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# ***PHYSICS***

## ***2022***

### ***Trial Examination***

***(2 hours 30 minutes)***

| <i>Section</i> | <i>Number of questions</i> | <i>Number of questions to be answered</i> | <i>Number of marks</i> |
|----------------|----------------------------|---|------------------------|
| A              | 20                         | 20  | 20                     |
| B              | 18                         | 18  | 110                    |
|                |                            |   | Total 130              |

(Note: Use the formula/data sheets supplied by VCAA)

## SECTION A –20 Multiple-choice questions (20 marks)

### Instructions for Section A

Answer **all** questions in this section.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams are **not** drawn to scale.

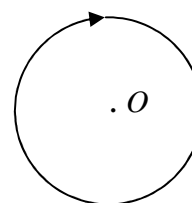
Take the value of  $g$  to be  $9.80 \text{ N kg}^{-1}$ .

### Question 1

An electron moves in a circular path (centred at  $O$ ) as shown in the following diagram.

The magnetic field causing the motion of the electron is

- A. uniform and directed into the page
- B. radial and directed from  $O$
- C. radial and directed towards  $O$
- D. circular and centred at  $O$



### Question 2

Let  $R_E$  be the radius of planet Earth. The gravitational field of the Earth at  $R_E$  above its surface is  $g_a$ .

When the gravitational field is  $\frac{g_a}{4}$ , the distance above its surface is

- A.  $5R_E$
- B.  $4R_E$
- C.  $3R_E$
- D.  $2R_E$

### Question 3

Electric current flows into the page in each of two parallel long straight wires A and B as shown in the diagram.

The direction of the magnetic force on wire B is

- A. vertically upwards
- B. to the left
- C. into the page
- D. none of the above



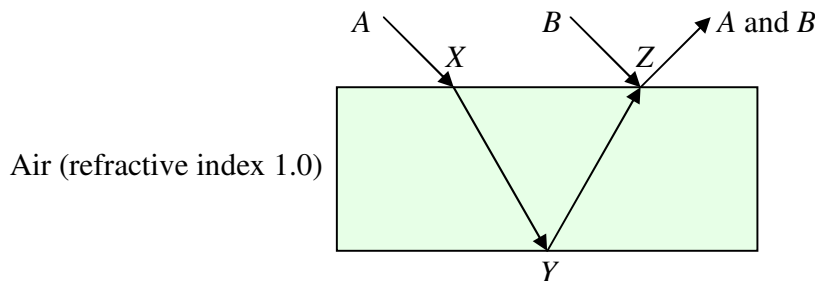
**Question 4**

Energy ( $\times 10^6$  J) required bringing a 1 kg mass from the surface of the Earth to an altitude of 1 Earth radius is closest to

- A. 60
- B. 53
- C. 46
- D. 38

*The following information is for Questions 5 and 6*

Two parallel light rays *A* and *B* ( $\lambda = 700$  nm) hit a rectangular transparent block at *X* and *Z* respectively. Ray *A* continues inside the block, reflects at the opposite side at *Y*, finally exits the block at *Z* and combines with reflected Ray *B*. The refractive index of the block is 1.5.

**Question 5**

The critical angle for total internal reflection is closest to

- A.  $37^\circ$
- B.  $42^\circ$
- C.  $47^\circ$
- D.  $52^\circ$

**Question 6**

Destructive interference occurs when Ray *A* and Ray *B* combine. The possible distance *XY* (in nm) is closest to

- A. 200
- B. 350
- C. 525
- D. 600

**Question 7**

A satellite has an orbital radius of  $R$  and a period of  $T$ . When its orbital radius is doubled, its period is closest to

- A.  $2.3T$
- B.  $2.8T$
- C.  $\pi T$
- D.  $3.5T$

**Question 8**

The mass measurements (in grams) of four samples are: 34.23, 0.0030, 100.0 and 10.070.

The total mass (in grams) of the four samples is closest to

- A. 144.3030
- B. 144.303
- C. 144.3
- D. 144

*The following information is for Questions 9 and 10*

A 100 kg crate slides at constant velocity down a plane inclined at  $30^\circ$  to the horizontal.

