Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
2011

Physics

Assessment Unit A2 2

assessing

Fields and their Applications

[AY221]

MONDAY 6 JUNE, AFTERNOON

AY221

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in question **5(a)**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.
Question 9 contributes to the synoptic assessment required of the specification. Candidates should allow approximately 15 minutes to complete this question.

For Examiner's use only	
Question Number	**Marks**
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total Marks	

6492

Examiner Only	
Marks	Remark

1 (a) What is a gravitational field?

____

____ [1]

(b) Calculate the mass of the Earth if the gravitational field strength at the Earth's surface is 9.81 N kg^{-1} and the mean radius of the Earth is 6.37×10^3 km.

Mass = ____________ kg [3]

(c) (i) "GOES–10" is the name given to one of the Geostationary Operational Environmental Satellites that the USA uses to monitor weather. Its orbital radius is 3.58×10^4 km **above the Earth's surface**. State the period of a geostationary satellite.

Period = ____________ s [1]

(ii) "GOES–10" has a mass of 2.11×10^3 kg. Calculate the centripetal force required to keep it moving in this orbit. Remember the mean radius of the Earth is 6.37×10^3 km.

Force = ____________ N [3]

(iii) When this satellite reaches the end of its useful life it is boosted out of its geosynchronous orbit into a higher orbit. Determine the satellite's new period if the new orbit has a radius of 6.22×10^4 km above the Earth.

Period = ____________ s [2]

Examiner Only	
Marks	Remark

2 **(a)** Define electric field strength.

____

____ [2]

(b) **(i)** According to the Bohr model of hydrogen, an electron in its ground state will orbit the nucleus with a radius of 5.29×10^{-13} m. Given that the nucleus of hydrogen consists of a single proton, calculate the electric field strength due to the proton at this radius. The proton may be taken to be a point charge.

Electric field strength = ____________ $N\,C^{-1}$ [3]

(ii) **(1)** Calculate the magnitude of the force between the electron and the proton when the electron is in its ground state.

Force = ____________ N [2]

(2) State whether the force is attractive or repulsive and explain your answer.

____

____

____ [1]

3 **(a)** The time constant of a resistor–capacitor (R–C) circuit is numerically equal to the product of the resistance and the capacitance in the circuit. In the space below, draw a circuit diagram that will enable the time constant of a resistor–capacitor network to be determined.

[3]

(b) **(i)** Describe how the circuit is used to obtain results from which the time constant may be determined. You should name any additional equipment required.

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____

____

____

____

____ [2]

(ii) Explain how the results from **(b)(i)** are analysed to obtain a value for the time constant.

____

____

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____ [3]

Examiner Only	
Marks	Remark

4 A wire is suspended in the magnetic field between two identical magnets so that it is perpendicular to the magnetic field direction. The wire is suspended so that it cannot move. The shaded face is the **north** pole of each magnet. The two magnets are placed on electronic scales. The wire is attached to a variable power supply unit and an ammeter. The reading on the scales is adjusted to zero. See **Fig. 4.1**.

