Please write your name neatly in the box.

2024

HIGHER SCHOOL CERTIFICATE EXAMINATION – TRIAL PRACTICE I

Physics

General Instructions

- Reading Time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks

- Attempt Questions 1–20
- Allow about 30 minutes for this section

Section II – 80 marks

- Attempt Questions 21-34
- Allow about 2 hours 30 minutes for this section

Section I

Part A – 20 marks

Allow about 30 minutes for this part.

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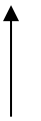
1 Two golfers, Jimmy and Johnny used different golf clubs to hit identical golf balls from the same golf tee. Jimmy's ball had a shorter time of flight than Johnny's ball, but they both return to the ground at the same position.

Which of the following sets of vectors best represents the horizontal and vertical components of the initial velocity of their golf balls?

	JIMMY'S BALL		JOHNNY'S BALL	
	Vertical	*Horizontal*	*Vertical*	*Horizontal*
(A)				
(B)				
(C)				
(D)				

2 A satellite is in a stable, circular orbit around the Earth where it experiences an acceleration due to gravity of 1.5 m s^{-2}.

If the mass of the satellite is 540 kg, its altitude is closest to?

(A) 1.6 x 10^4 km

(B) 1.6 x 10^7 km

(C) 1.0 x 10^4 km

(D) 1.0 x 10^7 km

3 A slingshot launches a steel ball with a velocity of 90 m s^{-1} at an angle of 65° from the vertical.

After four seconds, the speed of the steel ball is closest to:

(A) 50 m s^{-1}

(B) 60 m s^{-1}

(C) 70 m s^{-1}

(D) 80 m s^{-1}

4 A 200 g ball attached to a string of length 1.8 m is undergoing vertical circular motion at a constant speed, with a frequency of 0.75 Hz.
At the point where the ball is moving upward and the centripetal force is provided purely by tension in the string, a timer is started.
Exactly 1.50 s after the timer has started, what is the tension in the string?

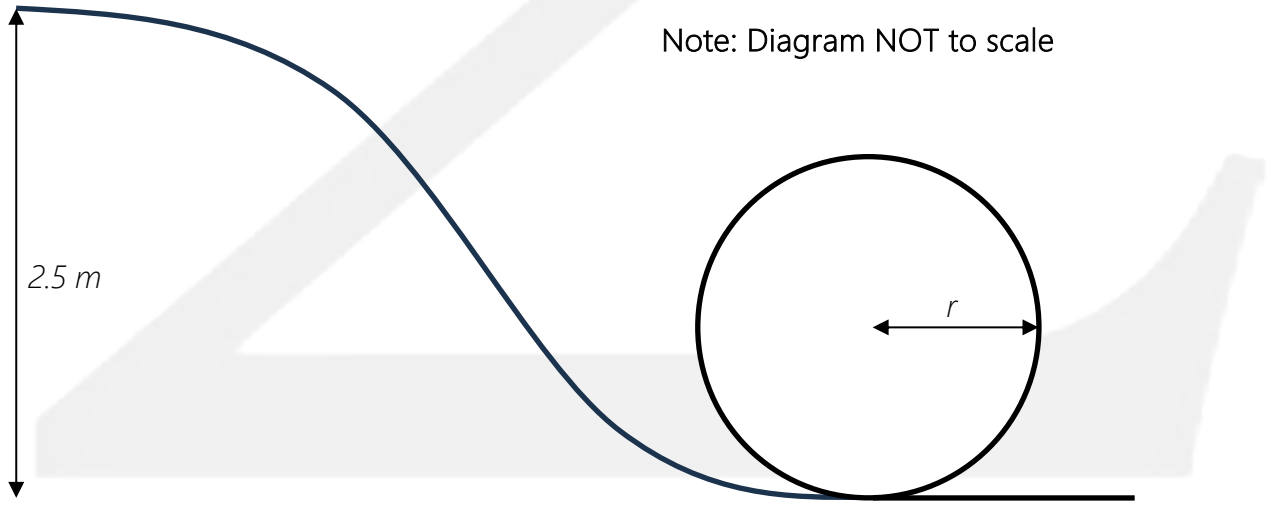
(A) 6.6 N

(B) 8.0 N

(C) 8.5 N

(D) 9.4 N

5 A marble is released, from rest, from a height, 2.5 m above the ground.
This marble then safely completes a loop-de-loop as shown in the diagram below.



The maximum radius, *r*, allowed for the marble to safely complete the loop-de-loop is closest to:

(A) 0.5 m

(B) 0.75 m

(C) 1.0 m

(D) 1.25 m

6 A circular coil of wire with diameter 7.5 cm is placed in a magnetic field of strength 5.8 mT such that it has maximum flux through its surface area. The coil is then rotated by 25°.

The magnitude of the change in magnetic flux through the coil is closest to:

(A) 2.4×10^{-6} Wb

(B) 9.6×10^{-6} Wb

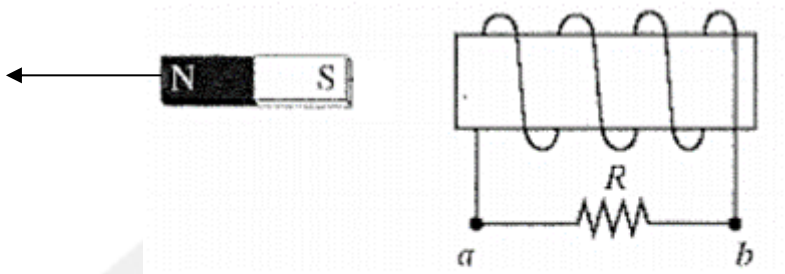
(C) 2.3×10^{-5} Wb

(D) 9.3×10^{-5} Wb

7 A bar magnet is placed so that it is initially outside a large coil and is then moved away from the coil, as shown below.

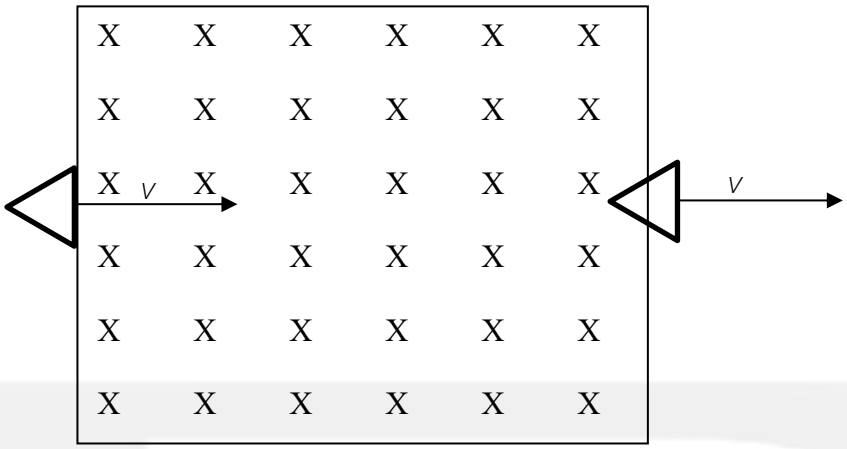
The coil is connected to a resistor, R.

Which of the following responses best represents the magnetic pole produced on the Right-Hand side of the solenoid and the polarity of *a* compared to *b*?



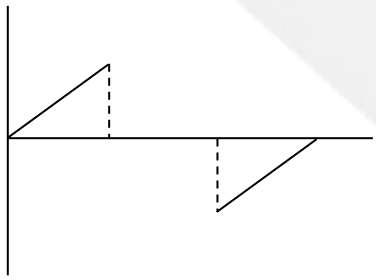
	Magnetic Pole on RHS of solenoid	*Polarity of **a** compared to **b***
(A)	North Pole	Positive
(B)	North Pole	Negative
(C)	South Pole	Positive
(D)	South Pole	Negative

8 A triangular coil moves across the page at a constant speed, *v*.
This coil enters and exits the magnetic field as shown below.

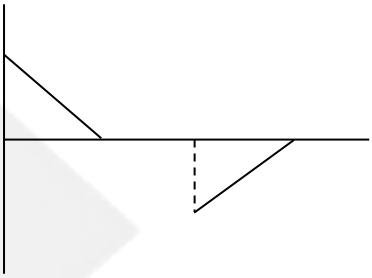


The graph of the EMF induced in the coil vs. time is **BEST** represented by which of the following?