**Question 9**

The reaction force (N) of the plane on the crate is closest to

- A. 980
- B. 849
- C. 500
- D. 490

**Question 10**

Due to friction, the crate exerts on the inclined plane a force of

- A. 980 N
- B. 849 N
- C. 500 N
- D. 490 N

**Question 11**

Consider the three frames of reference: (I) a descending lift coming to a stop, (II) a geostationary satellite, and (III) a train climbing up a straight sloping track at increasing speed.

Newton's First Law **holds** in

- A. (I) and (II) only
- B. (II) and (III) only
- C. (I) and (III) only
- D. none of the three frames of reference

**Question 12**

Spaceship A and Spaceship B travel side by side passing Earth at  $0.8c$ .

A clock on Spaceship A advances 60 seconds as observed by a traveler in Spaceship A.

The durations (in seconds) measured by an observer in Spaceship B and by an observer on Earth are respectively

- A. 60 and 60
- B. 60 and 75
- C. 60 and 100
- D. 75 and 60

**Question 13**

The time taken to travel a distance of  $98.5 \text{ m} \pm 0.2\%$  is  $20.3 \pm 0.1 \text{ s}$ .

The average speed (in  $\text{m s}^{-1}$ ) is best represented by

- A.  $4.85 \pm 0.04$
- B.  $4.852 \pm 0.7\%$
- C.  $4.852 \pm 0.034$
- D.  $4.8522 \pm 0.7\%$

**Question 14**

A stretched string has a length of 0.45 m. A standing wave is formed in the stretched string.

The vibrating string produces a sound wave in the air.

The sound wave in the air has a wavelength of 2.0 m and a speed of  $336 \text{ ms}^{-1}$ .

A possible wavelength (cm) of the standing wave in the stretched string is closest to

- A. 200
- B. 100
- C. 50
- D. 30

**Question 15**

A basket ball is initially thrown horizontally to the right in a school gymnasium. During its flight to the ground, its acceleration is best described as

- A.  $9.8 \text{ m s}^{-2}$  vertically downwards
- B. less than  $9.8 \text{ m s}^{-2}$  vertically downwards
- C. greater than  $9.8 \text{ m s}^{-2}$  vertically downwards plus a component to the right
- D. less than  $9.8 \text{ m s}^{-2}$  vertically downwards plus a component to the left

**Question 16**

A person attempts a bungee jump through air. Maximum speed of the person occurs when

- A. air resistance on the person is at its maximum value
- B. air resistance on the person is at its minimum value
- C. air resistance and force of gravity on the person are equal
- D. force of gravity and force of the extended bungee cord on the person are equal

**Question 17**

The dual nature of light can **best** be demonstrated by

- A. diffraction of light experiment
- B. single photon double slit experiment
- C. single electron double slit experiment
- D. photoelectric effect experiment

**Question 18**

Quantised energy levels of a hydrogen atom can be explained by

- A. absorption/emission spectra
- B. single electron diffraction experiment
- C. De Broglie's idea of matter wave
- D. dispersion of light experiment

**Question 19**

The sky appears blue on a clear day. This phenomenon is best explained by

- A. refraction of light
- B. diffraction of light
- C. polarization of light
- D. interference of light

**Question 20**

In a photoelectric effect experiment, electrons are emitted when light is directed at a metal (one of the electrodes) inside a photocell.

The emitted electrons have a range of kinetic energy. The range of kinetic energy can be determined by

- A. varying the accelerating voltage
- B. varying the retarding voltage
- C. changing the intensity of light
- D. changing the frequency of light

## SECTION B

### Instructions for Section B

Answer **all** questions in this section.

Where an answer box is provided, write your final answer in the box.

If an answer box has a unit printed in it, give your answer in that unit.

In questions where more than one mark is available, appropriate working **must** be shown.

Unless otherwise indicated, the diagrams are **not** drawn to scale.

Take the value of  $g$  to be  $9.8 \text{ N kg}^{-1}$  or  $9.8 \text{ m s}^{-2}$ .

### Question 1 (15 marks)

The following diagram shows a uniform and static magnetic field of  $1.5 \text{ T}$  directed into the page.