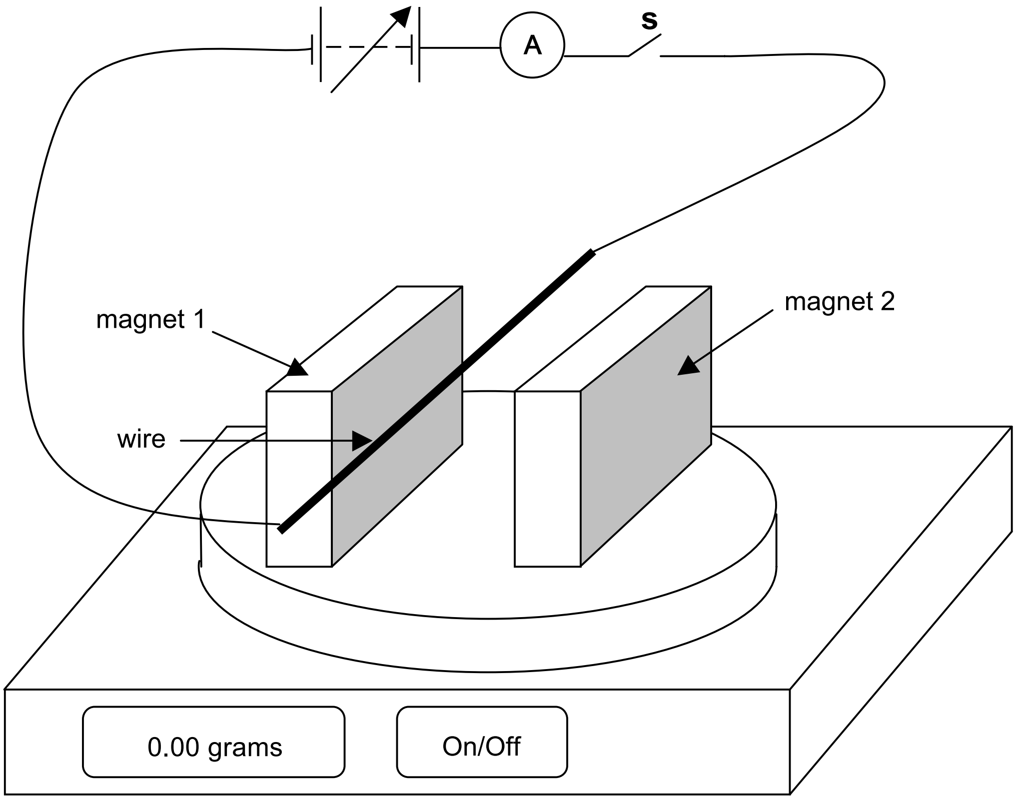

Fig. 4.1

(a) **(i)** The switch, s, is then closed. On **Fig. 4.1** carefully draw an arrow to indicate the direction of the force now experienced by the wire. Remember, the shaded face of each magnet is the north pole. [1]

(ii) By considering Newton's Third Law, state and explain the effect of this force on the reading on the electronic scales.

___

___

___ [2]

Examiner Only	
Marks	Remark

(b) The change in scale reading from 0.00 g when different currents were passed through the wire is given in **Table 4.1**. The average force acting on the magnets was also calculated and included in **Table 4.1**.

Examiner Only	
Marks	Remark

Table 4.1

Current/A	Change in scale reading/g		Average Force/N
	Reading 1	Reading 2	
1.37	0.35	–0.35	0.0035
2.44	0.62	–0.63	0.0061
3.67	0.94	–0.94	0.0092
4.29	1.10	–1.10	0.0108
4.99	1.28	–1.28	
5.55	1.43	–1.42	0.0140
6.38	1.63	–1.64	0.0161

(i) State how it is possible to obtain two scale readings for each current using the arrangement in **Fig. 4.1**.

____

____ [1]

(ii) **Use the values in Table 4.1** to calculate the average force, to three significant figures, when a current of 4.99 A flows. The value of the physical constant required must be that given in the data sheet.

Force = ______________ N [2]

(c) Spreadsheet software was used to analyse the results in **Table 4.1**. **Fig. 4.2** shows the graph obtained.