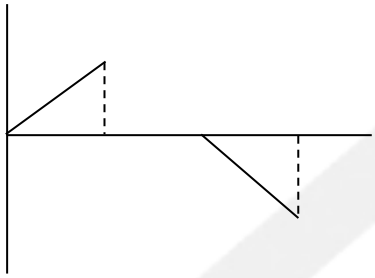
(A)



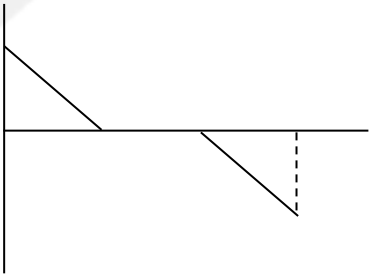
(B)



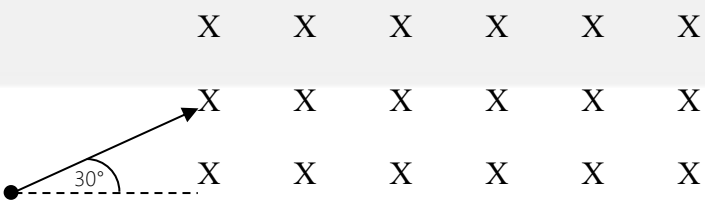
(C)



(D)



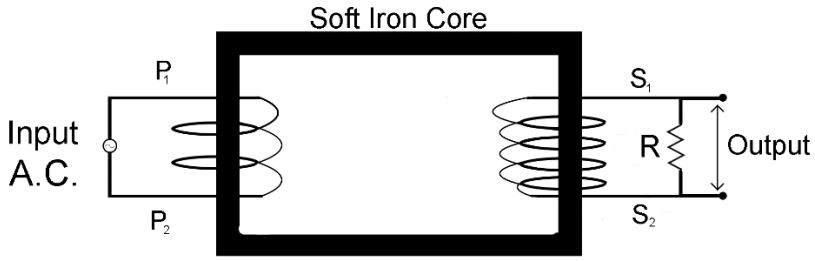
9 An electron enters a magnetic field of strength 30 mT at a speed of 6.0×10^5 m s^{-1} as shown below.



The magnitude of the force acting on the electron is closest to:

(A) 0
(B) 1.4×10^{-15} N
(C) 2.5×10^{-15} N
(D) 2.9×10^{-15} N

10 An ideal transformer is shown below.



If the Input is 20 V @ 2 A, which of the below best represents the output?

	Voltage (Volts)	Current (Amps)
(A)	40	1
(B)	40	4
(C)	50	0.8
(D)	50	5

11 Which one of the following is used to determine the density of a star?

(A) Doppler Broadening

(B) Doppler Shift

(C) Pressure Broadening

(D) Rotational Velocity

12 Unpolarised light of intensity 2.5 W m^{-2} is incident on polarising filter A whose polarising axis is 30° to the right of the vertical. This light then passes through polarising filter B whose polarising axis is 20° to the left of the vertical. What is the intensity of the light coming out of polarising filter B?

(A) 0.5 W m^{-2}

(B) 0.8 W m^{-2}

(C) 1.0 W m^{-2}

(D) 1.2 W m^{-2}

13 A π meson has a half life of roughly 18 ns when at rest.
In a particle accelerator, the half life of the π meson was found to be measured as 72 ns from the frame of reference of the laboratory.
The speed of the π meson would be closest to:

(A) 0.87 c

(B) 0.94 c

(C) 0.97 c

(D) 0.995 c

14 The image below best represents which type of spectra?

(A) Absorption spectra

(B) Blackbody spectra

(C) Continuous spectra

(D) Emission spectra

15 Light of wavelength 450 nm is incident on a metal surface with a work function of 1.2 eV.
The speed of the ejected electrons is closest to:

(A) 2.6×10^5 m s^{-1}

(B) 3.7×10^5 m s^{-1}

(C) 5.2×10^5 m s^{-1}

(D) 7.4×10^5 m s^{-1}

16 A helium white dwarf evolves from which type of star?

(A) Blue supergiant

(B) High mass main sequence star

(C) Low mass main sequence star

(D) Red Giant

Note:

If you are a Girraween student, please answer the replacement Q16 and mark your response on the multiple choice sheet.

17 Which one of the following **BEST** describes the model of the atom put forward by JJ Thomson?

(A) Large positive region of influence with negative corpuscles within it.

(B) Small, dense positive region with negative charges moving around it.

(C) Small, dense positive region with negative charges moving around it in defined orbits.

(D) The atom is indivisible.

18 What is the highest energy photon released in the Balmer series?

(A) 1.89 eV

(B) 2.86 eV

(C) 3.03 eV

(D) 3.40 eV

19 The Davisson-Germer experiment was used to support which of the following?

(A) The Rutherford model of the atom

(B) Chadwick's discovery of the neutron

(C) The wave nature of the electron

(D) Time dilation

20 The H_α spectral line is one of the most prominent spectral lines present in our Sun.
At rest, the wavelength of this spectral line is 656.28 nm in air.
Due to the Sun's rotational motion along our line of sight, this spectral line differs on opposite ends of the Suns equator by 9.00×10^{-12} m.
Assuming that the rotation of the Sun is purely along our line of sight and the apparent change in wavelength can be approximated by the equation below:

$$\boldsymbol{\lambda_{observed} = \lambda_{rest} \times \left(1 - \frac{v}{c} \cos \theta\right)}$$

Where θ is the difference in angle between 'with our line of sight' and the linear velocity of the Sun's equator.
Given that the diameter of the Sun is 1.39×10^6 km, the rotational period of the Sun at the equator is closest to?

(A) 23 days

(B) 25 days

(C) 33 days

(D) 41 days

Section II

Part B – 80 marks

Allow about 2 hours 30 minutes for this part.

Question 21 (7 marks)

A manned satellite of mass 11 200 kg is placed into a stable, perfectly circular orbit around Earth at an altitude of 350 km.

(a) Find the speed at which the satellite orbits the Earth 2

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(b) Explain why, even though the satellite is moving at a constant speed, the net force acting on the satellite is not zero. 3

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(c) Outline why a person on this satellite feels weightless. 2

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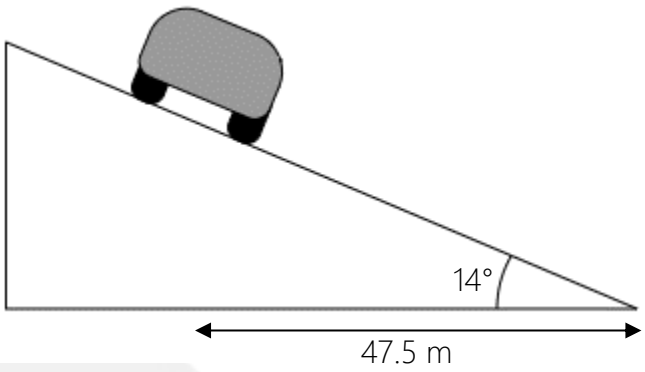
Question 22 (6 marks)

A car of mass 1 250 kg travels around a frictionless track which is banked at 14° at a radius of 47.5 m.

(a) Clearly label all the forces acting on the car below. 4



(b) Show that the ideal speed of the car around the banked track is given by the following equation: 1

$$v_{ideal} = \sqrt{gr \tan \theta}$$

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(c) Hence, or otherwise, solve for the ideal speed of the car around the banked track. 1

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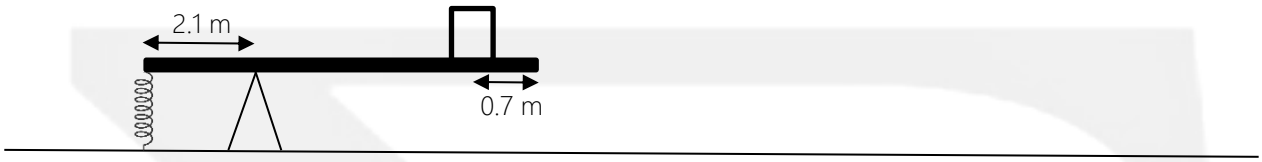
Question 23 (4 marks)

A homogenous platform of mass 210 kg and length 5.8 m is balancing on a fulcrum as shown in the diagram below.

The centre of mass of a 75 kg block is placed 0.7 m from the right side of the platform and a spring is attached to the very left-hand side of the platform and is anchored to the ground.



If the platform remains balanced.