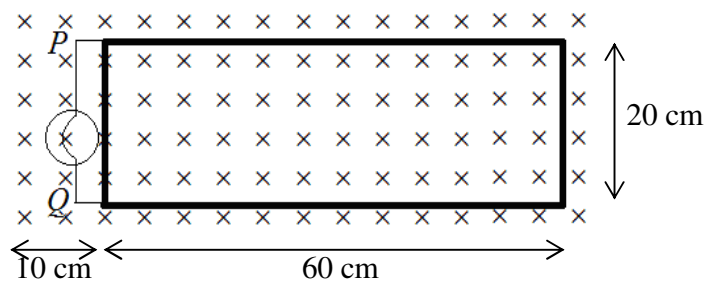
A light globe of resistance  $0.50 \Omega$  is connected to the terminals  $P$  and  $Q$  of a rectangular coil of 50 turns of enameled copper wire. The coil has negligible resistance.

The side lengths of the rectangular coil are  $60 \text{ cm}$  and  $20 \text{ cm}$ .

The coil is completely inside the magnetic field **initially**. It is pulled to the left at  $0.10 \text{ m s}^{-1}$ .

The diagram below shows the position of the rectangular coil at time  $t = 0$ .

Consider the emf induced **only** by the rectangular coil.



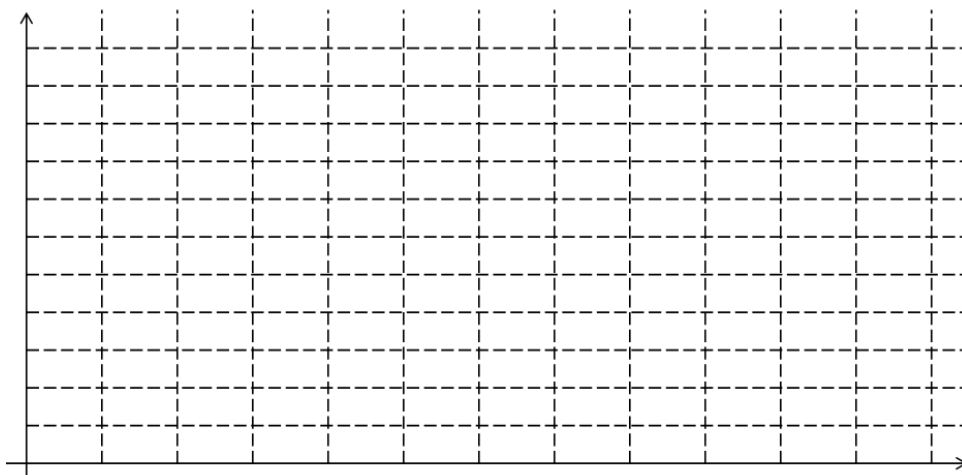
a. Calculate the maximum flux through the coil.

1 mark

wb

b. Sketch an appropriate graph showing the magnetic flux (magnitude) through the rectangular coil of 50 turns of enameled copper wire for the first 10 seconds. Label the axes and show units.

4 marks





c. Calculate the maximum difference in potential between  $P$  and  $Q$ .

2 marks

V

d. Calculate the maximum power of the light globe.

1 mark

W

e. Determine the polarity of terminal  $P$ . Explain your answer.

2 marks

f. Describe and determine the force required to pull the coil to the left at  $0.10 \text{ m s}^{-1}$  during the first 10 seconds.

3 marks

N

g. Determine the amount of work done by the force in the first 5 seconds.