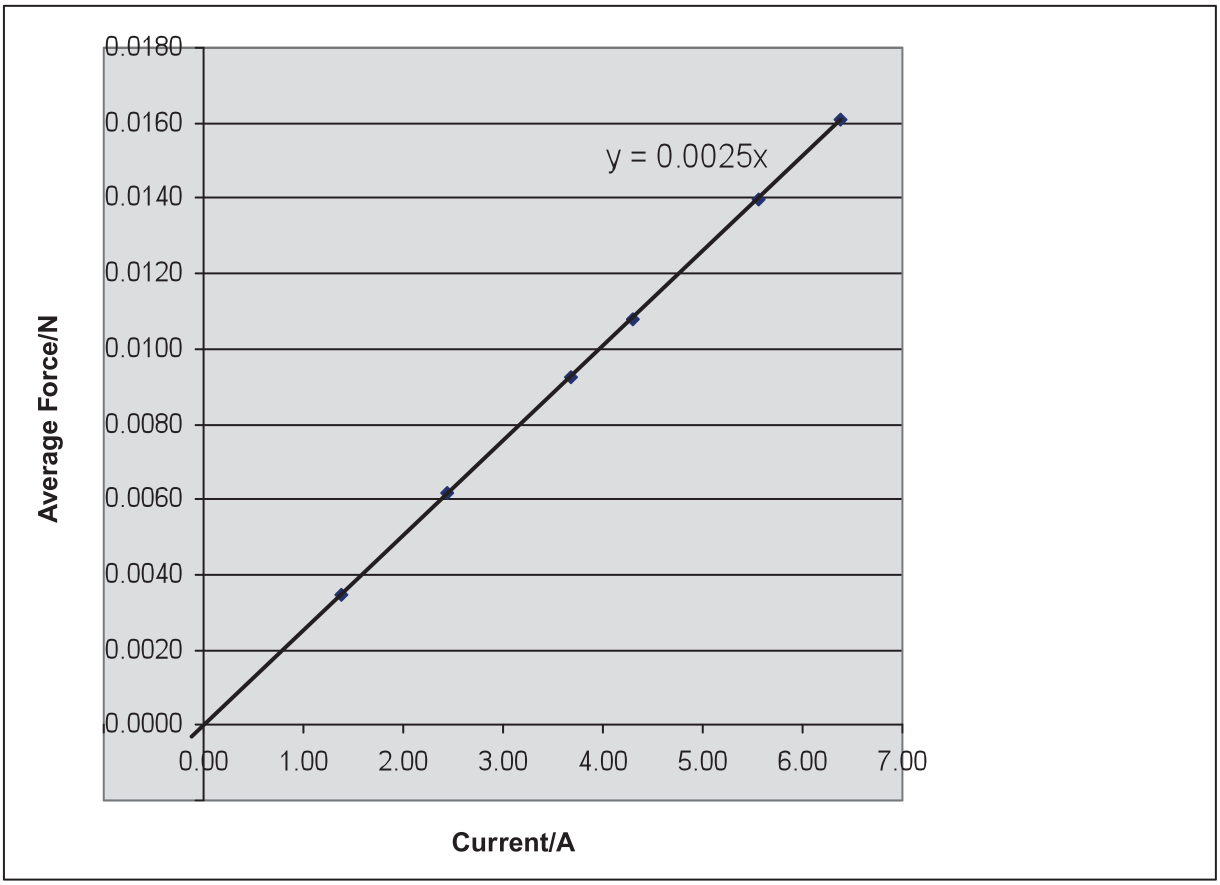

Fig. 4.2

Examiner Only	
Marks	Remark

(i) Use information in **Fig. 4.2** to determine the force produced by a current of 4.00 A.

Force = ______________ N [1]

(ii) Given that the length of the wire in the magnetic field was 0.12 m, calculate the magnetic flux density between the magnets.

Flux density = ______________ T [2]

Where appropriate in this question you should answer in continuous prose. You will be assessed on the quality of your written communication.

Examiner Only	
Marks	Remark

5 **(a)** Transformers are electrical devices that are used to change the value of an alternating voltage. **Fig. 5.1** illustrates part of the structure of a transformer. In the actual transformer the coils would be wound tightly around the laminated iron core and there would be leads to the primary coil and leads from the secondary coil. The coils are made from insulated copper wire.