(a) Calculate the force exerted by the spring on the platform. 2

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(b) Calculate the force exerted by the fulcrum on the platform. 2

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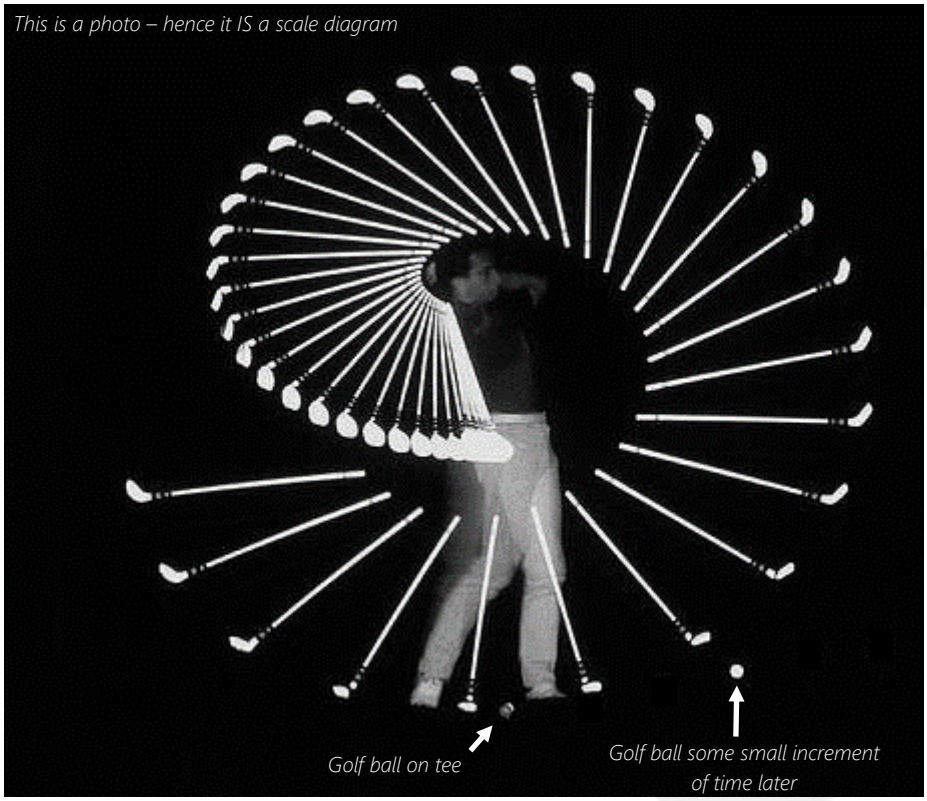
Question 24 (5 marks)

A golfer is filmed with a stroboscope as they hit a golf ball off a tee.

The position of the golf ball is marked on the tee and marked again some unknown **SUPER** small increment of time later **(cannot be determined from information in the question).**



Measurements:

Golfer height – 1.75 m

Stroboscope frequency – 50 Hz

After ball is hit:

$$\frac{\text{Ball speed}}{\text{Club speed}} = 1.5$$

Hint:

You **WILL** need a ruler and a protractor 😊

Find the range of the golf ball the ground is flat. Explain any measurements you have taken.

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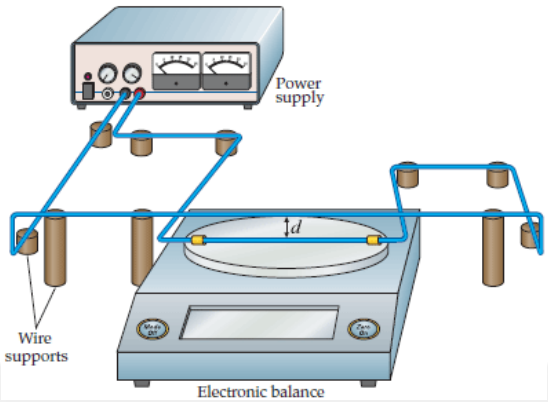
Question 25 (5 marks)

A current balance is shown below:



A straight 10.5 cm section of wire is placed on top of the pan of an electronic balance.

This section of wire is connected in series with a power supply and a long straight horizontal section of wire that is parallel to it and positioned 1.75 cm directly above it (labelled 'd' in diagram).

When the power supply is switched on, the reading on the balance changes by 4.55 mg.

(a) Should the reading on the balance increase or decrease? Why? 3

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(b) Calculate the current through the wires 2

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Question 26 (7 marks)

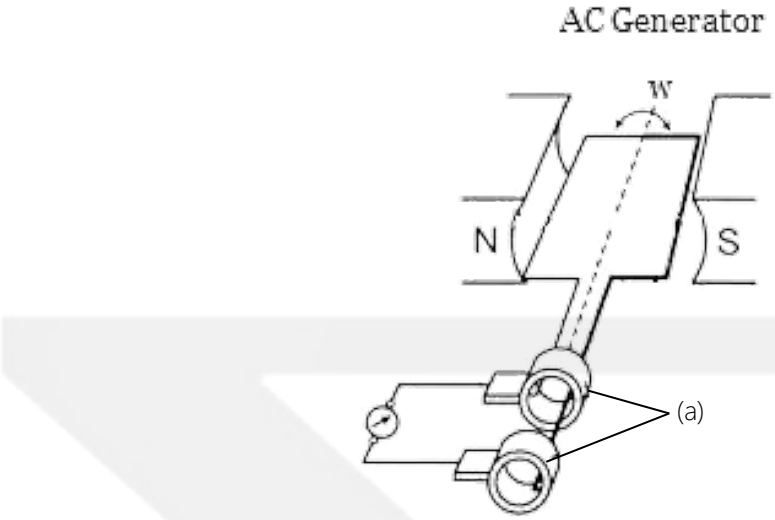
Describe the structure and explain the operation of a step-down transformer, including strategies used to improve transformer efficiency.

Include a relevant diagram to support your response

Question 27 (8 marks)

The diagram below shows a schematic representation of an AC generator.

This generator rotates clockwise.



(a) Identify the name and function of the part of the generator labelled (a). 2

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(b) Label the direction of the current in the rotor coil. 1

(c) Label the direction of the current in the external circuit. 1

(d) Label the polarity of the carbon brushes. 1

(e) In the position shown above, would the induced EMF be zero or a maximum value? Explain. 3

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Question 28 (6 marks)

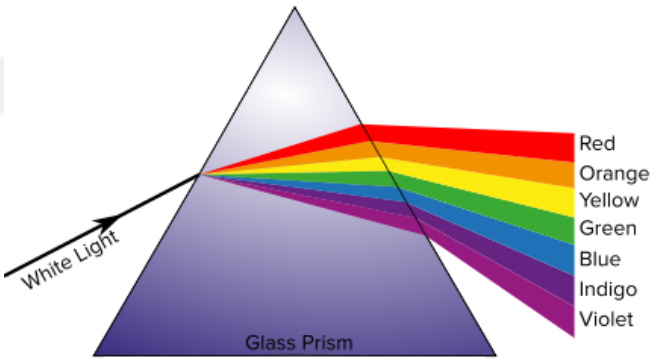
Outline how aspects of a star's motion can be determined from an analysis of its spectral lines.

Question 29 (4 marks)

Back when Chris was a wee little lad, his uncle Christiaan had a debate with some English guy about who had the most luscious hair. Shut up. I'm not jealous.

They also dabbled in some Physics and shone some light through some prisms.

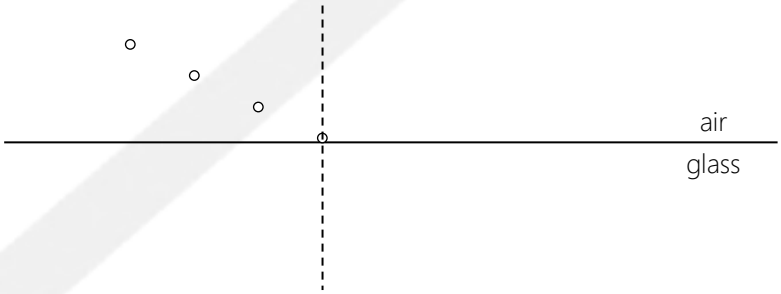
makes laser sounds Do they even make a sound? That's the big question...



Outline the English ~~noobs~~ guy's explanation of the dispersion of white light.

The diagram below shows white light approaching the air-glass boundary.

Complete the diagram to support your response.



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Question 30 (5 marks)

A 0.5 mW laser of wavelength 475 nm is pointing from the surface of the Earth directly at the Moon. The laser beam spreads out at an angle of 1.5 milliradians.

If the distance between the surface of the Earth and the surface of the Moon is 380 000 km, calculate the number of photons which strike a 1 square kilometre section of the Moon each minute.

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Question 31 (3 marks)

Barnard's Star is 5.96 light years away from the Earth.

A passenger on board a spacecraft travelling at relativistic speeds experiences a travel time of 11 years from Earth to Barnard's Star.

At what speed was the spaceship travelling?