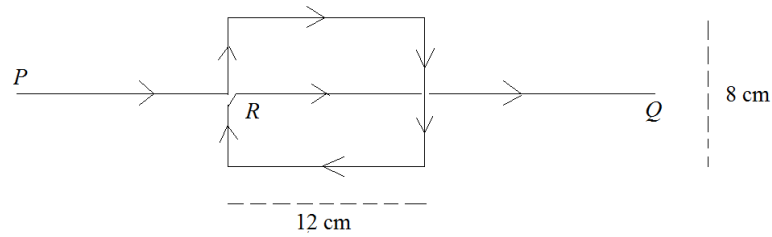
2 marks

J

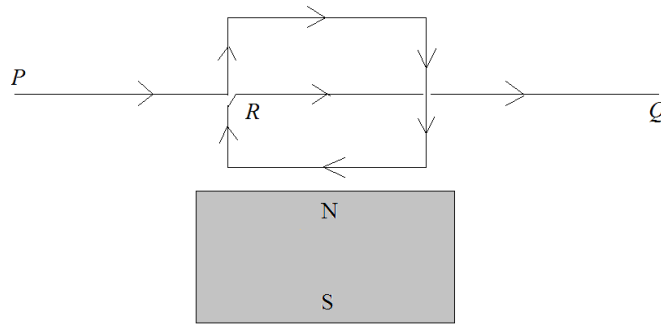
**Question 2** (8 marks)

An enameled copper wire is bent into the shape as shown below.

**Section RQ is continuous.** The rectangular loop has dimensions of 8 cm and 12 cm.



A magnet is placed just below the coils.  $PQ$  is the axis of rotation.



Assume that the magnet provides a magnetic field of 1.5 T at the lower side and decreasing gradually to 0.3 T at upper side when the loop is vertically orientated.

The arrows show the current flow in the coil when terminals  $P$  and  $Q$  are connected to a battery.

Assume that there is **zero** friction and air resistance on the moving parts.

Directions: up/down; left/right; into/out of the page; clockwise/anticlockwise

The coil is at rest initially.

- a. Compare the direction and magnitude of the magnetic forces on the lower and upper sides of the vertically orientated loop.

3 marks

|            |   |            |   |
|------------|---|------------|---|
| Lower side | N | Upper side | N |
|------------|---|------------|---|

- b. When view from the left, describe and explain the motion of the coil.

3 marks

- c. If there is some friction/air resistance on the moving parts, describe and explain the motion of the coil.

2 marks

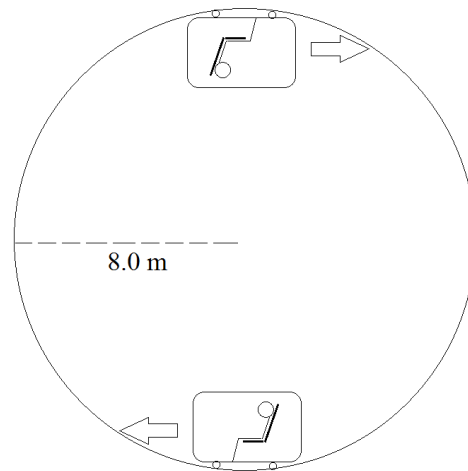
**Question 3** (10 marks)

Person A of mass 65 kg is in a vertical circular rollercoaster ride.

The diagram below shows the person at the highest and lowest point of the ride.

The rollercoaster is designed to have a maximum acceleration of  $4.1g$  ( $g = 9.8 \text{ m s}^{-2}$ ).

Assume that there is **zero** friction, air resistance and driving force on the carriage.



a. Determine the maximum speed of the carriage around the loop.

2 marks

|                   |
|-------------------|
| $\text{m s}^{-1}$ |
|-------------------|

b. Determine the maximum speed of the carriage at the highest point of the ride.

2 marks

|                   |
|-------------------|
| $\text{m s}^{-1}$ |
|-------------------|

c. Describe and explain the experience of Person A in part b in terms of acceleration and reaction force on the person.

3 marks

Now Person B of mass 85 kg is in the vertical circular rollercoaster ride under the same conditions.

d. Describe and explain the experience of Person B at the highest point in terms of maximum speed, acceleration and reaction force on the person.

3 marks

**Question 4** (8 marks)

An electron is introduced into a laboratory vacuum chamber at the surface of Earth.

A uniform electric field  $E$  and a uniform magnetic field  $B$  is maintained in the chamber to keep the particle moving in a horizontal straight line at a speed of  $1.5 \times 10^2 \text{ m s}^{-1}$ .

The electric field is directed upwards, and it is generated by a potential difference of 12 V over 3.0 m.

Assume that force of gravity on the electron is insignificant.

