| Surname | Centre Number | Candidate Number |
|---|---|---|
| Other Names | | 2 |

WJEC CBAC

# GCE AS/A level

1321/01

## PHYSICS – PH1
Motion, Energy and Charge

A.M. WEDNESDAY, 15 January 2014

1 hour 30 minutes

| For Examiner's use only | | |
|---|---|---|
| **Question** | **Maximum Mark** | **Mark Awarded** |
| **1.** | **9** | |
| **2.** | **11** | |
| **3.** | **17** | |
| **4.** | **13** | |
| **5.** | **10** | |
| **6.** | **8** | |
| **7.** | **12** | |
| **Total** | **80** | |

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### ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

### INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.

### INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 80.

The number of marks is given in brackets at the end of each question or part question.

You are reminded of the necessity for good English and orderly presentation in your answers.

You are reminded to show all working. Credit is given for correct working even when the final answer given is incorrect.

Examiner only

**Answer all questions.**

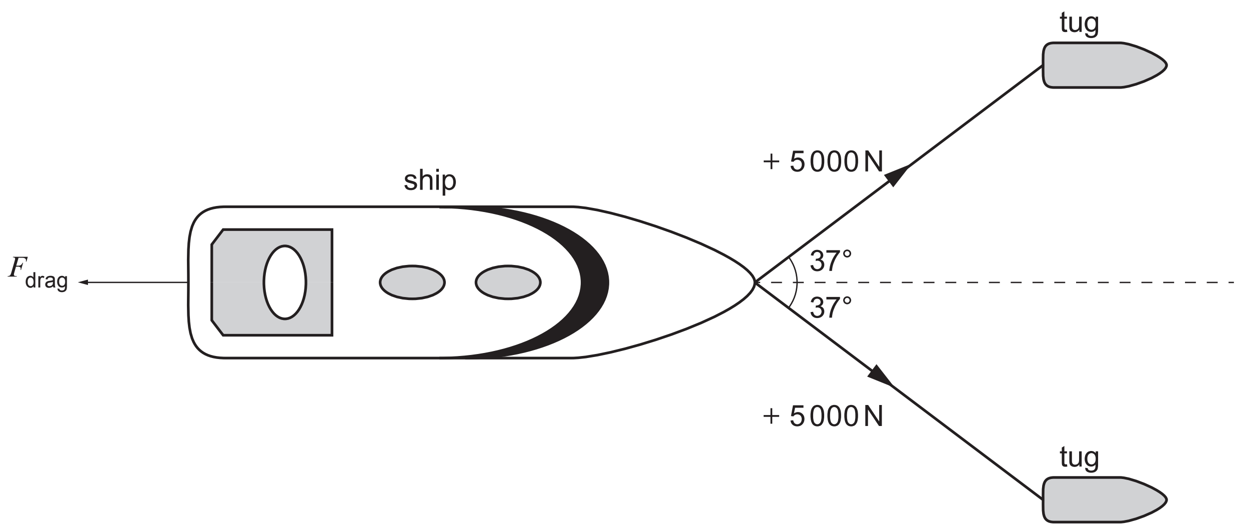
**1.** *(a)* State what is meant by a vector quantity. [1]

*(b)* Newton's second law of motion can be expressed by the equation:

$$\sum F = ma$$

Name the vector quantities in this equation. [2]

*(c)* A ship is being pulled along by cables attached to two tugs as shown. $F_{drag}$ represents the total drag force that acts on the ship at the instant shown.




(i) Show clearly that the magnitude of the resultant of the forces applied **by the tugs** is approximately 8000 N. [2]

(ii) Given that $\sum F = +\,2000\,\text{N}$ for the situation shown above, determine the value of $F_{drag}$. [1]

Examiner only

*(d)* At a later stage the tension in the cables is changed so that the ship moves forward with a **constant speed** of 2.5 m s$^{-1}$. Calculate the work done on the ship by the tugs in one minute. [Assume $F_{\text{drag}}$ is the same as that calculated in *(c)*(ii).] [3]

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Examiner only

**2.** The current $I$ in a metal conductor of cross-sectional area $A$ is given by:

$$I = nAve$$

*(a)* State the meanings of $n$ and $v$. [2]

$n$ ..........

$v$ ..........