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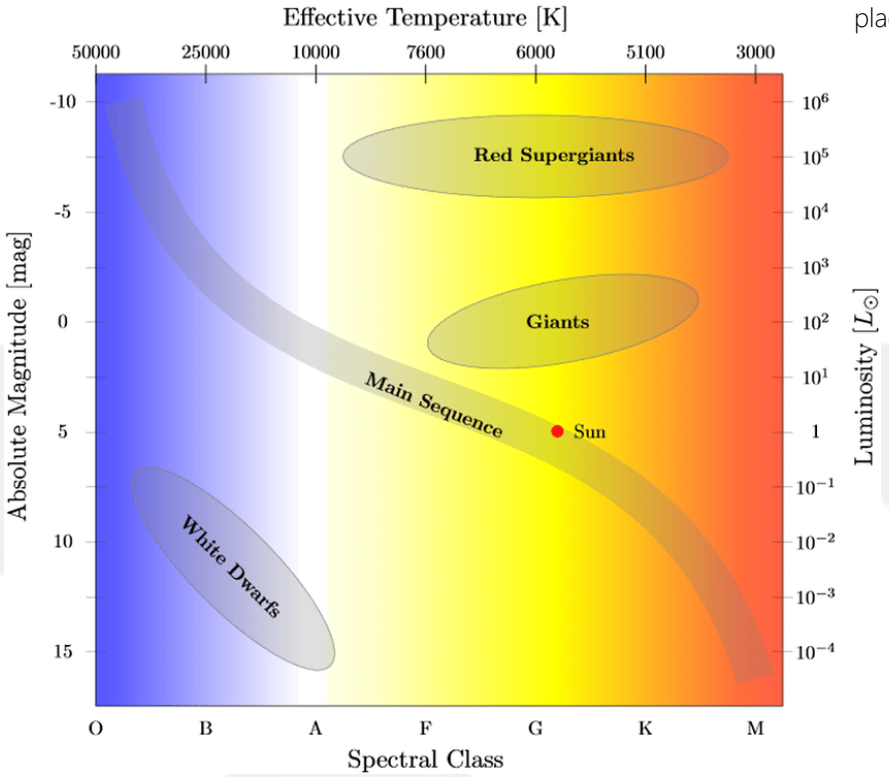
Question 32 (7 marks)

Note:

If you are a Girraween student, please answer the replacement questions in place of Q32 & Q33.

The position of our Sun is marked on the main sequence in the H-R diagram below.



(a) Sketch the expected evolutionary pathway for our Sun . 2

(b) Describe, in detail, the processes which will occur within our Sun during its lifetime. 5

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Question 33 (5 marks)

Note:

If you are a Girraween student, please answer the replacement Questions in place of Q32 & Q33

The Hubble-Lemaitre Law states:

$$\boldsymbol{v = H_0 d}$$

Where:

v = recessional velocity of galaxy

d = distance of galaxy from Earth

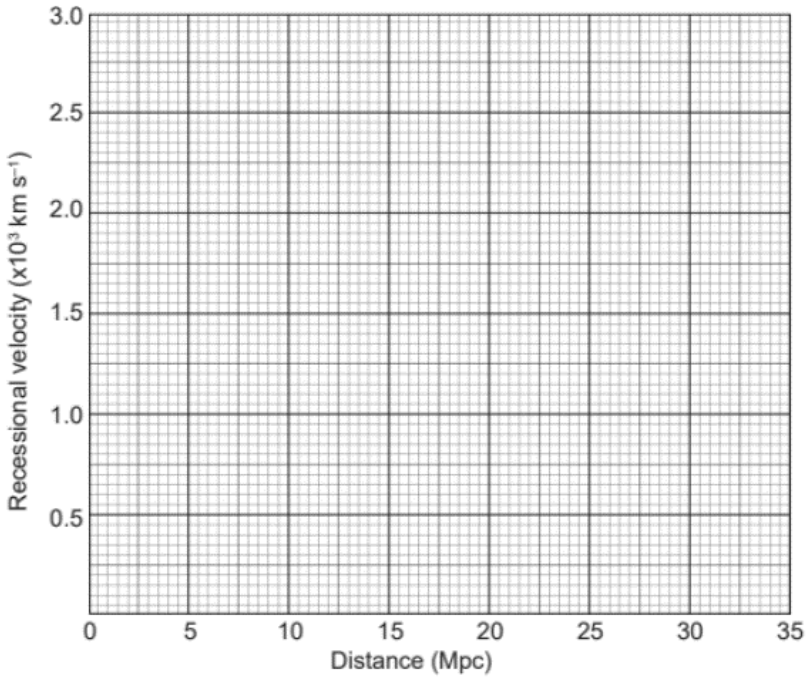
H_0 = Hubbles constant

Below is some data Hubble used to graphically determine the value of the constant.

Galaxy	Distance (Mpc)	Velocity ($x10^3$ km s^{-1})
NGC 1357	24.7	2.2
NGC 1832	31.0	2.8
NGC 2775	17.9	1.5
NGC 2903	7.0	0.5
NGC 3368	11.9	0.9

Note: 1 parsec (pc) = 3.26 light years

(a) Graph the recessional velocity vs. distance on the set of axes provided below and draw a line of best fit. 2



(b) Calculate Hubble's constant from your line of best fit and use this to determine the age of the universe in years. 3

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Question 34 (8 marks)

Analyse the relationship between theory and experiment.

Refer to historical examples in your response.

QUESTION NUMBER

EXTRA WRITING SPACE

WRITE THE QUESTION NUMBER(S) IF APPLICABLE

EXTRA WRITING SPACE

WRITE THE QUESTION NUMBER(S) IF APPLICABLE

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QUESTION NUMBER

Please write your name neatly in the box.

2024

HIGHER SCHOOL CERTIFICATE EXAMINATION – TRIAL PRACTICE I

Physics

General Instructions

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- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
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Total marks: 100

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- Allow about 30 minutes for this section

Section II – 80 marks

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Solutions and Feedback ☺

Multiple Choice Solutions

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

Section II

Part B – 80 marks

Allow about 2 hours 30 minutes for this part.

Question 21 (7 marks)

(a)

Criteria	Marks
Correctly DERIVES the orbital velocity equation AND Correctly calculates the speed of the satellite	2
Correctly DERIVES the orbital velocity equation OR Correctly calculates the speed of the satellite	1

Sample answer

$$F_G = F_C$$

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

$$v = \sqrt{\frac{GM}{r}}$$

$$v = \sqrt{\frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{6.721 \times 10^{6}}} = 7717\ m\ s^{-1}$$

(b)

Criteria	Marks
Clear explanation of why the net force on the satellite is not zero AND States that the direction of the satellite is changing	3
Clear explanation of why the net force on the satellite is not zero	2
Partial explanation of why the net force acting on the satellite is not zero	1

Sample answer

As the satellite orbits the Earth, the direction of its motion (and hence it's velocity) changes.

Seeing as $\boldsymbol{a} = \frac{\Delta v}{\Delta t}$, then the object undergoes an acceleration and hence, according to F_{net} = ma, must be subject to a net force.

(c)

Criteria	Marks
Clear explanation of why the person feels weightless	2
Makes ONE relevant statement regarding the scenario	1

Sample answer

Both the satellite and the person inside the satellite are in 'free-fall' around the Earth. Both the satellite and the person are experiencing the same acceleration (provided by gravity), therefore there is no way for the satellite to provide a normal / reaction force to the person and seeing as the sensation of weight depends on the magnitude of this normal / reaction force, then the person would feel weightless.

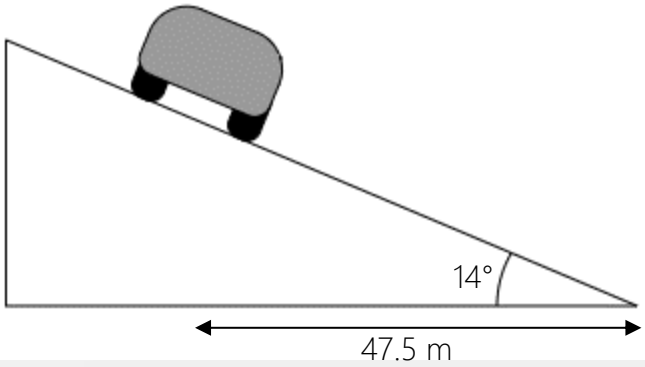
Feedback:
Students were mostly able to calculate the orbital speed of the satellite although many didn't derive the equation for orbital velocity. Most issues in the calculation were incorrectly determining the radius to the satellite, either not converting the 350 km to m, or forgetting to add the radius of the Earth.

In part b, students needed to recognise the difference between speed and velocity as being due to the changing direction in order to access full marks. Many students mistakenly discussed a constant linear velocity or suggested that a constant velocity could still lead to an acceleration. Some students struggled to make the link between force and acceleration.

In part c, many students included a calculation or explanation of why increasing r led to decreased force of gravity, without recognising that the weightlessness was due to a lack of normal force rather than a decreasing gravitational force.

