Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

Jamie

Monday 15 May 2017 (afternoon)

1 hour 15 minutes

Candidate session number

17	M	TZ	2	P	2	P	M	S	L

Instructions to candidates

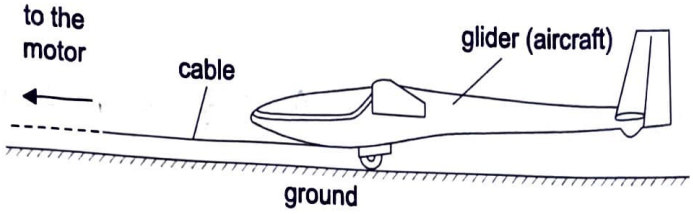
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

35/50

2217–6517

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A glider is an aircraft with no engine. To be launched, a glider is uniformly accelerated from rest by a cable pulled by a motor that exerts a horizontal force on the glider throughout the launch.



(a) The glider reaches its launch speed of 27.0 m s^{-1} after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground. **2** [2]

$s = \frac{(v+u)t}{2} = \frac{27.11}{2}$ ✓

$= 148.5$ m

$= 150$ m ✓

DATA
$u = 0$ ms^{-1}
$v = 27.0$ ms^{-1}
$t = 11.0$ s
$s = ?$

(b) The glider and pilot have a total mass of 492 kg. During the acceleration the glider is subject to an average resistive force of 160 N. Determine the average tension in the cable as the glider accelerates. **3** [3]

⇒ force req. to accelerate = $F = ma$

⇒ $a = \frac{v^2-u^2}{2s} = \frac{27^2}{5\times148.5} = 2.45$ ms^{-2} ✓

$\therefore F = 492 \times 2.45$ ✓ $= 1207.6$ N

⇒ $T = F + F_r = 1207.6 + 160$ N $= 1367.6$ N

$= 1370$ N ✓

DATA
$m = 492$ kg
$F_r = -160$ N
$T = ?$

(This question continues on the following page)

(Question 1 continued)

(c) The cable is pulled by an electric motor. The motor has an overall efficiency of 23 %. Determine the average power input to the motor. 2 [3]

power = FV = 1367.7 × 27.0
= 36927.9 W

DATA
F = 1367.6 N
V = 27.0 $m s^{-1}$

efficiency = $\frac{\text{useful out}}{\text{total in}}$

∴ total in = $\frac{36927.9}{0.23}$
= 1.61×10^5 W
= 1.6×10^5 W

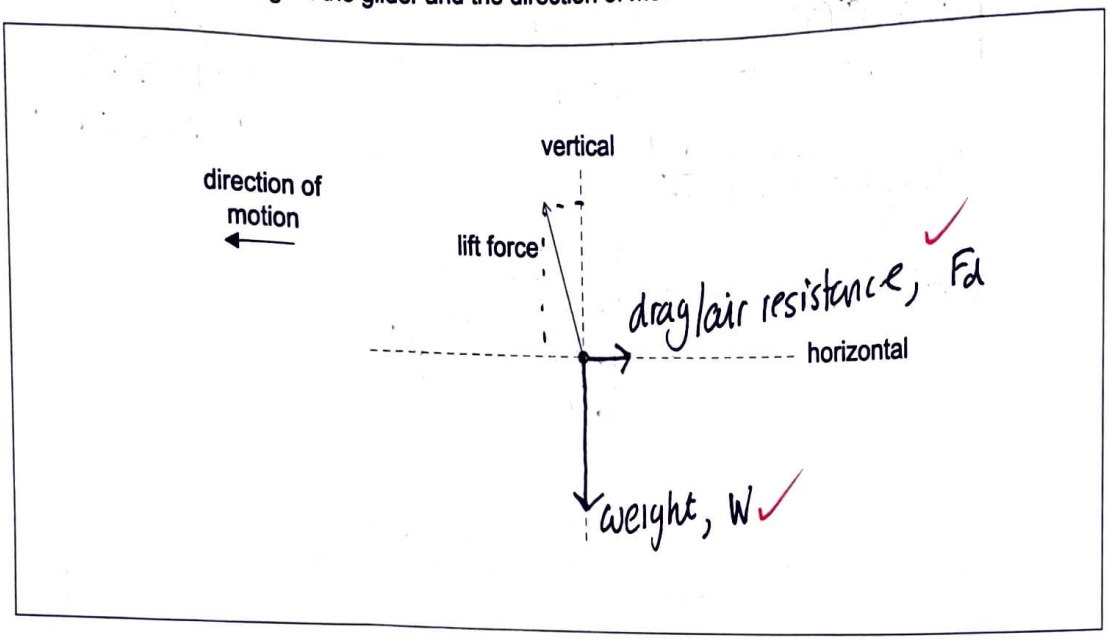
(d) The cable is wound onto a cylinder of diameter 1.2 m. Calculate the angular velocity of the cylinder at the instant when the glider has a speed of 27 m s^{-1}. Include an appropriate unit for your answer. 1 [2]

