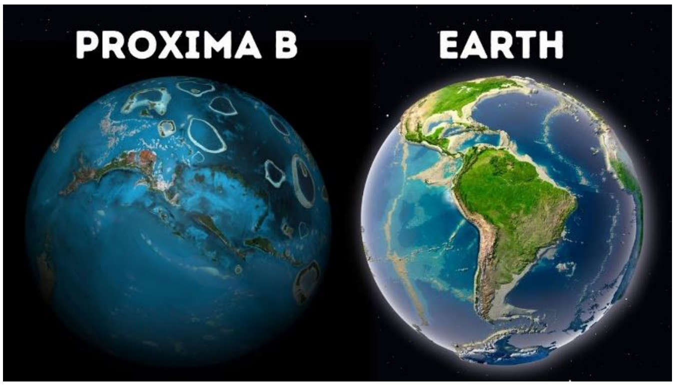
CANDIDATE NUMBER

NAME

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 34 (8 marks) **Marks**

Proxima Centauri is small dim red dwarf star that is the closest star to our solar system. In 2016 it was determined that there is a planet around this star which was named Proxima B. Its mass is estimated to be 1.2 times that of Earth and its radius is estimated to be 1.3 times the radius of the Earth. It has an orbital radius of 7.5×10^9 m from Proxima Centauri and an orbital period of 11.2 Earth Days around it.



(a) For the planet Proxima B:

i. Calculate the surface gravity on Proxima B.

$g = \frac{GM}{r^2} = \frac{G(1.2M_E)}{(1.3r_E)^2}$ method ok - 1

$= \frac{6.67\times10^{-11} \times 1.2 \times 6\times10^{24}}{(1.3 \times 6.371 \times 10^6)^2} = \boxed{7.0\ m/s^2}$

Can also be solved by ratios

$g = 9.8\left(\frac{1.2}{1.3^2}\right)$

2

ii. Calculate the escape velocity from Proxima B's surface.

$K = \Delta U \rightarrow \frac{1}{2}mv^2 = \frac{GMm}{r}$

$v^2 = \frac{2GM}{r}, \quad v = \sqrt{\frac{2GM}{r}}$

$\sqrt{\frac{2\times6.67\times10^{-11}\times1.2\times6\times10^{24}}{1.3\times6.371\times10^6}}$

$\boxed{= 10,769\ m/s}$

2

Question 34 continued on next page.

Question 34 continued **Marks**

(b) For the star Proxima Centauri:

i. Determine the mass of the star Proxima Centauri

$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ $M = \frac{4\pi^2 r^3}{GT^2}$ - (1)

$r = 7.5 \times 10^9$ m

$T = 11.2 \times 24 \times 60 \times 60$

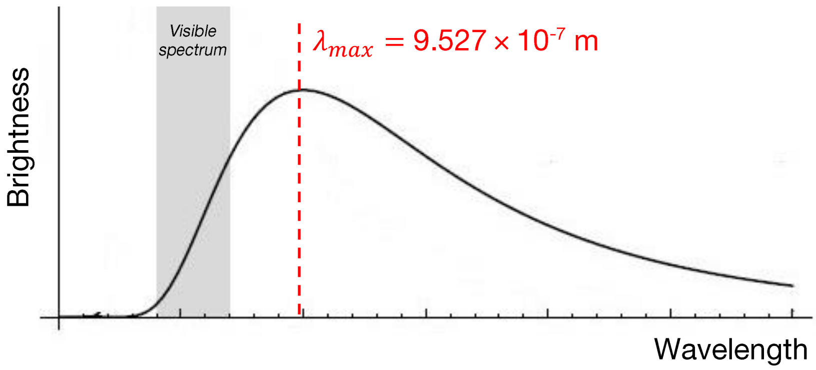
$= 967{,}680$ s - (1)

$M = \frac{4\pi^2 (7.5\times10^9)^3}{6.67\times10^{-11}(967680)^2}$

$= \boxed{2.67 \times 10^{29} \text{ kg}}$

3

ii. When analysing the spectrum of Proxima Centauri it is found that it is emitting the most amount of light at a wavelength of $\lambda_{max} = 9.527 \times 10^{-7}$ m



Determine the surface temperature of the star.