*(b)* Show that the equation is correct in terms of units. [3]

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*(c)* (i) The current in a copper wire is 2.0 A. The wire has a cross-sectional area of 1.2 mm$^2$ and is 5.0 m long. Calculate the time it takes a free electron in the wire to travel from one end to the other. [Take $n_{copper} = 8 \times 10^{28}\ \text{m}^{-3}$.] [3]

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(ii) The **same current** (2.0 A) is now passed through a **thinner** wire of the **same length and material**. Use the above equation to explain the effect this change would have on the time for an electron to travel from one end to the other. [3]

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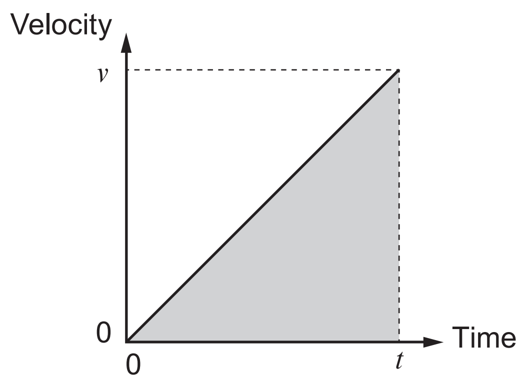
Examiner only

**3.** *(a)* A velocity-time graph is given for a body which is accelerating from rest in a straight line.




(i) What does the shaded area under the graph represent? [1]

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(ii) Use the graph to show that, using the usual symbols:

$$x = \frac{1}{2}at^2$$

[3]

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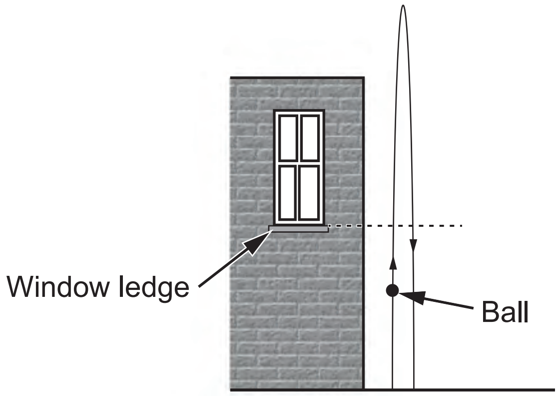
Examiner only

*(b)* A ball is thrown vertically upwards and passes a window ledge 0.3 s after being released. It passes the window ledge on its way back down, 1.6 s **later**. Ignore air resistance.




(i) Determine the time of flight of the ball. [1]

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(ii) Calculate the initial velocity of the ball when it is released. [3]

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(iii) Calculate the height of the window ledge above the ground. [2]

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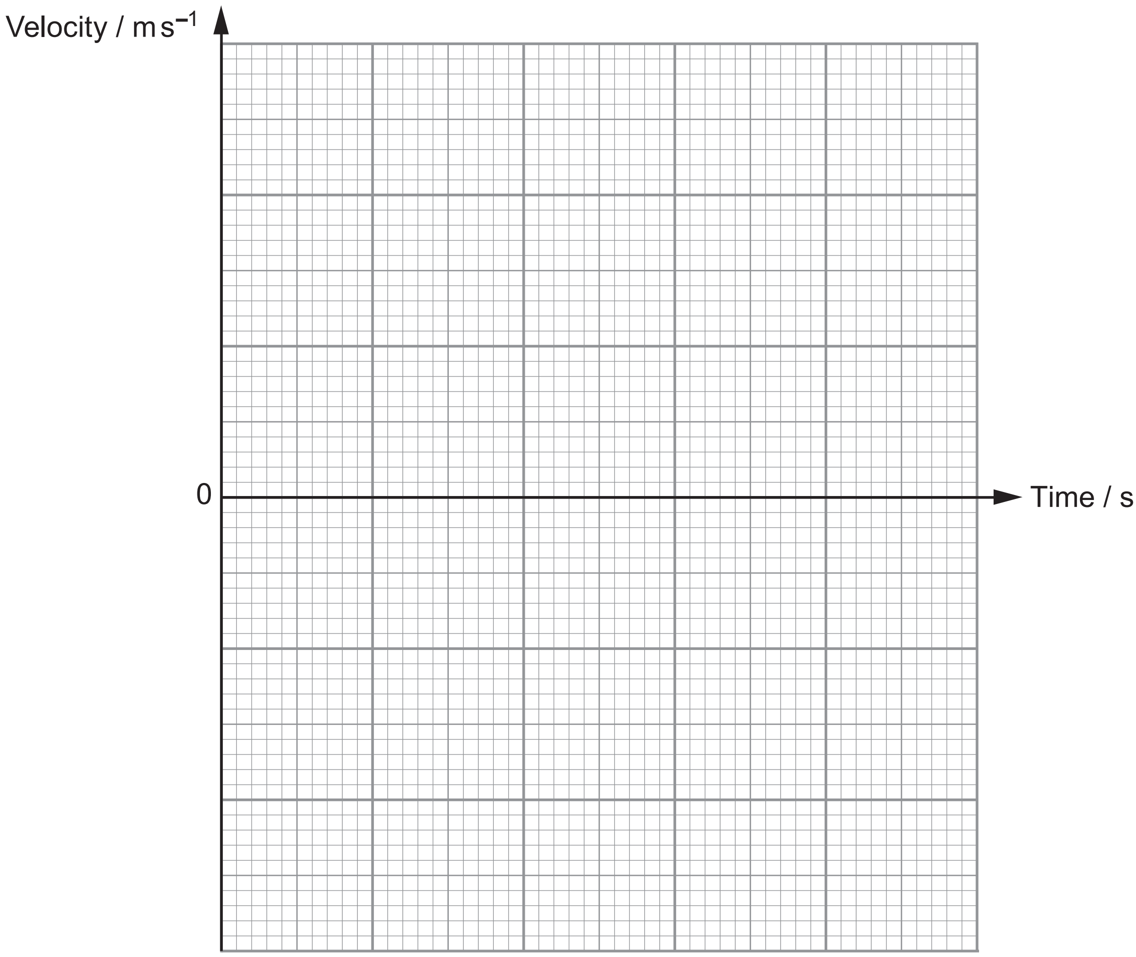
Examiner only