→ radius, r = 0.6 m
→ V = ωr
∴ ω = V/r = 27/0.6 = 45 deg s^{-1}
rad s^{-1}

(This question continues on the following page)

(Question 1 continued)

(e) After takeoff the cable is released and the unpowered glider moves horizontally at constant speed. The wings of the glider provide a lift force. The diagram shows the lift force acting on the glider and the direction of motion of the glider.



Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions. 2 [2]

(f) Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight. 0 [2]

all forces are equal and opposite. According to Newtons second law, no acceleration (vertical or horizontal) can occur when all forces cancel.

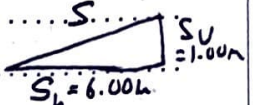
(This question continues on the following page)

-2

(Question 1 continued)

(g) At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is 12.5 m s^{-1}. Calculate the **velocity** of the glider. Give your answer to an appropriate number of significant figures. 2 [3]

→ $V_h = s_h / t$ → $t = 6.00 / 12.5 = 0.48$ s



→ diagonal distance, $s = \sqrt{6^2 + 1^2} = 6.083$ m

→ $v = s / t = 6.083 / 0.48 = 12.7$ m s^{-1} ✓✓

-1

2. (a) Outline, with reference to energy changes, the operation of a pumped storage hydroelectric system. 2 [2]

1) Water is stored with gravitational potential energy at the top (eg. of a dam).
2) On request, water is let out. It converts gravitational potential to kinetic energy as it loses height.
3) By spinning a turbine, the kinetic energy is converted to electrical energy.
4) Water can then be pumped back up during off-peak times!

(b) The hydroelectric system has four 250 MW generators. The specific energy available from the water is 2.7 kJ kg^{-1}. Determine the maximum time for which the hydroelectric system can maintain full output when a mass of 1.5×10^{10} kg of water passes through the turbines. 2 [2]

DATA
$P = 4 \times 250 \times 10^6$ W
$E_s = 2.7 \times 10^3$ J kg^{-1}
$m = 1.5 \times 10^{10}$ kg

Total energy available, $E = E_s \times m$
$= 2.7 \times 10^3 \times 1.5 \times 10^{10}$
$= 4.05 \times 10^{13}$ J

$P = \frac{E}{t} \rightarrow 4 \times 250 \times 10^6 = \frac{4.05 \times 10^{13}}{t}$

$\therefore t = 40500$ s
$= 11.25$ hours

(c) Not all the stored energy can be retrieved because of energy losses in the system. Explain **one** such loss. 1 [1]

friction between the water and the surrounding environment as it moves (e.g. friction with the pipes)

(This question continues on the following page)

(Question 2 continued)

(d) At the location of the hydroelectric system, an average intensity of 180 W m^{-2} arrives at the Earth's surface from the Sun. Solar photovoltaic (PV) cells convert this solar energy with an efficiency of 22 %. The solar cells are to be arranged in a square array. Determine the length of **one** side of the array that would be required to replace the hydroelectric system. [2]

2

$\rightarrow P_{in} = \frac{P_{out}}{0.22} = \frac{4\times250\times10^{6}}{0.22} \approx 4.55\times10^{9}\,W$