$\lambda_{max} = 952.7 \times 10^{-9}$ m

$T = \frac{2.90 \times 10^{-3}}{952.7\times10^{-9}} = \boxed{3042 \text{ K}}$ - (1)

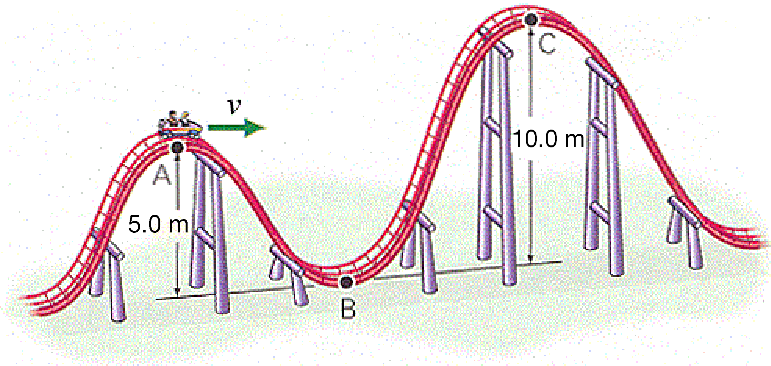
1

using °C makes the answer wrong.

- missing units means answer is ambiguous and wrong.

Question 35 (4 marks) **Marks**

In an amusement park a rollercoaster track is being designed for a rollercoaster car of mass 540 kg.



The rollercoaster car needs a certain velocity at point A to make it over point C (with a minimum speed of 1.4 m s^{-1} for safety). Using conservation of kinetic and gravitational potential energy, the predicted speed at points A and B can be calculated. The following table provides information about the track at each point and the predicted speed at each point.

	Point A	Point B	Point C
Vertical Height (m)	5.0	0	10.0
Radius of Curvature (m)	7.5	8.0	6.2
Predicted Speed (m s^{-1})	10	14.1	1.4

(a) Determine the magnitude of the Normal force on the rollercoaster car at point B at the predicted speed given.

At point B

N, F_c, W

$\Sigma F = N - W = \frac{mv^2}{r}$ — 1

$N = mg + \frac{mv^2}{r}$

$= 540\left(9.8 + \frac{14.1^2}{8}\right)$

$\boxed{= 18{,}711.68\ N}$ — 1

2

(b) Determine the maximum speed, v, that the rollercoaster can go at point A, before it leaves the tracks and assess if the predicted speed of 10 m s^{-1} is too high.

At point A

N, W, F_c

$F_c = W - N$

$\frac{mv^2}{r} = mg - N$, v is max when $N \to 0$

1

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

$v = \sqrt{rg} = \sqrt{7.5 \times 9.8} = \boxed{8.57\ m/s}$

car exceeds this, so the track will leave 1

2

Question 36 (4 marks) **Marks**

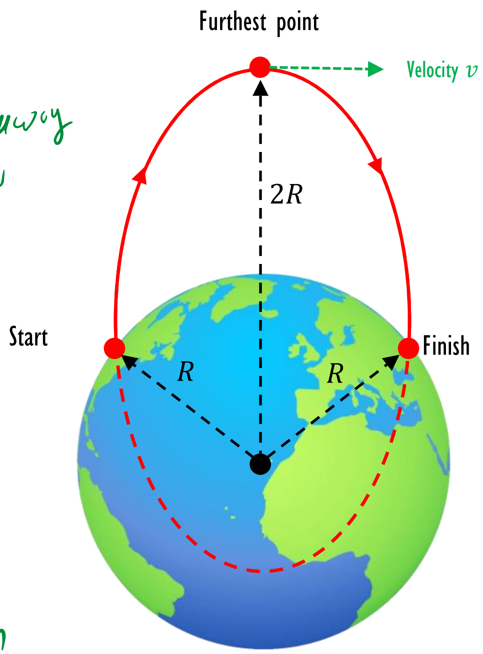
A projectile is launched from one point of the Earth to a point on the other side. The trajectory of this projectile (ignoring all atmospheric friction) has the shape of an elliptical orbit with the centre of the Earth as a focus. This is depicted below.

Too many are substituting straight away and making more errors

Solving algebraically first

This clearly shows what variables can be simplified or eliminated.

making substitution into $v^2 = u^2 - \frac{GM}{R}$ easier



Note

gravity is not constant so $U = mgh$ cannot be used

AND

gravity is not vertical so projectile motion equations cannot be used.

When launched it has an initial speed of 8200 m s^{-1} at a distance of R from the centre of the Earth and reaches a maximum distance from the centre of the Earth of $2R$ which is the furthest distance from the Earth's surface.

Using the law of conservation of energy, determine the speed, v, of the projectile when it is furthest from the Earth's surface. (Assume there is no air resistance acting on the projectile.) 4

Total energy is constant so $U_i + K_i = U_f + K_f$ ← need correct conservation of energy expression

$U_i = -\frac{GMm}{R}$, $U_f = -\frac{GMm}{2R}$ $[U_i - U_f = K_f - K_i]$

$K_i = \frac{1}{2}mu^2$ $K_f = \frac{1}{2}mv^2$

(2) correct forms of energy used

(1) Use COE to get correct equation.