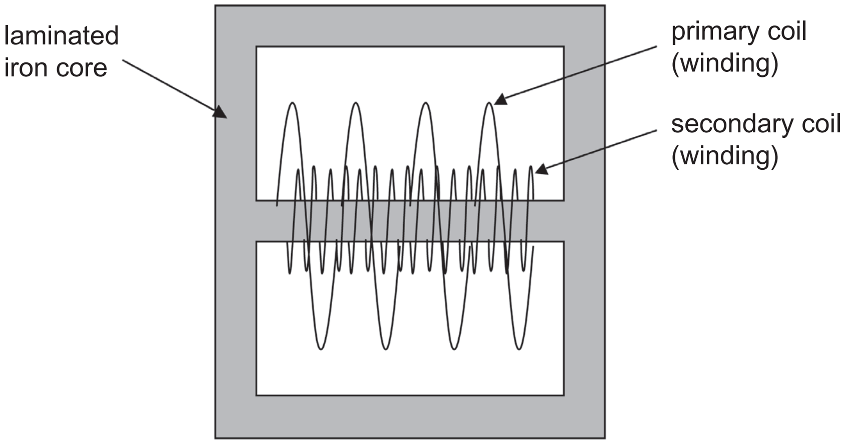

Fig. 5.1

Transformers of this design type have an efficiency of about 97%. Explain how the transformer described above minimises energy losses.

____

____

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____

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____

____

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____

____

____

____ [4]

Quality of written communication [2]

(b) (i) The primary coil of this transformer, with 500 turns, is connected to a 230 V a.c. supply. Show that the EMF induced in the 2800 turns of the secondary coil is 1.29 kV.

Examiner Only	
Marks	Remark

EMF = ____________ V [2]

(ii) The 2800 turns of the secondary coil are wound on the laminated iron core which has a cross-sectional area of 2.20×10^{-4} m^2. Calculate the change in magnetic flux density every second to cause 1.29 kV to be induced in the secondary coil of this transformer.

Change in magnetic flux density per second = ________ T s^{-1} [3]

6 (a) A proton enters the uniform electric field between two horizontal plates. It enters horizontally with a speed $v_0 = 4.00 \times 10^5$ m s^{-1}. **Fig. 6.1** illustrates this situation.

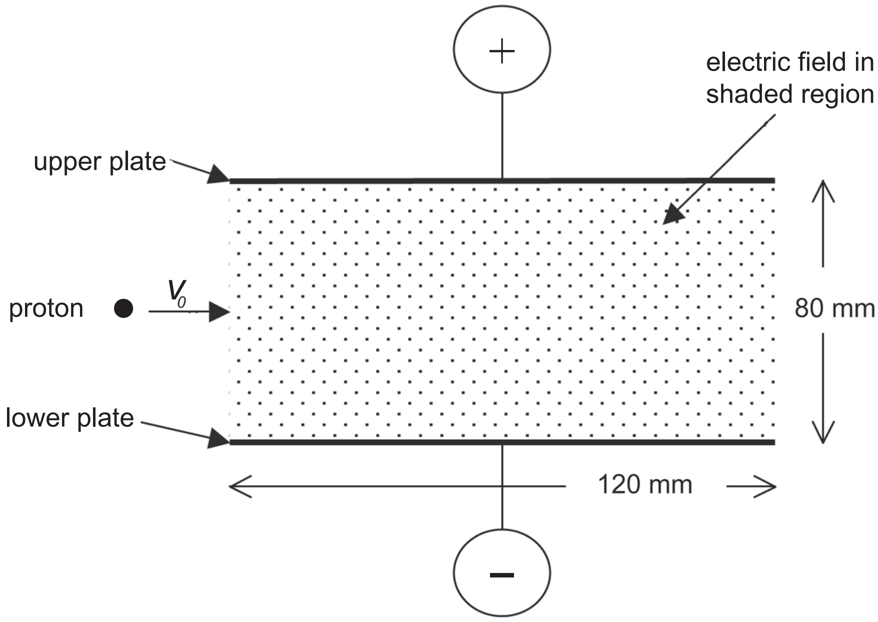

Fig. 6.1

(i) Calculate the magnitude of the electric field strength E if the voltage between the plates in **Fig. 6.1** is 148 V.