(c) Draw, on the grid below, a velocity-time graph for the whole of the ball's flight. Include suitable scales on both axes. [3]




(d) In reality, air resistance also acts on the ball. In the spaces provided draw **three** free body diagrams showing the forces acting on the ball at the positions indicated. **Label** these forces. [4]

| | | |
|---|---|---|
| As the ball passes the window ledge **travelling upwards** | At maximum height above the ground | As the ball passes the window ledge **travelling downwards** |

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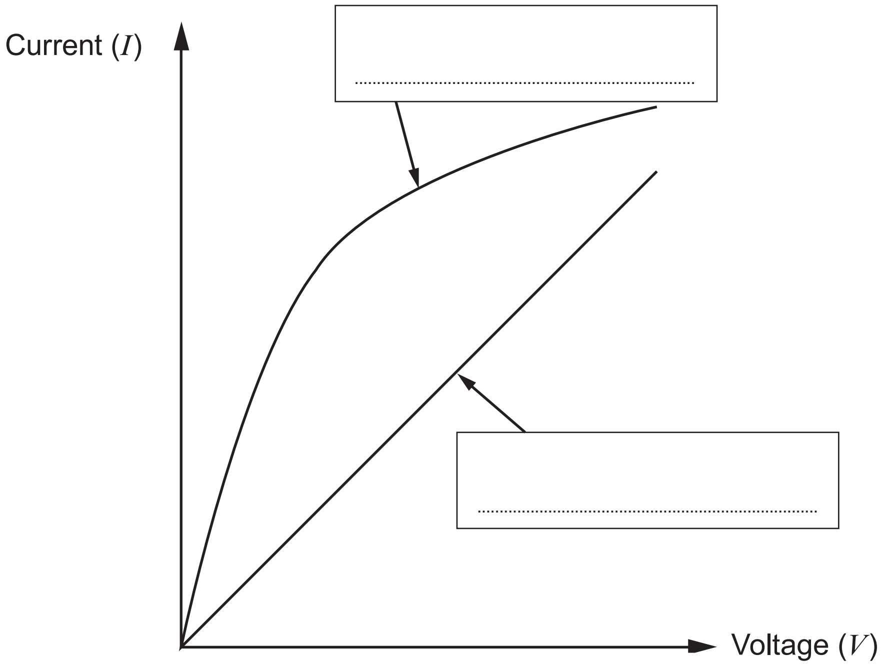
**4.** *(a)* Graphs are drawn for a metal wire at constant temperature and for the filament of a lamp.

Examiner only




(i) Complete the boxes, labelling the graphs with the component they represent. [1]

(ii) Suggest reasons for the different shapes of the two graphs. [5]

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Examiner only

*(b)* X and Y are two lamps.