$-GM\cancel{m}\left(\frac{1}{R} - \frac{1}{2R}\right) = \frac{1}{2}\cancel{m}(v^2 - u^2)$

$v^2 - u^2 = -2GM\left(\frac{1}{2R}\right) = -\frac{GM}{R}$

$v^2 = u^2 - \frac{GM}{R} = (8200)^2 - \frac{6.67\times10^{-11} \times 6\times10^{24}}{6.37\times10^{6}\,m}$

$v^2 = 4.42\times10^6$

$\boxed{v = 2103 \text{ m/s}}$ (1)

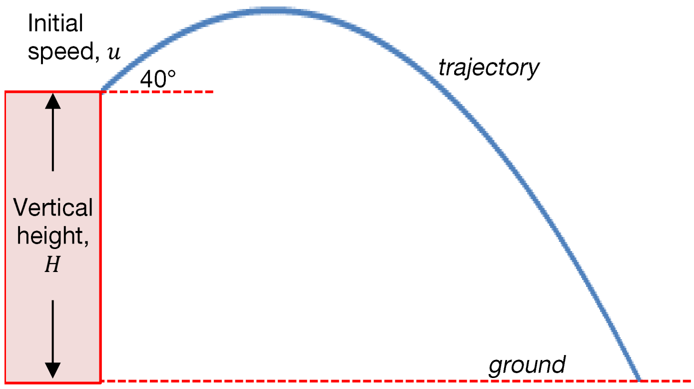
answers using $U = mgh$ get close to correct answer but are incorrect as 'g' is not constant

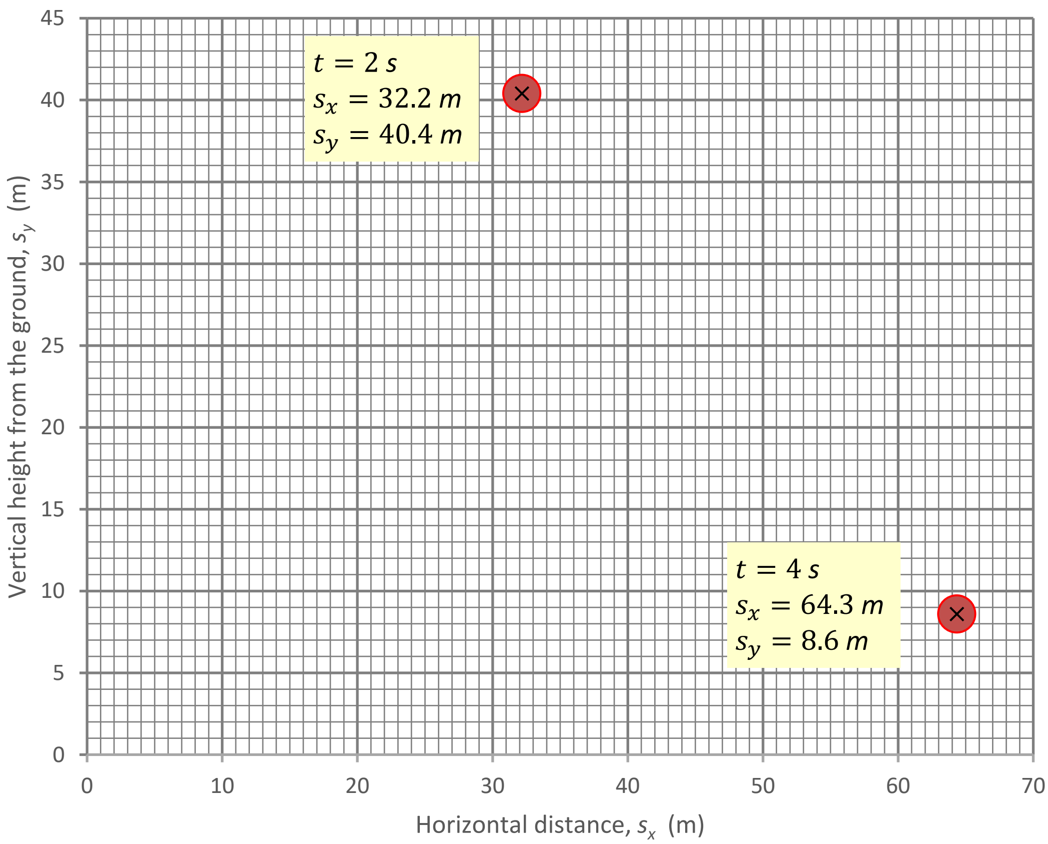
(max 2 marks) – they are solving an easier problem.