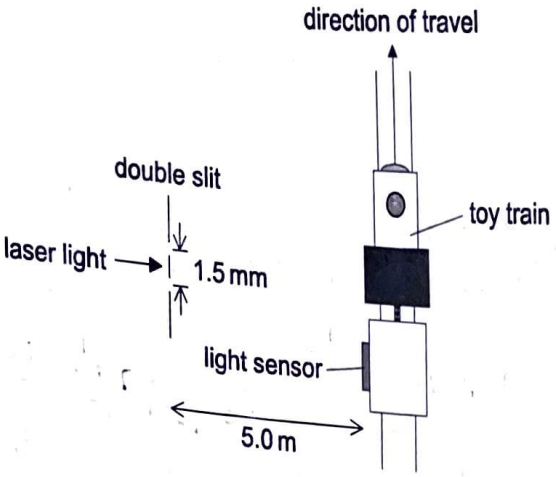
$\rightarrow$ intensity $= \frac{P_{in}}{A} \rightarrow A = \frac{P_{in}}{I}$

$= \frac{4.55\times10^{9}}{180} = 2.53\times10^{7}\,m^2$ ✓

$\rightarrow$ side length of square $= \sqrt{2.53\times10^{7}} = 5028\,m$ ✓ ✓ accuracy

DATA
$I = 180\,W\,m^{-2}$
$e = 0.22$
$P_{out} = 4\times250\times10^{6}\,W$

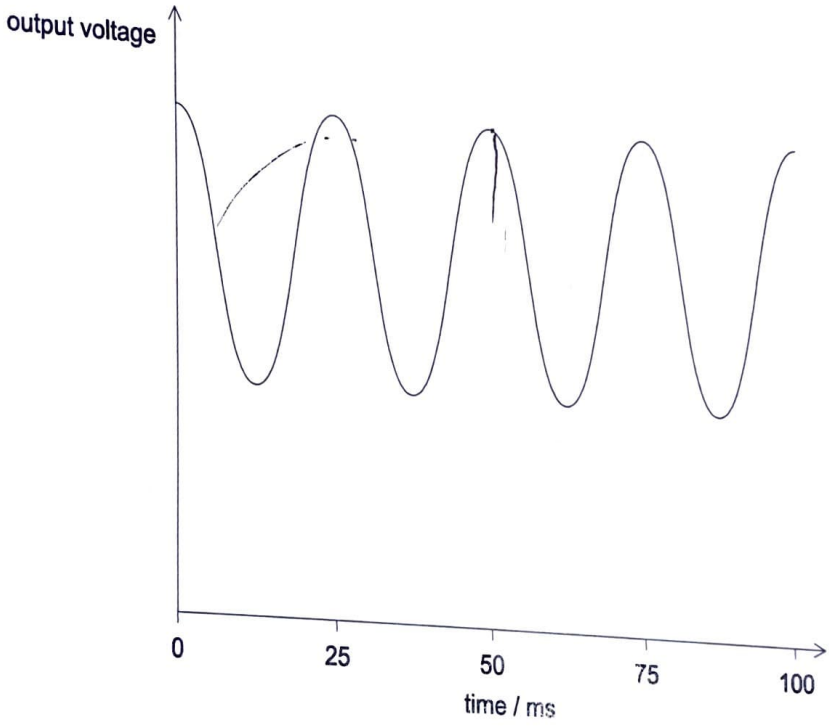
3. A student investigates how light can be used to measure the speed of a toy train.



(not to scale)

Light from a laser is incident on a double slit. The light from the slits is detected by a light sensor attached to the train.

The graph shows the variation with time of the output voltage from the light sensor as the train moves parallel to the slits. The output voltage is proportional to the intensity of light incident on the sensor.



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(Question 3 continued)

(a) Explain, with reference to the light passing through the slits, why a series of voltage peaks occurs. [3]

3

- as the light passing through both slits diffract, points of constructive and destructive interference occur due to superposition of waves.
- at the light sensor, high voltage readings occur at maxima (constructive), and vice versa.
- the fringe width ~~occurs~~ is the distance between two successive maxima.