(i) Lamp X is labelled at 12 V, 24 W. Calculate the current in the lamp when it operates at its rated voltage. [1]

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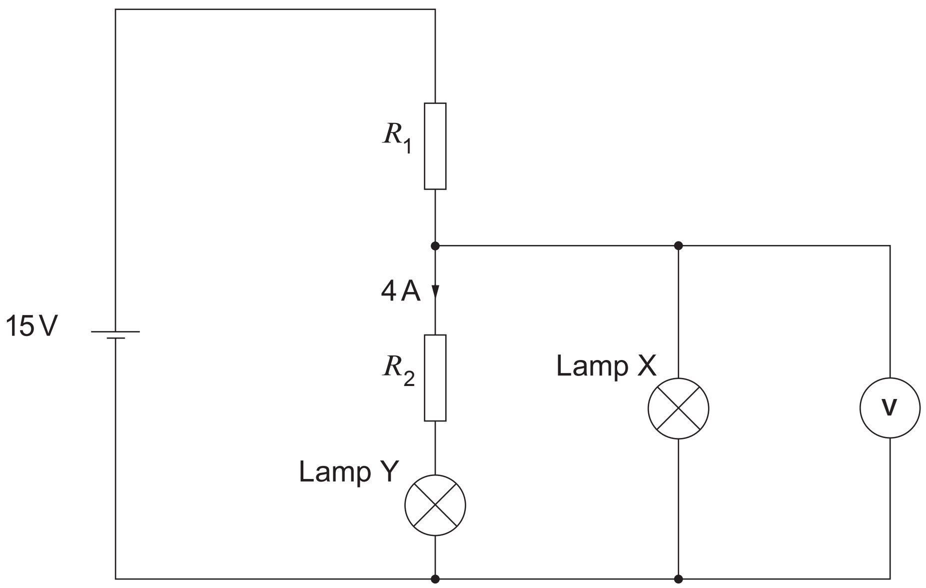
(ii) Lamp Y is labelled at 6 V, 4 A. In the following circuit, the values of $R_1$ and $R_2$ are chosen so that **both lamps operate at their rated voltages**.




(I) State the reading on the voltmeter. .............................................................................. [1]

(II) Calculate the pd across $R_2$. [1]

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(III) Calculate $R_2$. [1]

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(IV) Calculate $R_1$. [3]

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Examiner only

**5.** A resistance strain gauge is a device used to detect very small changes in structures such as buildings and bridges. It consists of a very fine wire glued onto a thin plastic sheet. The gauge is attached to the structure under test, so that when the structure deforms the wire is either stretched or compressed.

*(a)* If the wire is stretched it gets **longer** and **thinner**. Using an equation to justify your answer, explain the effect that stretching the wire has on its resistance. [3]

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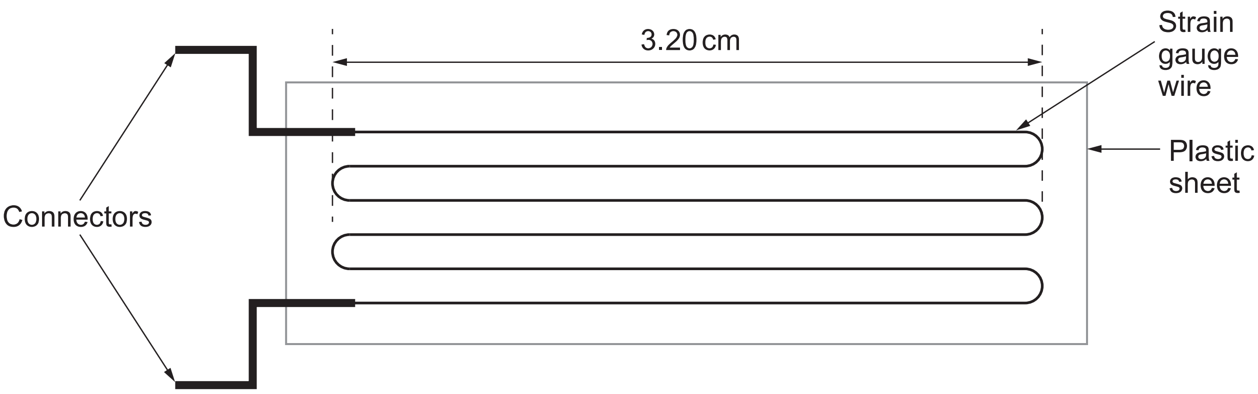
*(b)* The diagram shows a typical strain gauge. The wire is of circular cross-section and is arranged in a zig-zag pattern.