Directions: up/down; left/right; into/out of the page

- a. State the direction of the electric force on the electron in the uniform electric field  $E$ . 1 mark
- b. Describe the direction of the uniform magnetic field  $B$ . 1 mark
- c. Calculate the electric force on the electron. 2 marks

N

- d. Calculate the magnetic field strength required. 2 marks

T

Another charged particle which is 1000 times the mass and 2 times the charge of an electron is used instead of an electron.

- e. Discuss the changes if any to  $E$  and  $B$  necessary to keep the same speed and path of the particle. 2 marks

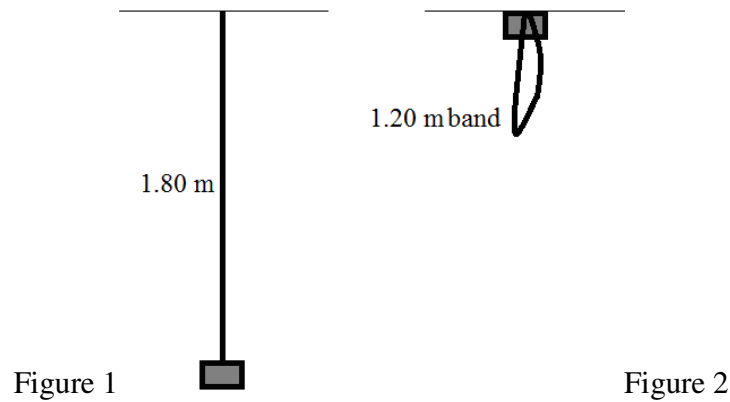
**Question 5** (8 marks)

An elastic band has a natural length of 1.20 m. One end of the band is fastened to the ceiling.

Figure 1 shows the elastic band with a 1.00 kg mass attached to the other end. The mass is at rest and the stretched elastic band is 1.80 m long

The attached mass is **lifted vertically upwards** so that it is in contact with the ceiling as shown in Figure 2.

The mass is then released. The elastic band follows Hooke's law.



a. Calculate the force constant  $k$  in Hooke's law  $F = kx$ .

1 mark

|                   |
|-------------------|
| $\text{N m}^{-1}$ |
|-------------------|

b. Calculate the amount of work done in lifting the mass to the ceiling while it is attached to the band.

3 marks

|   |
|---|
| J |
|---|

The mass is released from its new position.

c. Show that the stretched band is closed to 3.14 m long when the mass is at its lowest point.

2 marks

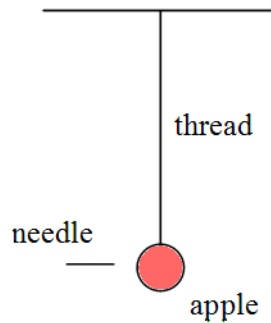
d. Calculate the maximum speed of the mass.

2 marks

**Question 6** (7 marks)

An apple (0.25 kg) is suspended with a thread (assume zero mass).

A sharp needle (10.0 grams) is projected at a speed of  $50 \text{ ms}^{-1}$  horizontally towards the apple. The needle travels a distance of 9.0 cm through the apple and exits the apple at  $40 \text{ ms}^{-1}$ .



a. Show that the speed of the apple is  $0.40 \text{ ms}^{-1}$  immediately after the exit of the needle.

2 marks

b. Show that the average force on the apple is approximately 49.8 N.

3 marks

c. Calculate the approximate time taken by the needle to pass through the apple.

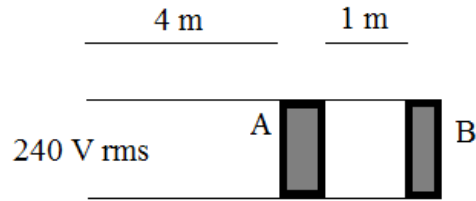
2 marks

**Question 7** (6 marks)

Two ohmic devices A ( $100\Omega$ ) and B ( $50\Omega$ ) are connected in parallel as shown in the diagram below.

The circuit is powered by an AC source of  $240\text{ V rms}$ .

The resistance per metre of the connecting wires in the circuit is  $0.05\ \Omega$ .



a. Calculate the rms current in device B.