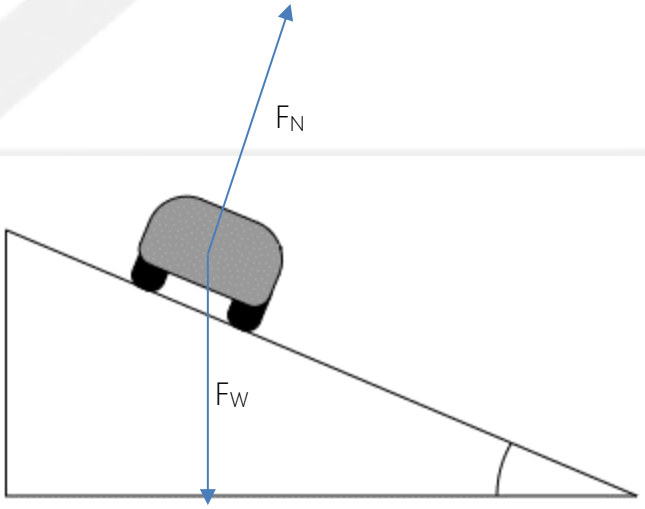
Question 22 (6 marks)

(a)



Criteria	Marks
Correctly labels the weight force and normal force AND NO EXTRA FORCES DRAWN AND Both forces drawn from the centre of mass of the object AND vertical forces cancel (i.e., $F_N\cos 14 \approx F_W$)	4
3 of the above	3
2 of the above	2
1 of the above	1

Sample answer



(b)

Criteria	Marks
Correctly derives the formula – showing ALL steps	1

Sample answer

$$\boldsymbol{F_N \sin\theta = \frac{mv^2}{r}\,(1)}$$

$$\boldsymbol{F_N \cos\theta = mg \rightarrow F_N = \frac{mg}{\cos\theta}\ (sub\ into\ (1))}$$

$$\boldsymbol{mg\tan\theta = \frac{mv^2}{r} \rightarrow v = \sqrt{gr\tan\theta}}$$

(c)

(d) Criteria	Marks
Correctly solves for the ideal speed	1

Sample answer

$$\boldsymbol{v = \sqrt{gr\tan\theta} = 10.8\ ms^{-1}}$$

Feedback:
In part a, many students included either gravity or normal force at an incorrect angle or included an additional force such as friction or an additional centripetal force. This made it difficult to derive the equation in part b. I generally accepted anywhere within the car as the centre of mass (I'm very kind), but not below the car.

Part b sometimes lacked the necessary working, and since the final answer was given in the question, it was essential to show the working to get to the final answer. If I couldn't see where the cos and sin parts came from (either in the working or from the diagram), I didn't award the mark.

Part c was very well done. Main issues were people having their calculators in radians (amateurs) or trying to find the length up to the car rather than using the radius given in the question.

Question 23 (4 marks)

(a)

Criteria	Marks
Correctly calculates the force exerted by the spring on the platform (including direction)	2
Makes some progress in calculating the force exerted by the spring on the platform	1

Sample answer

$$\boldsymbol{\tau_{net} = 0}$$

$$\boldsymbol{\therefore\ r_1F_1 = r_2F_2 + r_3F_3}$$

$$\boldsymbol{F_1 = \frac{r_2F_2 + r_3F_3}{r_1} = \frac{(0.8 \times 210 \times 9.8) + (3.0 \times 75 \times 9.8)}{2.1} = 1834\ N\ down}$$

(b)

Criteria	Marks
Correctly calculates the force exerted by the fulcrum on the platform (including direction)	2
Makes some progress in calculating the force exerted by the fulcrum on the platform	1

Sample answer

$$\boldsymbol{F_{net} = 0}$$

$$\boldsymbol{\therefore \sum F_{up} + \sum F_{down} = 0}$$

$$\boldsymbol{F_{Fulcrum} = F_{spring} + F_{W1} + F_{W2} = 4627\ N\ Upwards}$$

Feedback:
This question was generally poorly done. In part a, many students calculated a torque rather than a force, or considered the mass of the platform to be acting at a further position than the centre of mass. Many students didn't consider the torque of the platform itself, but rather considered only the box and the spring.

In part b, students again had difficulty distinguishing force from torque, or considered the mass of the box or platform, rather than adding the weight forces from both.

MANY students started calculating forces or torques without first writing the equation of what they were marking. In this case, it becomes very difficult to achieve partial marks. For part a, even recognising that the total torque of the system was 0 could get 1 mark, but students who didn't include this step in their working had difficulty accessing these lower marks. Showing working is essential!

Question 24 (5 marks)

(a)

Criteria	Marks
Correctly solves for the range of the golf ball	5
Makes substantial progress in determining the range of the ball	3-4
Calculates ONE relevant quantity	2
Provides ONE correct step in the calculation	1

Sample answer

Note: There is some tolerance in the measurements of the angles and distances, so there will be tolerances in the final answer.

Using scale diagram: 6 cm = 1.75 m

∴ 1 cm = 29.17 cm (should be 28-30 cm)

In increment of time prior to striking ball, golf club moves through an angle of 24° (measured by protractor) (best to use before as AFTER, the speed of golf club will change due to LOCOM)

Using $v=r\omega \rightarrow$ v=25 m s^{-1} (using horizontal displacement of golf club in same time interval also gives ~25 m s^{-1})

Using diagram, angle of elevation is roughly $\tan^{-1}(0.6/3)$ = 11°

$$Range = \frac{38^2 \sin 22}{9.8} = 55\ m$$

Feedback:
If you don't have a protractor, either ask to borrow one, or make up a number for the angle and use this made up number to do your calculations. You will still be able to achieve partial marks for the question.
Some students confused the velocity of the ball with the velocity of the golfer, or assumed that the time increment of 0.02s referred to the spacing between the photos of the ball, even though the question specifically said this wasn't the case.

Question 25 (5 marks)

(a)

Criteria	Marks
Correctly identifies that the reading on the balance should INCREASE AND Relates to an **additional** repulsive force between the two wires / force down on bottom wire when current is turned on	3
Correctly identifies that the reading on the balance should INCREASE AND Relates the change in reading on the scale to the forces between the wires	2
Correctly identifies that the reading on the balance should INCREASE OR Relates a change in reading on the scale to the forces between the wires	1

Sample answer

The reading on the balance should increase.

Before the current is turned on, the only force acting on the bottom wire (and hence the only force measured by the balance), is the weight force acting on the wire.

When the current is turned on, an additional force arises between the two wires. As the current will be in opposite directions, the parallel current carrying wires will experience a repulsive force between them.

This means the bottom wire will experience an additional force in the same direction as the weight force (vertically downwards) and hence the scale will experience a larger force, resulting in an increased reading displayed on the scale.

(b)

Criteria	Marks
Correctly calculates the current through the wires	2
Makes some progress in calculating the current through the wires	1

Sample answer

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

$$\boldsymbol{4.55 \times 10^{-6} \times 9.8 = \frac{2 \times 10^{-7} \times I^2 \times 0.105}{0.0175}}$$

$$\boldsymbol{\therefore I = 6.1\ A}$$

Feedback:
In part a, most students were able to determine that the reading on the balance increased due to repulsive force between the wires. However, many students struggled to relate this to an additional force beyond the original weight force.

In part b, majority of students were able to apply to correct equation for this calculation, but many converted the 4.55 mg to g, rather than kg, the SI unit for mass.

Question 26 (7 marks)

Criteria	Marks
• Demonstrates a thorough description of the structure of a transformer AND • Demonstrates an extensive understanding of the operation of a step-down transformer AND • Describes, in detail, 2 strategies used to improve transformer efficiency AND • Includes a relevant, labelled diagram	7
• Demonstrates a sound description of the structure of a transformer AND • Demonstrates a thorough understanding of the operation of a step-down transformer AND • Describes 2 strategies used to improve transformer efficiency AND • Includes a relevant diagram	6
• Demonstrates a sound description of the structure of a transformer AND • Demonstrates a sound understanding of the operation of a step-down transformer AND • Describes 2 strategies (or 1 in detail) used to improve transformer efficiency AND • Includes a relevant diagram	5
• Demonstrates a sound description of the structure and/or operation of a transformer • Describes 1 strategy used to improve transformer efficiency and/or includes a relevant diagram	3-4
• Demonstrates a basic description of the structure and/or operation of a transformer and/or strategies to improve efficiency	2
• Some relevant information	1

Sample answer

Structure:

- Two coils
- Iron core
- More coils in primary than secondary

Operation:

- AC in
- Change in current leads to change in flux
- Iron core carries flux
- Faradays law, flux change leads to emf, size depends on number of turns

Two strategies

e.g. laminate core, use soft iron, wires made of conducting material, wind coils on top of each other, use toroidal core

Relate strategy to efficiency, e.g. minimise eddy current/heat or increase flux linkage

Feedback:
Many diagrams weren't labelled – an unlabelled diagram is a scribble. Use your diagram to support your response, not just floating on the side. Better answers were able to refer to the diagram within the explanation of structure and/or function. Most students included a diagram of a transformer, but some also included a diagram showing the benefit of laminations for reducing eddy currents.