(i) Show that the resistance of the wire in the strain gauge is 56 Ω. Assume that its **diameter** is $1.75 \times 10^{-5}$ m and its resistivity, $\rho = 7.0 \times 10^{-8}$ Ωm. [3]

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Examiner only

(ii) Calculate the change in length needed to produce a 0.1% variation in resistance in the strain gauge opposite. For this calculation, **ignore changes in cross-sectional area.** [2]

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(iii) Suggest why it is beneficial for the wire to be arranged in a zig-zag pattern. [2]

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Examiner only

**6.** *(a)* State the **two** conditions necessary for a body to remain in equilibrium. [2]

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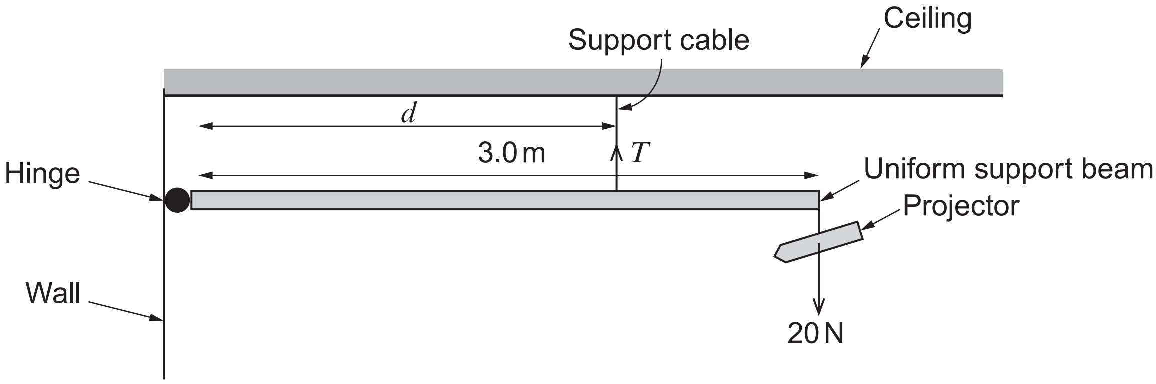
*(b)* A school technician installs a projector of weight 20 N and uniform support beam of weight 10 N in a classroom as shown.




(i) **Label** with an arrow on the diagram, the weight of the beam. [1]

(ii) The manufacturer states that, for safety purposes, the tension, $T$, in the support cable must not exceed 40 N. Calculate the minimum distance, $d$, that the technician can place the cable so that the tension in it does not exceed the safe limit. [3]

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(iii) Determine the size and direction of the force that the hinge exerts on the beam when the tension in the support cable is at its maximum safe limit. [2]

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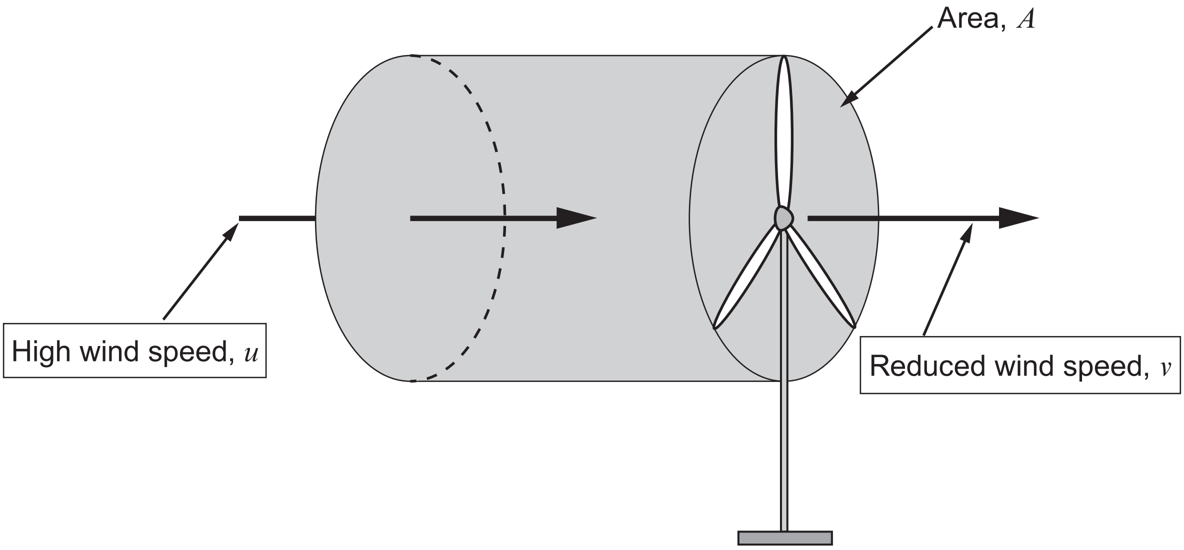
Examiner only

**7.** Wind turbines are used to generate electrical energy. They work by converting as much as possible of the kinetic energy of the air that moves through the area swept out by the blades into electrical energy.