(b) (i) The slits are separated by 1.5 mm and the laser light has a wavelength of 6.3×10^{-7} m. The slits are 5.0 m from the train track. Calculate the separation between two adjacent positions of the train when the output voltage is at a maximum. [1]

1

$s = \lambda D / d = (6.3 \times 10^{-7} \times 5.0) / (1.5 \times 10^{-3})$

$= 2.1 \times 10^{-3}$ m $= 2.1$ mm

(ii) Estimate the speed of the train. [2]

2

time between maxima (graph) $= 25 \times 10^{-3}$ s

distance between maxima $= 2.1 \times 10^{-3}$ s

$\therefore v = \frac{2.1 \times 10^{-3}}{25 \times 10^{-3}} = 0.084$ ms^{-1} $\approx$ 0.08 ms^{-1}

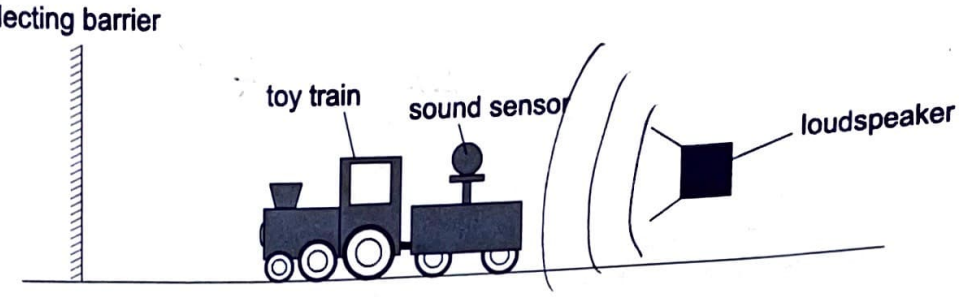
(This question continues on page 11)

Please **do not** write on this page.

Answers written on this page will not be marked.

(Question 3 continued from page 9)

(c) In another experiment the student replaces the light sensor with a sound sensor. The train travels away from a loudspeaker that is emitting sound waves of constant amplitude and frequency towards a reflecting barrier.



The sound sensor gives a graph of the variation of output voltage with time along the track that is similar in shape to the graph on page 8. Explain how this effect arises. 0 [2]

- ~~rather than diffraction patterns with light,~~ ~~this sound sensor is travelling between compressions and rarefactions in the longitudinal wave (giving maxima & minima).~~
- ~~there~~ the reflecting barrier causes the superposition of rarefactions and compressions of the sound wave particles, making a similar pattern to the diffraction pattern.

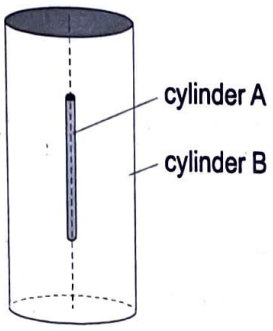
-2

4. The first scientists to identify alpha particles by a direct method were Rutherford and Royds. They knew that radium-226 ($^{226}_{88}Ra$) decays by alpha emission to form a nuclide known as radon (Rn).

(a) Write down the missing values in the nuclear equation for this decay. [1]

$$^{226}_{88}Ra \rightarrow \overset{222}{\underset{86}{}}Rn + \overset{4}{\underset{2}{}}\alpha$$

(b) Rutherford and Royds put some pure radium-226 in a small closed cylinder A. Cylinder A is fixed in the centre of a larger closed cylinder B.



At the start of the experiment all the air was removed from cylinder B. The alpha particles combined with electrons as they moved through the wall of cylinder A to form helium gas in cylinder B.

The wall of cylinder A is made from glass. Outline why this glass wall had to be very thin. [1]

- α particles form alpha decay.
- in this decay, the α particles ~~have a very~~ do not have a high penetrating power (a thin sheet could stop it).
- therefore, the glass must be very thin.

(This question continues on the following page)

(c) Rutherford and Royds expected 2.7×10^{15} alpha particles to be emitted during the experiment. The experiment was carried out at a temperature of 18 °C. The volume of cylinder B was 1.3×10^{-5} m^3 and the volume of cylinder A was negligible. Calculate the pressure of the helium gas that was collected in cylinder B. 3 [3]

$p = \frac{nRT}{V}$ $\left\{ n = \frac{N}{N_A} = \frac{2.7 \times 10^{15}}{6.02 \times 10^{23}} \right\}$

$= \frac{4.485 \times 10^{-9} \times 8.31 \times 291}{1.3 \times 10^{-5}}$ $= 4.485 \times 10^{-9}$ mol