Some people spent large amounts of time describing the purpose of a step-down transformer, and even identifying where it is used in household electricity supply. RTFQ. This question asked about structure, operation, and strategies for improved efficiency. It did not ask about the purpose or application of a step-down transformer. Most students who discussed application were not able to answer the full question.

When describing operation, it was so important to go through the steps of current inducing B field and change in flux inducing current. Transformers/motors are the summary of module 6, where you show that you understand the concepts by applying them to these situations.

You should be allll over this.

Question 27 (8 marks)

(a)

Criteria	Marks
Identifies the name of the part labelled (a) AND identifies the function of the part labelled (a)	2
Identifies the name of the part labelled (a) OR identifies the function of the part labelled (a)	1

Sample answer

Slip Rings.

These ensure a continuous connection is established between the coil and the external circuit.

(b)

Criteria	Marks
Labels the correct direction of current in the rotor coil	1

(c)

Criteria	Marks
Labels the correct direction of current in the rotor coil based on response to (b)	1

(d)

Criteria	Marks
Labels the correct direction of current in the rotor coil based on response to (c)	1

(e)

Criteria	Marks
Identifies that the EMF would be maximum in this position. AND Relates this to the concept of flux / rate of change in flux in detail.	3
Identifies that the EMF would be maximum in this position. AND Relates this to the concept of flux / rate of change in flux	2
Identifies that the EMF would be maximum in this position. OR Relates this to an induced EMF to the concept of flux / rate of change in flux	1

Sample answer

The induced EMF would be maximum at this position.

$$\varepsilon = -n\frac{\Delta\phi}{\Delta t} \qquad and \qquad \phi = BA\cos\theta$$

In the position shown, θ = 90°. This means that the flux passing through the coil at this time is zero.

It also means that the rate at which flux is changing through the coil is a maximum value. (should supplement this by a graph showing gradient is largest at x-intercept or by using some maffs.)

Seeing as $\varepsilon = -n\frac{\Delta\phi}{\Delta t}$, this means that the induced EMF would also be a maximum value at this position.

Feedback:
Nearly everyone used the word commutator in their description for part a. I have no idea why. Even those who were able to determine that these are slip rings described its purpose as maintaining the direction of current, rather than connection with the external circuit, so I think you are getting confused from the use of this word commutator.

Lots of people determined that flux is 0 at this position and incorrectly concluded that the change in flux is also 0. Remember that flux is a cos curve so the change in flux is not proportional to flux. Rather, change is largest at the point where flux is 0.

Question 28 (6 marks)

Criteria	Marks
Outlines how rotational and radial/translational motion of star can be determined, refers in detail to analysis of spectral lines	6
Outlines how rotational and radial motion of star can be determined, refers to analysis of spectral lines	5
Describes how rotational and/or radial motion of star can be determined, refers to spectral lines	3-4
Identifies an aspect of a star's motion that can be determined from spectral lines	2
Some relevant information	1

Sample answer

When analysing the absorption spectrum of a star, we can use the doppler effect to determine its motion.

The radial component of its translational velocity can be determined by examining the shift in the absorption lines in the spectrum of the star.

If the lines are red shifted, it means that the star is moving away from us

If the lines are blue shifted, it means that the star is moving towards us

The extent of the shift gives us an indication of how fast the star is moving away from / towards us, the larger the shift the larger the magnitude of the radial component of the translational velocity.

We are also able to determine the rotational velocity of the star.

Seeing as, from our position, a star has zero angular width, this means that we receive all the light from the star at once. If the star has a component of its rotational velocity along our line of sight, we will see one side of the star spinning towards us (i.e., spectral lines blue shifted) and one side of the star spinning away from us (i.e., spectral lines red shifted).

As the star spins along our line of sight, the tangential velocity at different points on the surface of the star is at different angles relative to our line of sight, resulting in the velocity towards / away from our line of sight being $v\cos\theta$, where θ is the angle between our line of sight and the tangential velocity vector, this results in a continuous redshift, from 0 (when $\theta = 90°$) to some max value (when $\theta = 0$), this results in a broadening effect (doppler broadening), rather than just a shift. [Diagram would be nice]

The extent of the broadening gives us an indication of the rotational velocity of the star along our line of sight.

Feedback:
Some students didn't read the question properly and wrote about density, temperature or chemical composition. Others went overboard on a long discussion about how spectral lines arise, referring to Planck's equation for the energy between the electron levels. None of this could achieve you any marks so it was largely ignored.

Lots of people included pictures to show doppler shift or the fact that rotation leads to movement both away and towards observer, these pictures were good. It was important to spell out that red shift = movement away and that blue shift = movement towards (some people gave lots of detail here), as well as link the magnitude of the shift to the magnitude of the velocity. This description of magnitude was missing from a lot of responses.

Similarly, when discussing doppler broadening, it was important to note that the amount of broadening, or thickness of spectral line, was linked to rotational velocity. Missing this cost you marks.

In general, for students who stayed on track, this question was well done.

Question 29 (4 marks)

Criteria	Marks
Shows correct path of red and blue/violet corpuscles AND Uses cause and effect to explain the differences in their paths, in detail	4
Shows correct path of red and blue/violet corpuscles AND Uses cause and effect to explain the differences in their paths	3
Shows correct path of red and blue/violet corpuscles AND/OR Describes the different forces on different particles	2
Describes the corpuscular model of light	1

Sample answer

Newton believed that white light was composed of different corpuscles, where different coloured corpuscles had different masses / sizes.

He believed that red light was the most massive and violet light had the least massive corpuscles.

When the white light is in air (or any uniform medium), the forces are uniform in all directions, meaning no net force acts on any corpuscle and they continue in a straight line.

When the corpuscles encounter a boundary (i.e., air $\rightarrow$ glass), there is an unbalanced force along the normal into the higher density medium.

Seeing as the same force is experienced by all corpuscles, those with higher mass experience less acceleration (F_{net} = ma) and hence their paths deflect less upon encountering the boundary.

Therefore, the red corpuscles deflect the least and travel the slowest through the glass, whereas the violet corpuscles deflect the most and travel the fastest through the glass.

Feedback:
This question was poorly done. Most students didn't refer to the effect of dispersion, and didn't include any discussion of colour at all. Others referred to the wave nature of light, irrelevant to Newton's understanding of light.

Many students confused the force with acceleration, saying that violet/blue corpuscles had the most mass and therefore the most force (causing large deflection), rather than recognising that smaller mass would lead to larger acceleration and thus larger deflection.

Some students explained the reasons why Newton was wrong, which is not relevant to the question which was asked.

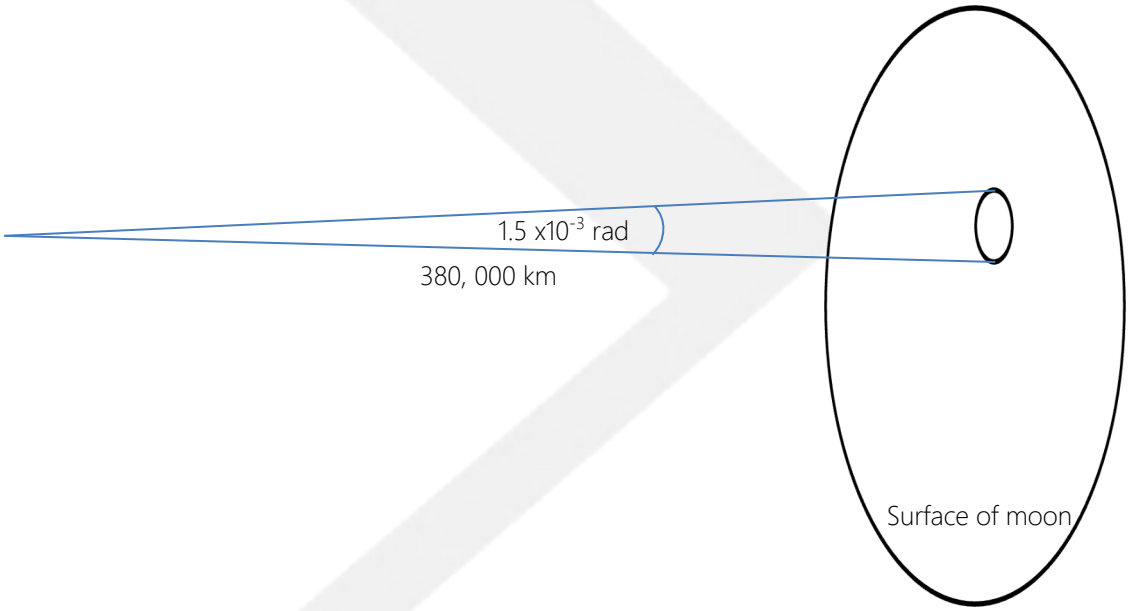
Too many students commented on Chris' poor genetics.