Question 37 (7 marks)

Marks

A projectile is launched at an initial speed u from a vertical height H from the ground, at an angle to the horizontal of $\theta = 40°$. Its trajectory is recorded with a camera that has, unfortunately, a slow capture time and can only take a picture of the projectile every 2 seconds. The graph below shows the camera recording the position of the projectile at times $t = 2$ and 4 seconds.





Question 37 continued on next page.

Question 37 continued **Marks**

(a) Determine the initial horizontal speed of the projectile from this graph.

At $t = 2$, $x = 32.2$, $y = 40.4$ m, $\Delta x = u_x t$, $u_x = \frac{64.3}{4} = 16.075 = \boxed{16.1 \text{ m/s}}$

At $t = 4$, $x = 64.3$ m, $y = 8.6$ m

1

(b) Determine the initial speed u of the projectile.

$u = \frac{u_x}{\cos 40^\circ} = \frac{16.075}{\cos 40^\circ} = \boxed{20.98 \text{ or } 21 \text{ m/s}}$

1

(c) Use the points on the graph to calculate the vertical velocity of the projectile at time $t = 2$ s.

between $t = 2 \to 4$ s $\Delta y = 8.6 \text{ m} - 40.4 \text{ m} = -31.8$ m/s

So $\Delta t = 2$ s, $\Delta y = -31.8$ m/s, $a_y = -9.8$ m/s², $u_y = ?$

$\Delta y = u_y t - 4.9t^2$, $u_y = \frac{1}{t}(\Delta y + 4.9t^2)$

$u_y = \frac{1}{2}(-31.8 + 4.9 \times 4) = \boxed{-6.1 \text{ m/s}}$

or 6.1 m/s downwards ① ①

OR

$v_y = u_y + a_y t$, $u_y = u \sin\theta$
$= 20.98 \sin 40^\circ$
$= 13.49 \text{ m/s}$

$= 13.49 - 9.8 \times 2$

$\boxed{= -6.1 \text{ m/s}}$ ①

correct direction ①

Some indication of direction is needed consistent with working

2

(d) Determine the initial vertical height H that the projectile was launched from.

method ①

$t = 0 \to 2$ $u_y = u \sin\theta$ $v_y = -6.1$ m/s, $u_y = 20.98 \sin 40^\circ = 13.49$ m/s

$\Delta y = \frac{v_y^2 - u_y^2}{-2 \times 9.8} = \frac{(-6.1)^2 - (20.98 \times \sin 40^\circ)^2}{-19.6} = \frac{(-6.1)^2 - (13.49)^2}{-19.6}$

height gain since launch $\boxed{= 7.386 \text{ m}}$ ①

So at $t = 2$ s, $y = 40.4$ m so $H + 7.386 = 40.4$ m

$H = 40.4 - 7.386 = \boxed{33 \text{ m}}$ ①

Multiple solutions possible (1-2 marks for valid method + 1 mark for correct solution)

3

END OF EXAMINATION

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HIGHER SCHOOL CERTIFICATE
EXAMINATION

Physics

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	$3.00 \times 10^{8} \text{ m s}^{-1}$
Electric permittivity constant, ε_0	$8.854 \times 10^{-12} \text{ A}^2 \text{ s}^4 \text{ kg}^{-1} \text{ m}^{-3}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7} \text{ N A}^{-2}$
Universal gravitational constant, G	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
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)	$1.097 \times 10^{7} \text{ m}^{-1}$
Atomic mass unit, u	1.661×10^{-27} kg $931.5 \text{ MeV}/c^2$
1 eV	1.602×10^{-19} J
Density of water, ρ	$1.00 \times 10^{3} \text{ kg m}^{-3}$
Specific heat capacity of water	$4.18 \times 10^{3} \text{ J kg}^{-1} \text{ K}^{-1}$
Wein's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

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

$$v = u + at$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Waves and thermodynamics

$$v = f\lambda$$

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

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

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

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

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

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

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

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

$$I_1r_1^2 = I_2r_2^2$$

$$Q = mc\Delta T$$

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

Electricity and magnetism

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

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

$$W = qV$$

$$W = qEd$$

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

$$B = \frac{\mu_0 N I}{L}$$

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

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

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

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

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

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

$$V = IR$$

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

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

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

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

$$V_p I_p = V_s I_s$$

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	79
Symbol	Au
Standard Atomic Weight	197.0
Name	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

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.