E = ___________ N C^{-1} [2]

(ii) Calculate the magnitude of the acceleration experienced by the proton if the electric field exerts a constant force of 2.96×10^{-16} N. The effect of gravity on the proton is negligible and can be ignored in this question.

Acceleration = __________ m s^{-2} [2]

Examiner Only	
Marks	Remark

(b) Calculate the magnitude and direction of the velocity of the proton on exiting the electric field. State the direction relative to the horizontal.

Examiner Only	
Marks	Remark

Velocity = ____________ m s^{-1}

Direction = ____ [5]

7 A synchrotron is a type of particle accelerator in which the kinetic energy of a charged particle is progressively increased as the particle moves around a circular track. **Fig. 7.1** shows the main components in this type of particle accelerator.

Examiner Only	
Marks	Remark

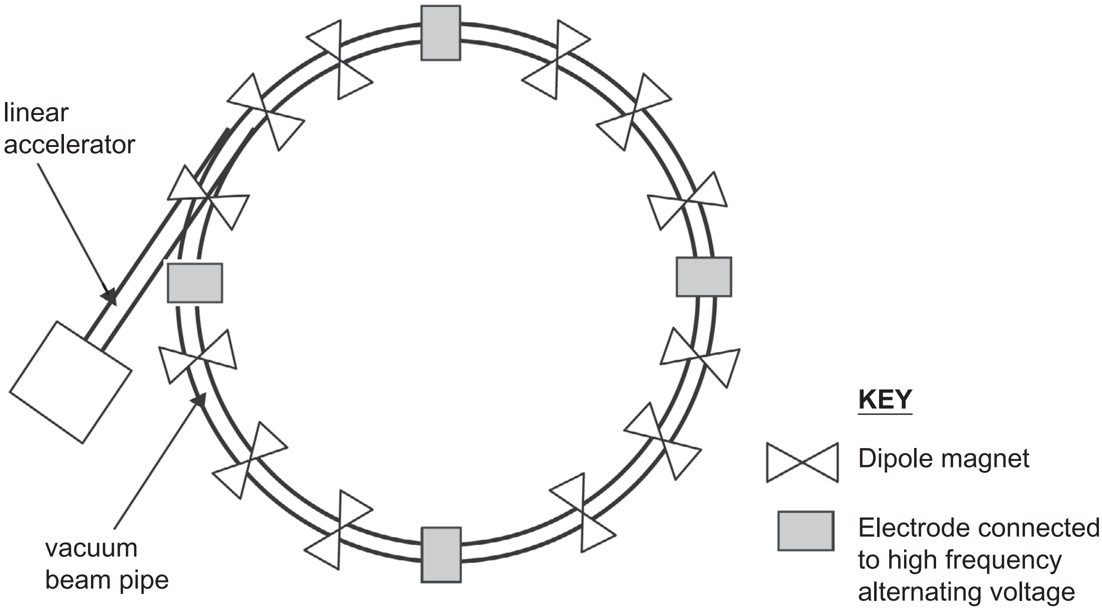

Fig. 7.1

(a) (i) Explain why there must be a vacuum in the beam pipe.

____

____ [1]

(ii) State the function of the electrodes connected to high frequency alternating voltage.

____

____ [1]

(iii) Protons are introduced to a synchrotron of **diameter** 12 km from a linear accelerator. The synchrotron increases the energy of the protons until they are moving at 98% the speed of light. However, when moving at this speed the protons have an effective mass that is 5 times larger than that given in the data sheet. Calculate the required magnetic flux density of the dipole magnets needed at this proton speed.

Examiner Only	
Marks	Remark

Flux density = __________ T [3]

(b) In the film "Angels and Demons" 0.125 g of antimatter is stolen from the particle accelerator complex CERN.

(i) What is antimatter?

____

____ [1]

(ii) Calculate the energy that would be released in the annihilation of this quantity of antimatter.

Energy ______________ J [3]

Examiner Only	
Marks	Remark

8 **(a)** Pions and kaons are classified as mesons. What is the composition of a meson?