$p = 0.833$ Pa $= 0.83$ Pa

DATA
$N = 2.7 \times 10^{15}$
$T = 18°C = 291$ K
$V_B = 1.3 \times 10^{-5}$ m^3

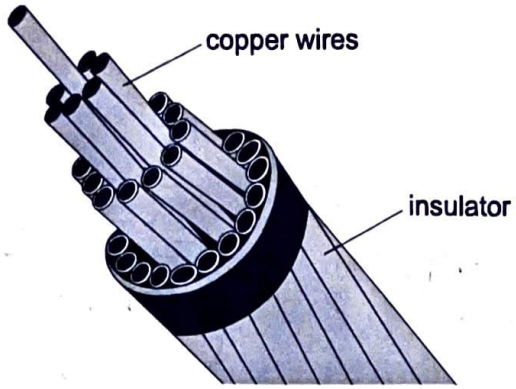
(d) Rutherford and Royds identified the helium gas in cylinder B by observing its emission spectrum. Outline, with reference to atomic energy levels, how an emission spectrum is formed. 1 [3]

→ By shining white light through the gas, the emission spectrum can be observed.
→ The helium will absorb all energy at the exact discrete energy levels required to excite the electrons.
→ The light that corresponds to these discrete energy levels will be absorbed, and removed from the emission spectrum, absorbed
→ The light will be emitted at a later time in random directions

(e) The work was first reported in a peer-reviewed scientific journal. Outline why Rutherford and Royds chose to publish their work in this way. 1 [1]

• peer reviewed scientific journals ensure the high academic integrity of the work is maintained. This would mean that Rutherford and Royds could be confident in their work

5. A cable consisting of many copper wires is used to transfer electrical energy from a generator to an electrical load. The copper wires are protected by an insulator.



(a) The copper wires and insulator are both exposed to an electric field. Discuss, with reference to charge carriers, why there is a significant electric current only in the copper wires. [3]

- Insulators do not conduct energy (such as electrical energy) well.
- energy flowing through the copper will not be able to escape easily.
- The electric field will not be able to penetrate the insulator, meaning that the charge carriers will not experience a force.

(This question continues on the following page)

-3

(Question 5 continued)

(b) The cable consists of 32 copper wires each of length 35 km. Each wire has a resistance of 64 Ω. The resistivity of copper is $1.7 \times 10^{-8}\ \Omega\,m$.

(i) Calculate the radius of each **wire**. 2 [2]

$\rho = RA/L \rightarrow A = \rho L/R$

$= \frac{(1.7\times10^{-8} \times 35\times10^{3})}{64}$ ✓

$= 9.297\times10^{-6}\ m$

$A = \pi r^2 \rightarrow r = \sqrt{A/\pi} = \sqrt{\frac{9.297\times10^{-6}}{\pi}} = 1.72\,mm$ ✓

$= 1.7\ mm$

DATA

$L = 35\times10^{3}\ m$

$\rho = 1.7\times10^{-8}\ \Omega m$

$R = 64\ \Omega$

(ii) There is a current of 730 A in the cable. Show that the power loss in 1 m of the cable is about 30 W. 2 [2]

$\rightarrow R = \rho L/A = (1.7\times10^{-8} \times 1)/(32 \times 9.297\times10^{-6})$ ✓

$= 5.714\ \Omega \times 10^{-5}$ ✓

$\rightarrow V = I^2R = 730^2 \times 5.714\times10^{-5}$

$= 30.45 \approx 30\ W$ ✓

(iii) When the current is switched on in the cable the initial rate of rise of temperature of the cable is 35 mK s^{-1}. The specific heat capacity of copper is 390 J kg^{-1} K^{-1}. Determine the mass of a length of one metre of the cable. 0 [2]

$I = \Delta q/\Delta t \rightarrow \Delta q = 730 \times 1 = 730\ J$

$Q = mc\Delta T \rightarrow m = \frac{Q}{c\Delta T} = \frac{730}{390 \times 35\times10^{-3}}$

$= 53.48\ kg$

$= 54\ kg$

DATA

$\Delta t = 1\ s$

$c = 390\ J\ kg^{-1}\ K^{-1}$

$\Delta T = 35\times10^{-3}\ K$

$m = ?$