Question 30 (5 marks)

Criteria	Marks
Correctly calculates the number of photons striking the surface each minute	5
Correctly calculates the number of photons striking the surface each minute with minor error or omission	4
Makes substantial progress to determining the number of photons striking the surface each minute	3
Calculates ONE relevant quantity	2
Provides ONE correct step in the calculation	1

Sample answer

$$P = \frac{E}{t} = \frac{nhf}{t} \rightarrow n = \frac{Pt}{hf} = \frac{0.5 \times 10^{-3} \times 60}{6.626 \times 10^{-34} \times \frac{3 \times 10^{8}}{475 \times 10^{-9}}} = 7.17 \times 10^{16}\ min^{-1}$$



$$Using\ l = r\theta \rightarrow l = 3.8 \times 10^{5}\ \times\ 1.5 \times 10^{-3} = 5.7 \times 10^{2}\ km$$

This is the value of the DIAMETER of the circular spot on the surface of the moon.

$$Using\ A = \pi r^2 \rightarrow A = \pi\ \times \left(\frac{5.7 \times 10^{2}}{2}\right)^2 = 2.55 \times 10^{5}\ km^2$$

$$\therefore n = \frac{7.17 \times 10^{16}}{2.55 \times 10^{5}} = 2.81 \times 10^{11}\ photons\ km^{-2}\ min^{-1}$$

Feedback:



Many students didn't attempt this question, or made a limited attempt.
Generally, students were able to recognise the relationship between power, energy and wavelength/Planck's constant, but had more difficulty determining the area of the moon that was hit by this beam.
Some students forgot the formula for the area of a circle, or were unable to determine the radius of the beam using the angle and distance to the moon.
Some students forgot how many metres in a kilometre or how many seconds in a minute.

This question was where I started to question why I tutor…..

Question 31 (3 marks)

Criteria	Marks
Correctly calculates the speed of the spaceship	3
Provides substantial working to calculate the speed of the spaceship	2
Provides one correct step in calculation	1

Sample Answer

$$t = \frac{d}{v}$$

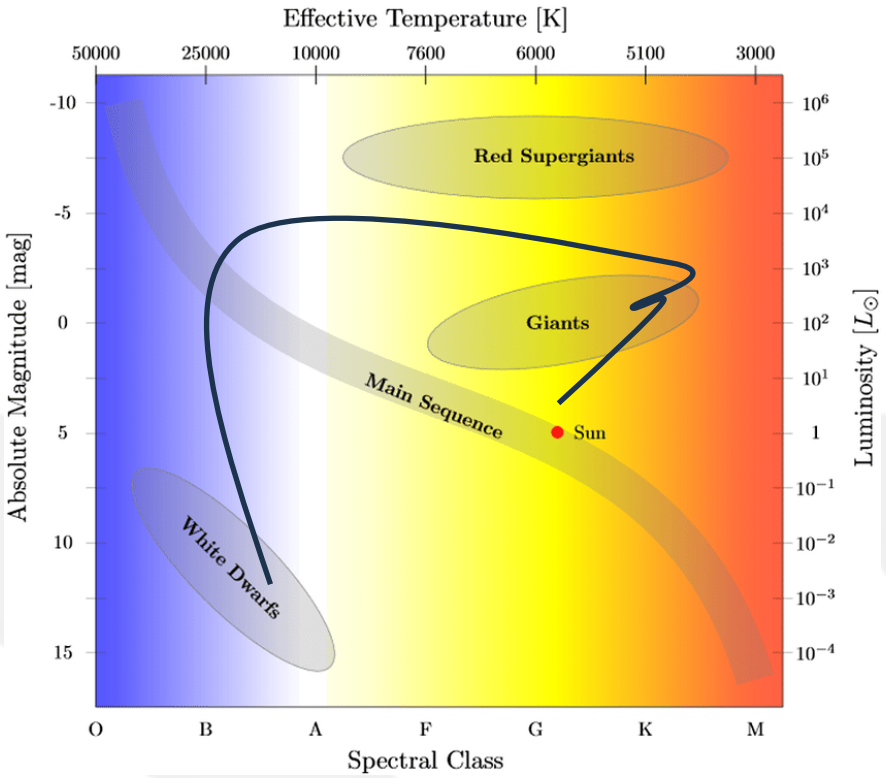
$$11 = \frac{5.96\sqrt{1 - v^2}}{v} \; (where\ v\ is\ in\ terms\ of\ c)$$

$$v = 0.476\ c$$

Feedback:
You can't turn a distance into a time using only a Lorentz factor. 5.96 ly is a distance, 11 years is a time. You needed to realise that these are related through v=d/t, as well as using the Lorentz factor to convert one of them to the same inertial reference frame as the other.

However, I didn't realise that my marking scheme was wrong until after I finished marking all of them so if you got 0.476c then I probably owe you a mark. ☺

Question 32 (7 marks)



(a)

Criteria	Marks
Correctly sketches the evolutionary pathway for the Sun	2
Sketch is MOSTLY correct	1

(b)

Criteria	Marks
Describes, in detail, the processes which will occur within our Sun during its lifetime. • Main Sequence • Giant phase (Red Giant, Red Clump, AGB) • White Dwarf	5
Describes the processes which will occur within our Sun during its lifetime but lacks detail or clarity. • Main Sequence • Giant phase • White Dwarf	4
Describes the processes which will occur within our Sun during 2 stages in its lifetime.	3
Identifies TWO processes which occurs within the Sun at some stage within its lifetime. OR Describes ONE process which occurs within the Sun at some stage	2
Identifies ONE process which occurs within the Sun at some stage within its lifetime.	1

Sample answer

Note:
No need to talk about the contraction of the gas cloud and formation of a star as the star has not been 'birthed' yet and hence it is not part of its 'lifetime' per se. But, if it's even MORE marks than this, go for it.

Also Note:
This answer is pretty fkn comprehensive.

Main Sequence:
During the Sun's lifetime on the main sequence, it is undergoing nuclear fusion of hydrogen to helium via the P-P chain and the C-N-O cycle in its core.

WOULD BE NICE IF YOU GAVE AN EQUATION OF EITHER OR BOTH

This gives rise to a radiative pressure which balances the gravitational force inwards, resulting in the star being in a hydrostatic equilibrium.

Energy is radiated away from the photosphere at the same rate as which energy is absorbed from the layers beneath the photosphere, meaning the photosphere is also in a thermal equilibrium and hence it emits a continuous black body spectrum with the wavelength of maximum emission being inversely proportional to the temperature of the photosphere.

Giant Phase:

Red Giant
When the Sun runs out of useable hydrogen within its core, it will have an inert core of helium surrounded by a shell of inert hydrogen. As no fusion reactions are occurring in the star, the radiative pressure outwards will cease and hence, with nothing to oppose the gravitational force inwards, the star will begin to contract.
As the star contracts, work is done on the gas by gravity and this results in a higher internal energy of the gas, resulting in an increase in temperature.
As the temperature increases, hydrogen in a shell surrounding the core now has the conditions necessary for hydrogen fusion to occur. Thus, hydrogen $\rightarrow$ helium fusion occurs via the CNO cycle in the shell surrounding the core. This results in a very large outward radiative pressure, causing the star to expand (and cool) until it gets to the point where the outward pressure is equal to the gravitational force inward (hydrostatic equilibrium)
The helium which is formed will settle into the core (due to higher density than surrounding hydrogen), increasing the amount of helium in the core, increasing the temperature of the core until it gets to ~100M Kelvin, which is the temperature required for Helium fusion to commence.

Red Clump
At this stage, the hydrogen fusion in the shell surrounding the core is supported by helium fusion in the core via the triple alpha process

WOULD BE NICE IF YOU GAVE AN EQUATION

This process continues until the core has exhausted its supply of He.

AGB (Asymptotic Giant Branch)

This leads to an inert carbon (and oxygen) core, which contracts further, but will not give rise to the temperatures required for C and O fusion into heavier elements (this occurs in stars > 8 solar masses). This core is surrounded by a shell of helium undergoing fusion via the triple alpha process, surrounded by a shell of hydrogen undergoing fusion via the C-N-O cycle.

This continues until the conditions for H / He fusion are no longer supported, at which stage, large winds are created on the star and drive off the outer layers of the star resulting in a planetary nebula.

At the centre of the planetary nebula is the remnants of the core of the giant star, which is now a white dwarf.

White dwarf

At this stage, there are no nuclear fusion reactions taking place. The star is in a hydrostatic equilibrium due to the gravitational contraction being opposed the electron degeneracy pressure within the white dwarf.

The white dwarf is now composed of degenerate matter, in which all of the available energy levels are filled with electrons. In order for gravity to compress the white dwarf any futher, it would need to force electrons into positions where they cannot go and this would violate Pauli's exclusion principle. In order to ensure this does not happen, an effective pressure (electron degeneracy pressure) is created which prevents the further collapse of the white dwarf.