____

____ [1]

(b) Consider **Equation 8.1** which represents β^- decay

$$^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + \bar{\upsilon}_e \qquad \textbf{Equation 8.1}$$

(i) Complete **Table 8.1** with respect to the particles in **Equation 8.1**.

Table 8.1

Particle	Name	Charge/C	Baryon Number	Lepton Number
n	neutron	0		
p	proton		+1	
e				+1
$\bar{\upsilon}_e$		0		

[5]

(ii) Which, if any, of the quantities charge, baryon number and lepton number must be conserved for any reaction to be possible? If none, write "none".

____

____ [1]

(c) What is the quark structure for a proton?

____

____ [1]

Examiner Only	
Marks	Remark

(d) Describe β^- decay in terms of quarks, include the intermediary stage of the virtual particle emitted in the process.

____

____ [2]

9 A digital single lens reflex camera (dSLR) allows a photographer to see the exact image that is to be photographed just before the photograph is taken. The major components of such a camera are shown in **Fig. 9.1**.

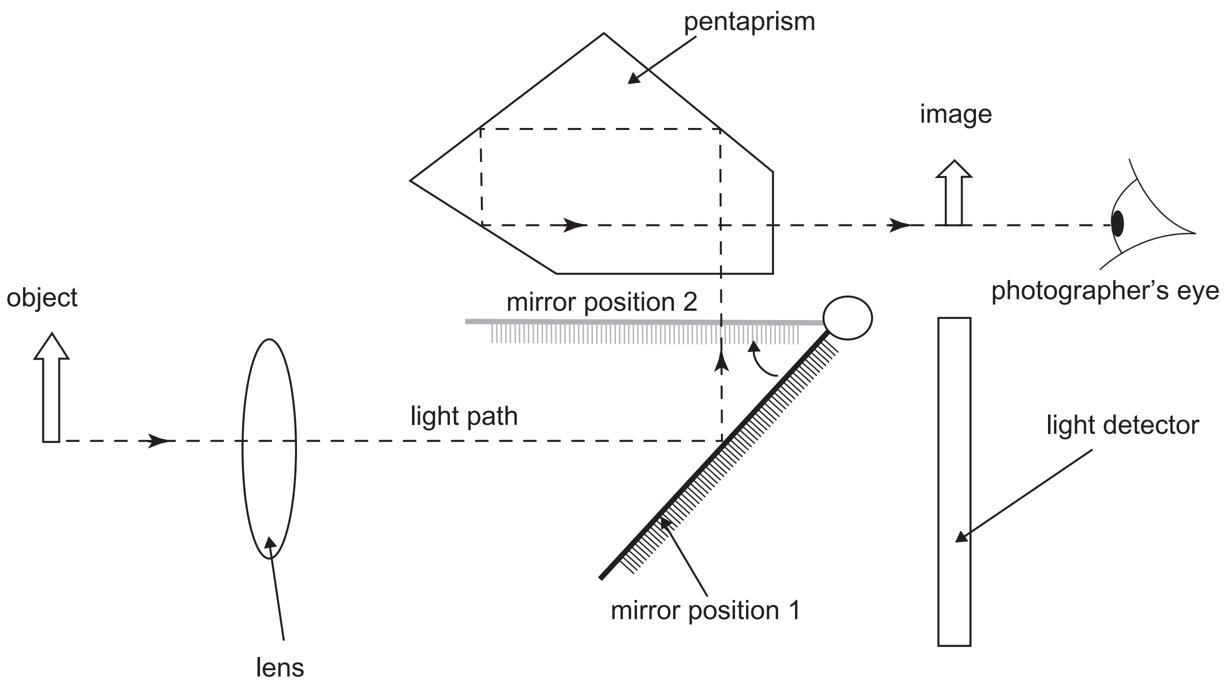

Fig. 9.1

Examiner Only	
Marks	Remark

(a) Refraction can be attributed to the fact that light has different speeds in different media. The speed of light in the glass from which the pentaprism is made is $1.92 \times 10^8\ \mathrm{m\,s^{-1}}$. Given that the refractive index can be expressed as the ratio of the speed of light in air to the speed of light in a medium, calculate the critical angle for the glass of the pentaprism.