3 marks

b. Calculate the total power loss in the connecting wires.

2 marks

c. Determine the total power of devices A and B.

1 mark

**Question 8** (6 marks)

A 75 kg person in a spacecraft departing Earth at  $2.7 \times 10^8 \text{ m s}^{-1}$  measures 1.2 s as the time of travel.

a. Determine the time of travel of the 75 kg person measured by an Earth observer.

2 marks

|   |
|---|
| s |
|---|

b. Determine the mass of the person in the spacecraft and the relativistic kinetic energy of the person measured by an Earth observer.

2 marks

|    |   |
|----|---|
| kg | J |
|----|---|

c. Determine the distance travelled by the spacecraft measured by an Earth observer.

2 marks

|   |
|---|
| m |
|---|



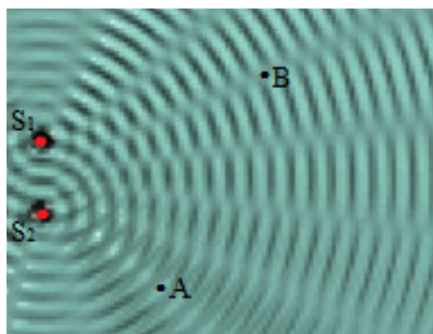
**Question 9** (7 marks)

Circular surface waves are generated by two dippers (sources) dipping into water at the same frequency of 10 Hz.

The depth of water is uniform.

The interference pattern is shown in the diagram below.

Distance  $S_2A$  is 1.05 m approximately.



a. Estimate the speed of the water waves.

2 marks

b. Estimate the difference between distances  $S_1B$  and  $S_2B$ .

2 marks

c. Suggest 3 ways to increase the number of nodal lines in the interference pattern.

3 marks

**Question 10** (7 marks)

Assume zero air resistance.

A 0.20 kg object is projected at  $\theta^\circ$  to the horizontal ground. It reaches a maximum height of 10 m at a speed of  $5.0 \text{ m s}^{-1}$ . It has a speed of  $11 \text{ m s}^{-1}$  at certain point of its flight.

- a. Determine the height of the object above the ground when it has a speed of  $11 \text{ m s}^{-1}$ . 2 marks

 m

- b. Determine the time when the object travels at  $11 \text{ m s}^{-1}$  on its downward flight. 3 marks

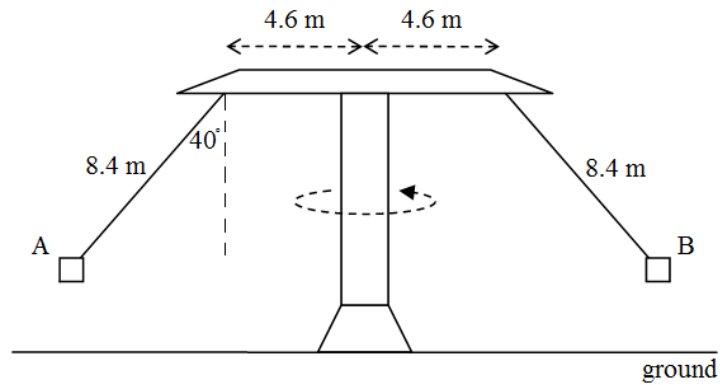
 s

- c. Determine the angle of projection  $\theta^\circ$ . 2 marks

**Question 11** (7 marks)

The diagram below shows a two-chair swing ride. Neglect the mass of the cables and treat the chair and person as one particle.

Particle A has a mass of 60 kg. The cable holding Particle A makes  $40^\circ$  with the vertical during rotation.



a. Draw arrows on the diagram above to show the forces on Particle A.

1 mark

b. Determine the tension in the cable holding Particle A during rotation.

2 marks

c. Determine the time to complete one revolution by Particle A.

3 marks

d. Particle B has a mass of 80 kg.

The cable holding Particle B makes  $\phi^\circ$  with the vertical during rotation. Find the value of  $\phi$ .

1 mark

**Question 12** (3 marks)

Electrons are emitted when a monochromatic light ray ( $\lambda = 410 \text{ nm}$ ) is directed at a piece of metal.