The white dwarf will continue to radiate away energy from its photosphere, but as it does not receive any energy from reactions underneath the photosphere, energy will be lost and the white dwarf will cool over time.

Feedback:

Part a was very poorly done. Only some students were able to recognise that the sun would become a red giant and then a white dwarf, and less than a handful could identify the path the sun would take, especially as a red giant.

In part b, most students recognised the proton-proton chain and, to a lesser extent, the CNO cycle as processes occurring in the sun during main sequence and/or red giant phase. Some students referred to the triple alpha process, but didn't distinguish between the various stages of the red giant phase.

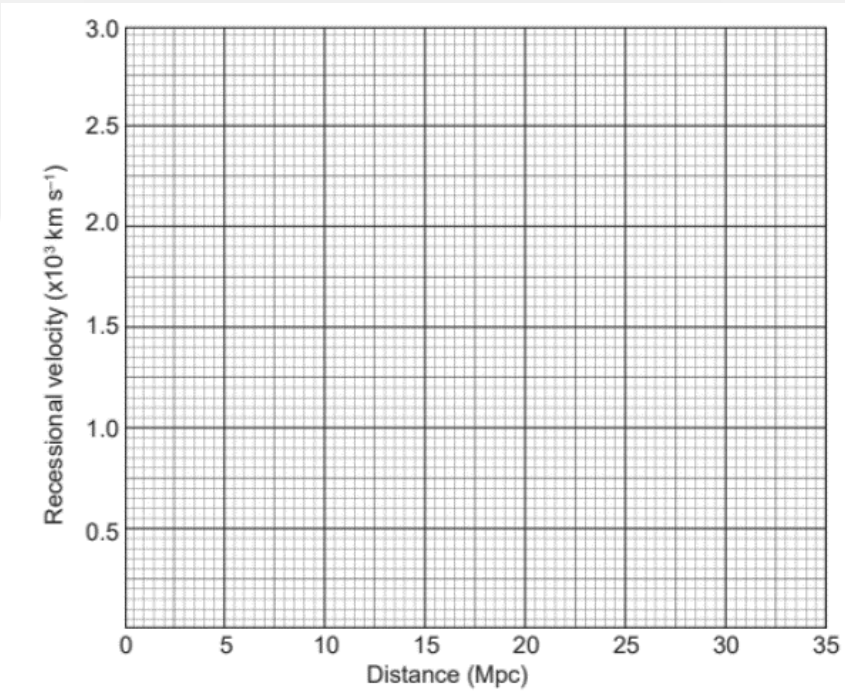
Some students suggested the sun would trigger a supernova or become a neutron star or black hole at some stage in its life cycle. The sun is not heavy enough to do this.

Many students understood the white dwarf phase of the stellar life cycle and discussed electron degeneracy as holding up the star, whilst others could only state that fusion wasn't happening, it was just hot and shining.

Question 33 (5 marks)

(a)

Criteria	Marks
Correctly plots all points AND Draws an appropriate line of best fit	2
Correctly plots 4 points OR Draws a mostly appropriate line of best fit	1



(b)

Criteria	Marks
Correctly calculates gradient of LOBF using 2 valid, widely spaced points ~$1x10^2$ km s^{-1} MPc^{-1} AND Uses gradient to determine age of the universe (~$3.1x10^{17}$ s → 9.8 billion years)	3
Calculates gradient of LOBF using 2 points AND Uses gradient to determine age of the universe	2
Calculates gradient of LOBF using 2 points OR Uses gradient to determine age of the universe	1

Feedback:
In part a, many students struggled to use the scale provided to accurately plot the points.

This is where I started questioning what you guys learnt in Year 7….

Most lines of best fit were good, but it was more difficult if you had incorrect points.

Many students could calculate a gradient using rise/run, although many students used data from the table instead of data from the graph. If the question says to use your graph you MUST use points on your line of best fit. Points from the table provided will NOT get you any marks. If the points from the table happen to lie on your graph, you can only use them if you CLEARLY show them being used to calculate a gradient (e.g. drawing the dotted lines on your graph from the point to the axes). You also need to pick points that are fairly well spaced so you don't have errors that are too large.

After determining the gradient, most students didn't know the units, didn't include the factor of 10^3 from the y axis, or forgot what a Mpc was. I'll forgive you for the Mpc one but the others….

A concerning number of students determined the age of the universe to be less than a minute…

That would be a very interesting universe indeed!

Question 34 (8 marks)

Criteria	Marks
• Provides an extensive understanding of the changing relationship between theory and experiment. • Uses at least 2 historical examples to support their answer.	8
• Provides an extensive understanding of the relationship between theory and experiment. • Uses 2 historical examples to support their answer.	7
• Provides a thorough understanding of the relationship between theory and experiment. • Uses 2 historical examples to support their answer.	6
• Provides a sound understanding of the relationship between theory and experiment. • Uses 2 historical examples to support their answer.	5
• Provides a sound understanding of the relationship between theory and experiment. • Answer supported by a relevant historical example	4
• Provides details of the relationship between theory and experiment. • Answer supported by a relevant historical example	3
• Identifies some details of theories and/or experiments	2
• Provides some relevant information	1

Sample answer

(Note: This answer was written by a student and achieved full marks. It may contain some minor inaccuracies.)

Throughout the advancement of science, theory and experiment went hand-in-hand. Scientists would undergo the scientific method, starting with a hypothesis, then designing and conducting an appropriate and valid experiment to test the hypothesis. After conducting the experiment, scientists would explain the observed results with a valid theory.

This method is visible in most historical experiments such as the Geiger-Marsden Experiment. The Geiger-Marsden experiment discovered the nucleus of the atom by firing alpha particles at a gold foil and detecting their deflections. Unexpectedly, about 1 in every 8000 particles was being deflected back at an angle larger than 90°. This led to Rutherford making his model of the atom to explain these results. Rutherford made a model with a large, dense, positively charged mass in the centre of the atom to explain the observed deflections in the Geiger-Marsden experiment. Thus, Rutherford explained the observed results of the experiment in his model, showcasing the relationship between theory and experiment. Historically, scientists like Rutherford would observe phenomena from experiments like the Geiger-Marsden experiment and explain it with appropriate theories, models or equations.

This relationship between theory and experiment, however, changed in the 1900s with the advent of quantum physics. Suddenly, many phenomena and relationships were being explained by theory earlier, and proven by experiment later. An example of this is De Broglie's wave-particle duality. De Broglie explained the idea of particles also possessing wave properties, however there was no experimental evidence. De Broglie proposed his matter waves in order to explain Bohr's model of the atom. De Broglie's theory was later experimentally proven through the Davisson-Germer experiment. When firing electrons at a nickel surface in a vacuum chamber, gas leaked out and the surface of the nickel was heated to preserve the conditions of the nickel. However, this caused the particles in the metallic lattice to clump together. When the electrons were fired at the nickel, they passed through the gaps formed by the nickel, allowing the electrons to diffract as they passed through the gaps. The interference pattern was detected and thus proved that electrons had wave properties and can be explained as waves proposed earlier by De Broglie. This highlights the changing nature of the relationship between theory and experiment as De Broglie proposed his theory earlier and it was later proved by the Davisson-Germer experiment, in contrast to earlier when theory was used to explain the results from experiment such as Rutherford making his model of the atom to explain the results observed in the Geiger-Marsden experiment.

Feedback:
Many students reinterpreted this question as being a completely different question, such as "how does experiment support a theory?" or, more concerningly, "how did the model of the atom change over time?"
This is an analyse question, so it focuses on relationships between ideas, in this case, the different relationships that exist between theory and experiment. As a bare minimum, you should have discussed:

- Experiment leading to a theory e.g. Rutherford's gold foil
- Theory leading to an experiment e.g. the Hafele Keating experiment

You could also consider theories that arise from observation (e.g. Planck's quantisation of light energy) that needed more experimental evidence before being accepted.
It's not an identify question, so you couldn't just state one relationship between theory and experiment, you needed multiple.

The question states that you must refer to historical examples, when you see a plural you have to do more than one. In this case, that means more than one theory and more than one experiment.

Many students had the misconception that a theory is a guess and that an experiment proves it right or wrong. This is very concerning. Theories are accepted scientific ideas.

Many students referred to experiments "proving" experiments right or wrong which is not great wording, experiments can support theories or not support them, but they don't really prove anything, only maths has proofs, science has strong evidence for.

Also this is not an English essay, you don't need to use fancy words especially when you don't know what they mean. You don't need a conclusion that restates things you've already said or PEEL paragraphs.

You needed to make very clear links between theories and experiments, and for the full 8 marks, you needed to show an understanding of how the relationship between theory and experiment has changed over time, especially after 1900 (modern physics), where theories are now proposed based on calculation or thought experiment, and the experimental support comes later.