Angle = ________ ° [3]

(b) The mirror reflects the light that is **incident on it through 90°** as shown in **Fig. 9.1**. When the photograph is taken the mirror moves from position 1 to position 2 so that the light strikes the detector. **The mirror is horizontal in position 2** and it takes 80 ms to move from position 1 to position 2 and vice versa.

(i) State the angle through which the mirror is turned.

Angle = ________ ° [1]

(ii) Calculate the average angular velocity of the mirror as it turns between positions 1 and 2.

Angular velocity = ___________ rad s^{-1} [3]

(c) The light detector has an effective area of 7.68 cm^2 and is divided into 12 million identical picture elements (pixels). If each pixel is a square calculate the length of one side.

Length = _________ μm [3]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(d) Digital camera detectors make use of semiconductors. Photons incident on semi-conductors can cause an electron to be excited from the low energy valence band to the high energy conduction band. For this to occur the energy of the incident photon must be in excess of the band gap energy. **Fig. 9.2** illustrates the arrangement of the bands.

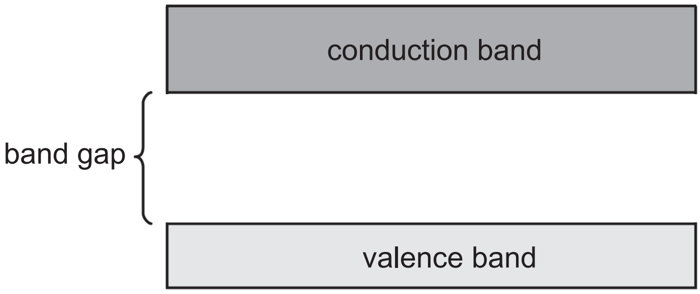

Fig. 9.2

(i) The energy band gap for silicon is 1.1 eV. Calculate the maximum wavelength of the electromagnetic radiation that will just enable an electron to cross the band gap.

Wavelength = _____________ m [3]

(ii) A total charge of 3.52×10^{-18} C was detected in a particular pixel. How many photons were incident on that pixel if the photon absorption efficiency is 40%?
Absorption efficiency is the percentage of incident photons that cause an electron to be promoted from the valence band to the conduction band.

Number of photons = ____________ [3]

THIS IS THE END OF THE QUESTION PAPER

GCE Physics

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
(unified) atomic mass unit	1 u = 1.66×10^{-27} kg
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall on the Earth's surface	$g = 9.81$ m s^{-2}
electron volt	1 e$V = 1.60 \times 10^{-19}$ J

The following equations may be useful in answering some of the questions in the examination:

Mechanics

Conservation of energy	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force
Hooke's Law	$F = kx$ (spring constant k)

Simple harmonic motion

Displacement	$x = A \cos \omega t$

Sound

Sound intensity level/dB	$= 10 \lg_{10} \frac{I}{I_0}$

Waves

Two-source interference	$\lambda = \frac{ay}{d}$

Thermal physics

Average kinetic energy of a molecule	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$
Kinetic theory	$pV = \frac{1}{3}Nm\langle c^2\rangle$
Thermal energy	$Q = mc\Delta\theta$

Capacitors

Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
Capacitors in parallel	$C = C_1 + C_2 + C_3$
Time constant	$\tau = RC$

Light

Lens formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Magnification $m = \frac{v}{u}$

Electricity

Terminal potential difference $V = E - Ir$ (E.m.f. E; Internal Resistance r)

Potential divider $V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$

Particles and photons

Radioactive decay $A = \lambda N$

$A = A_0 e^{-\lambda t}$

Half-life $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

de Broglie equation $\lambda = \frac{h}{p}$

The nucleus

Nuclear radius $r = r_0 A^{\frac{1}{3}}$

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