*(a)* (i) The volume of air arriving on the blades per second is $Au$. Show that the kinetic energy per second (the power, $P$) arriving is given by:

$$P = \tfrac{1}{2} A\rho u^3$$

where $\rho$ is the density of the air. [2]

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(ii) Use the above equation to complete the following sentences: [2]

(I) The power arriving is proportional to the *square of the radius.* So doubling the length of the turbine blades will increase the power arriving by a factor of

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(II) Doubling the wind speed will increase the power arriving by a factor of

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Examiner only

(iii) The blades cannot remove **all** the energy arriving from the wind. Having passed through the blades, the moving air has a reduced speed, $v$, as shown in the diagram. The following equation can be used to approximate the power possessed by this moving air:

$$P = \tfrac{1}{2} A \rho v^3$$

Use this equation and the one in *(a)*(i) to write an expression for the power **lost** by the air as it passes through the moving blades. [1]

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(iv) Suggest why it is not a good idea to erect wind turbines short distances behind each other. [1]

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(v) A wind turbine has blades of length 2.0 m. Wind of speed 7.0 m s$^{-1}$ arrives on the blades, which is reduced to 5.0 m s$^{-1}$ after passing through the blades. Calculate the net power input to the wind turbine. [Assume $\rho_{air}$ = 1.2 kg m$^{-3}$.] [2]

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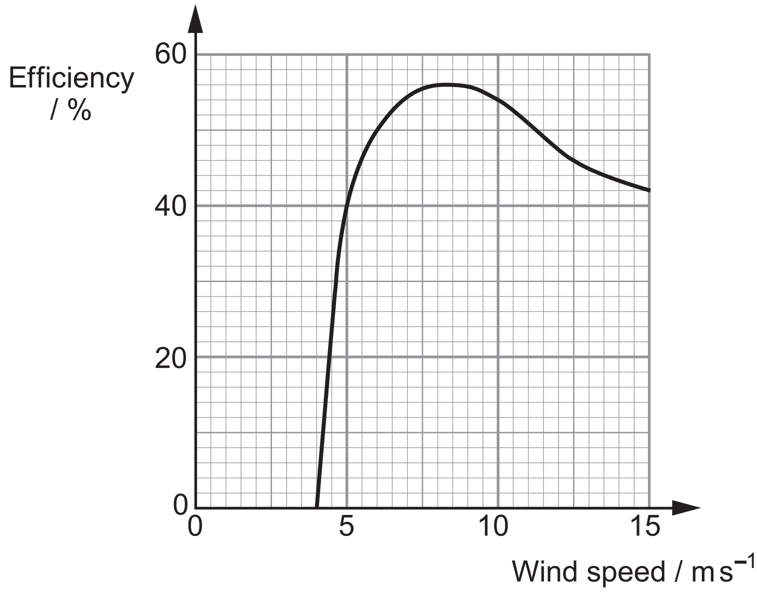
Examiner only

(b) The calculation in *(a)*(v) assumes that all the kinetic energy lost from the wind is converted into electrical energy. This is not the case as electrical generators in the wind turbines are not 100% efficient. A significant amount of energy is lost due to friction between the moving parts of the turbine for example. Below is a typical graph of efficiency against the speed of the wind arriving on the blades.




(i) Suggest why no power is generated for wind speeds up to 4.0 m $s^{-1}$. [1]

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(ii) Use the graph to determine the actual power generated by the turbine in *(a)*(v) in a wind of speed 7.0 m $s^{-1}$. [2]

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(c) State why an undersea turbine of the same size as the wind turbine in *(a)*(v), when placed in a water current of speed 7.0 m $s^{-1}$, would provide significantly greater power output than the wind turbine. [1]

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**END OF PAPER**

**GCE PHYSICS**
**TAG FFISEG**
Advanced Level / Safon Uwch

## Data Booklet

A clean copy of this booklet should be issued to candidates for their use during each GCE Physics examination.

Centres are asked to issue this booklet to candidates at the start of the GCE Physics course to enable them to become familiar with its contents and layout.