The threshold frequency of light for photoemission is  $6.5 \times 10^{14} \text{ Hz}$ .

a. Show that the work function of the metal is approximately  $4.3 \times 10^{-19} \text{ J}$ .

1 mark

b. Determine the **range** of kinetic energy of the photoelectrons.

2 marks

**Question 13** (3 marks)

Two stretched wires (1 m and 3 m long) vibrate at the same frequency of 21 Hz.

The 1-metre wire and the 3-m wire vibrate at the first and third harmonics respectively.

a. Determine the value of  $\frac{\text{wave speed in the 1 m wire}}{\text{wave speed in the 3 m wire}}$ .

2 marks

b. Determine the frequency of the fifth harmonic of the 3 m wire.

1 mark

**Question 14** (3 marks)

Neutron diffraction is used to study the structure of crystalline solids.

In such a study, neutrons of the same energy are directed at a polycrystalline powder.

Typical separation between atoms in a crystal is 0.1 nm. Neutron mass  $\approx 1.67 \times 10^{-27}$  kg

Estimate the speed of the neutrons to produce a clear diffraction pattern.

3 marks

**Question 15** (5 marks)

A diffraction pattern is formed over time by passing photons from a dim light source through a tiny opening.

The number of photons emitted by the source in one second is estimated to be  $10^6$ .

a. Estimate the average separation between photons.

2 marks

b. Explain how the diffraction pattern can be used to demonstrate Heisenberg's uncertainty principle. 3 marks

**Question 16** (7 marks)

The following data are obtained from a photoelectric effect experiment, showing the stopping voltage required for light of a particular wavelength.

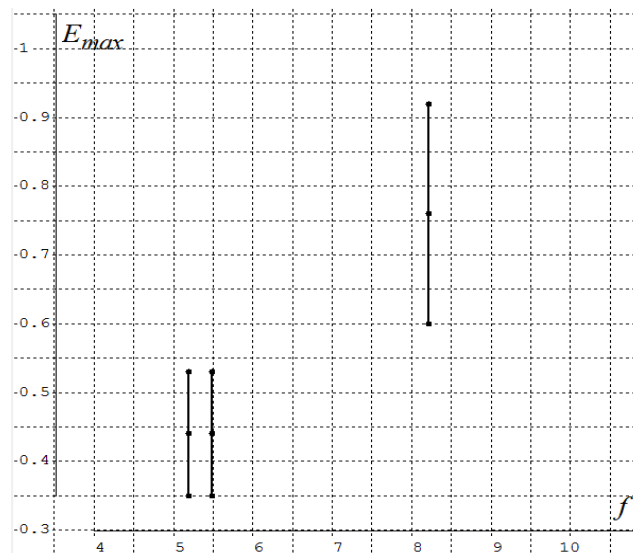
| Wavelength $\lambda$ (nm) | Stopping voltage $V_s$ (V) |
|---------------------------|----------------------------|
| $365 \pm 2$               | $0.76 \pm 0.16$            |
| $405 \pm 2$               | $0.60 \pm 0.12$            |
| $546 \pm 2$               | $0.44 \pm 0.09$            |
| $577 \pm 2$               | $0.44 \pm 0.09$            |

a. Complete the following table for the above data, including uncertainties.

2 marks

| Frequency $f$ ( $10^{14} \text{ s}^{-1}$ ) | Maximum kinetic energy of photoelectrons $E_{\text{max}}$ (eV) |
|--|--|
| $8.22 \pm 0.05$                            | $0.76 \pm 0.16$  |
|  | $0.60 \pm 0.12$  |
| $5.49 \pm 0.02$                            | $0.44 \pm 0.09$  |
| $5.20 \pm$                                 | $0.44 \pm 0.09$  |

A graph of  $E_{\text{max}}$  (eV) versus  $f$  ( $10^{14} \text{ s}^{-1}$ ) is shown below for the three calculated frequencies in the table.



b. Plot the remaining point accurately on the graph above and draw the line of best fit.

2 marks

c. Estimate Planck's constant from your line of best fit. Include uncertainty estimation in your answer using maximum and minimum possible slopes.

3 marks

eVs

**End of trial examination**