### Values and Conversions

| | | | |
|---|---|---|---|
| Avogadro constant | $N_A$ | = | $6{\cdot}02 \times 10^{23}\ \text{mol}^{-1}$ |
| Fundamental electronic charge | $e$ | = | $1{\cdot}60 \times 10^{-19}\ \text{C}$ |
| Mass of an electron | $m_e$ | = | $9{\cdot}11 \times 10^{-31}\ \text{kg}$ |
| Molar gas constant | $R$ | = | $8{\cdot}31\ \text{J mol}^{-1}\ \text{K}^{-1}$ |
| Acceleration due to gravity at sea level | $g$ | = | $9{\cdot}81\ \text{m s}^{-2}$ |
| Gravitational field strength at sea level | $g$ | = | $9{\cdot}81\ \text{N kg}^{-1}$ |
| Universal constant of gravitation | $G$ | = | $6{\cdot}67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$ |
| Planck constant | $h$ | = | $6{\cdot}63 \times 10^{-34}\ \text{J s}$ |
| Boltzmann constant | $k$ | = | $1{\cdot}38 \times 10^{-23}\ \text{J K}^{-1}$ |
| Speed of light *in vacuo* | $c$ | = | $3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$ |
| Permittivity of free space | $\varepsilon_0$ | = | $8{\cdot}85 \times 10^{-12}\ \text{F m}^{-1}$ |
| Permeability of free space | $\mu_0$ | = | $4\pi \times 10^{-7}\ \text{H m}^{-1}$ |
| Stefan constant | $\sigma$ | = | $5{\cdot}67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$ |
| Wien constant | $W$ | = | $2{\cdot}90 \times 10^{-3}\ \text{m K}$ |

$T/\text{K} = \theta/{}^\circ\text{C} + 273{\cdot}15$

$1\ \text{u} = 1{\cdot}66 \times 10^{-27}\ \text{kg}$

## AS

$\rho = \dfrac{m}{V}$

$v = u + at$

$x = \frac{1}{2}(u + v)t$

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

$v^2 = u^2 + 2ax$

$\Sigma F = ma$

$W = Fx\cos\theta$

$\Delta E = mg\Delta h$

$E = \frac{1}{2}kx^2$

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

$Fx = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$P = \dfrac{W}{t} = \dfrac{\Delta E}{t}$

$I = \dfrac{\Delta Q}{\Delta t}$

$I = nAve$

$R = \dfrac{\rho l}{A}$

$R = \dfrac{V}{I}$

$P = IV$

$V = E - Ir$

$\dfrac{V}{V_{\text{total}}}\left(\text{or } \dfrac{V_{\text{OUT}}}{V_{\text{IN}}}\right) = \dfrac{R}{R_{\text{total}}}$

$c = f\lambda$

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

$\lambda = \dfrac{ay}{D}$

$d\sin\theta = n\lambda$

$n_1v_1 = n_2v_2$

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

$E_{k\max} = hf - \phi$

$\lambda_{\max} = W\,T^{-1}$

$P = A\sigma T^4$

efficiency = $\dfrac{\text{useful energy transfer}}{\text{total energy input}} \times 100\%$

### Particle Physics

| | Leptons | | | Quarks | |
|---|---|---|---|---|---|
| particle (symbol) | electron ($e^-$) | electron neutrino ($\nu_e$) | | up (u) | down (d) |
| charge ($e$) | – 1 | 0 | | $+\frac{2}{3}$ | $-\frac{1}{3}$ |
| lepton number | 1 | 1 | | 0 | 0 |

## A2

$\omega = \dfrac{\theta}{t}$

$v = \omega r$

$a = \omega^2 r$

$a = -\omega^2 x$

$x = A\sin(\omega t + \varepsilon)$

$v = A\omega\cos(\omega t + \varepsilon)$

$T = 2\pi\sqrt{\dfrac{m}{k}}$

$p = mv$

$Q = mc\Delta\theta$

$p = \dfrac{h}{\lambda}$

$\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c}$

$M/\text{kg} = \dfrac{M_r}{1\,000}$

$pV = nRT$

$p = \frac{1}{3}\rho\overline{c^2}$

$U = \frac{3}{2}nRT$

$k = \dfrac{R}{N_A}$

$W = p\Delta V$

$\Delta U = Q - W$

$C = \dfrac{Q}{V}$

$C = \dfrac{\varepsilon_o A}{d}$

$U = \frac{1}{2}QV$

$Q = Q_0 e^{-t/RC}$

$F = BIl\sin\theta$ and $F = Bqv\sin\theta$

$B = \dfrac{\mu_o I}{2\pi a}$

$B = \mu_o nI$

$\Phi = AB\cos\theta$

$V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}}$

$A = \lambda N$

$N = N_o e^{-\lambda t}$ or $N = \dfrac{N_o}{2^x}$

$A = A_o e^{-\lambda t}$ or $A = \dfrac{A_o}{2^x}$

$\lambda = \dfrac{\log_e 2}{T_{½}}$

$E = mc^2$

## A2

### Fields

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2} \qquad E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \qquad V_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r} \qquad W = q\Delta V_E,$$

$$F = G\frac{M_1M_2}{r^2} \qquad g = \frac{GM}{r^2} \qquad V_g = \frac{-GM}{r} \qquad W = m\Delta V_g$$

### Orbiting Bodies

Centre of mass: $r_1 = \frac{M_2}{M_1+M_2}d$;

Period of Mutual Orbit: $T = 2\pi\sqrt{\frac{d^3}{G(M_1+M_2)}}$

### Options

**A:** $\frac{V_1}{N_1} = \frac{V_2}{N_2}$; $E = -L\frac{\Delta I}{\Delta t}$; $X_L = \omega L$; $X_C = \frac{1}{\omega C}$; $Z = \sqrt{X^2+R^2}$; $Q = \frac{\omega_0 L}{R}$

**B: Electromagnetism and Space-Time**

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$; $\Delta t = \frac{\Delta\tau}{\sqrt{1-\frac{v^2}{c^2}}}$

**B: The Newtonian Revolution**

$$\frac{1}{T_P} = \frac{1}{T_E} - \frac{1}{t_{opp}}$$

$$\frac{1}{T_P} = \frac{1}{T_E} + \frac{1}{t_{inf\ conj}}$$

$$r_P = a(1-\varepsilon)$$

$$r_A = a(1+\varepsilon)$$

$$r_Pv_P = r_Av_A$$

**C:** $\varepsilon = \frac{\Delta l}{l}$; $Y = \frac{\sigma}{\varepsilon}$; $\sigma = \frac{F}{A}$; $U = \frac{1}{2}\sigma\varepsilon V$

**D:** $I = I_0\exp(-\mu x)$; $Z = c\rho$

**E:** $\frac{\Delta Q}{\Delta t} = -AK\frac{\Delta\theta}{\Delta x}$; $U = \frac{K}{\Delta x}$ $\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$ Carnot efficiency $= \frac{(Q_1-Q_2)}{Q_1}$

## Mathematical Information

### SI multipliers

| Multiple | Prefix | Symbol |
|---|---|---|
| $10^{-18}$ | atto | a |
| $10^{-15}$ | femto | f |
| $10^{-12}$ | pico | p |
| $10^{-9}$ | nano | n |
| $10^{-6}$ | micro | μ |
| $10^{-3}$ | milli | m |
| $10^{-2}$ | centi | c |

| Multiple | Prefix | Symbol |
|---|---|---|
| $10^{3}$ | kilo | k |
| $10^{6}$ | mega | M |
| $10^{9}$ | giga | G |
| $10^{12}$ | tera | T |
| $10^{15}$ | peta | P |
| $10^{18}$ | exa | E |
| $10^{21}$ | zetta | Z |

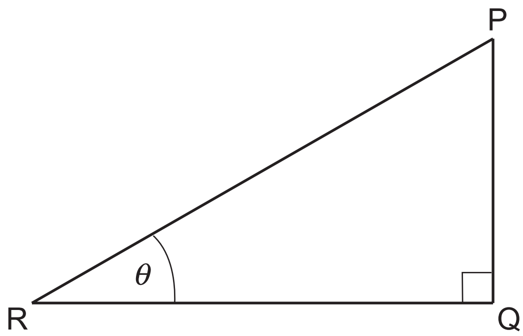
### Areas and Volumes

Area of a circle = $\pi r^2 = \dfrac{\pi d^2}{4}$

Area of a triangle = $\frac{1}{2}$ base × height

| Solid | Surface area | Volume |
|---|---|---|
| rectangular block | $2\,(lh + hb + lb)$ | $lbh$ |
| cylinder | $2\pi r\,(r + h)$ | $\pi r^2 h$ |
| sphere | $4\pi r^2$ | $\frac{4}{3}\pi r^3$ |

### Trigonometry




$$\sin\theta = \frac{PQ}{PR},\quad \cos\theta = \frac{QR}{PR},\quad \tan\theta = \frac{PQ}{QR},\quad \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$PR^2 = PQ^2 + QR^2$$

### Logarithms (A2 only)

[Unless otherwise specified 'log' can be $\log_e$ (i.e. ln) or $\log_{10}$.]

$\log(ab) = \log a + \log b$

$\log\left(\dfrac{a}{b}\right) = \log a - \log b$

$\log x^n = n\log x$

$\log_e e^{kx} = \ln e^{kx} = kx$

$\log_e 2 = \ln 2 = 0{\cdot}693$