Please check the examination details below before entering your candidate information

Candidate surname	Matheson	Other names	Lewis

Centre Number: 9 1 0 9 3

Candidate Number: 8 3 7 0

Pearson Edexcel Level 3 GCE

Friday 24 May 2024

Morning (Time: 1 hour 45 minutes)

Paper reference **9PH0/01**

Physics

Advanced

PAPER 1: Advanced Physics I

You must have:
Scientific calculator and ruler
Data, Formulae and Relationships Booklet (enclosed)

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- You are advised to show your working in calculations including units where appropriate.

Turn over

P 7 4 4 6 8 A 0 1 2 4

Pearson

Answer ALL questions.

All multiple choice questions must be answered with a cross in the box ☒ for the correct answer from A to D. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Which of the following is the base unit for charge?

☒ **A** As ✓

☐ **B** C

☐ **C** JV^{-1}

☐ **D** Q

Derived unit

Not base units

Symbol for charge

(Total for Question 1 = 1 mark)

2 Which of the following could **not** be accelerated in a LINAC?

☐ **A** electron

☒ **B** helium atom ✓

☐ **C** proton

☐ **D** uranium ion

No charge

Accelerates charged particles

(Total for Question 2 = 1 mark)

3 A toy car moves up a slope at a constant speed, as shown. The car is moved by a motor with a power output of 5.2 W. The car gains a gravitational potential energy of 0.40 J in a time of 1.1 s.

Which of the following expressions gives the work done, in J, against resistive forces?

☐ **A** 5.2 − (0.40 × 1.1)

☒ **B** (5.2 × 1.1) − 0.40 ✓

☐ **C** (5.2 ÷ 1.1) + 0.40

☐ **D** (5.2 × 1.1) + 0.40

$W = \Delta E = E_T - E_p$

$= Pt - mgh$

$= (5.2 \times 1.1) - 0.40$

(Total for Question 3 = 1 mark)

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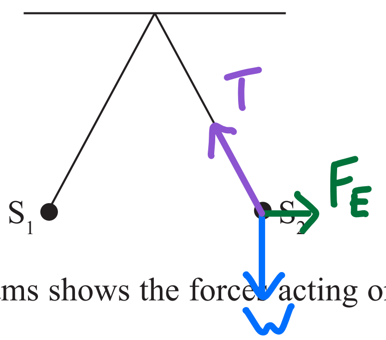
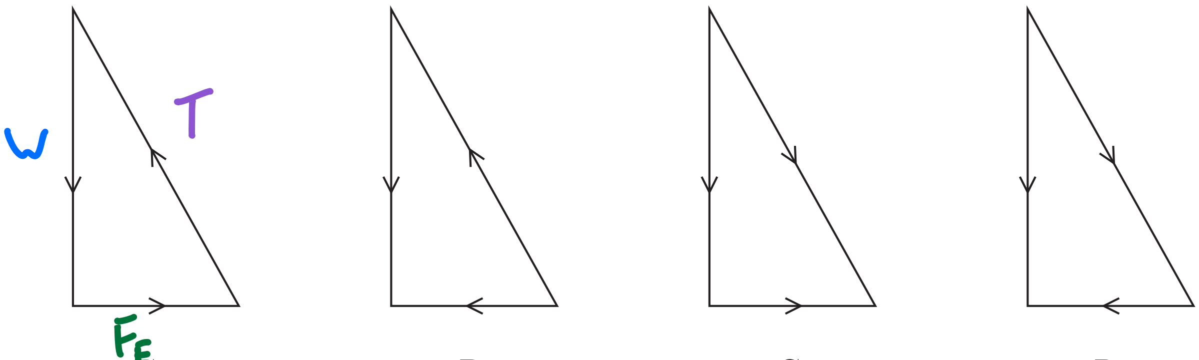
Questions 4 and 5 refer to two small positively charged spheres S_1 and S_2 suspended by threads, as shown.



4 Which of the following vector diagrams shows the forces acting on S_2?



- [x] **A** ✓
- [ ] **B**
- [ ] **C**
- [ ] **D**

(Total for Question 4 = 1 mark)

5 The electrostatic force between the two charges is initially *F*.

The charge on S_1 is doubled whilst the charge on S_2 is unchanged. The distance between S_1 and S_2 doubles.

Which of the following is the new force on S_2?

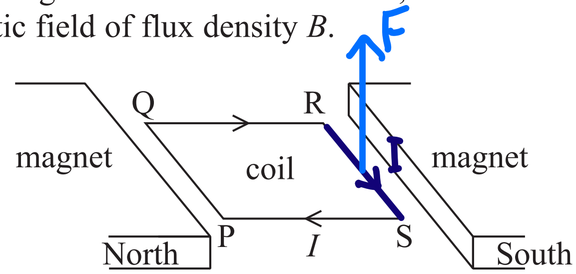
- [ ] **A** $\frac{F}{4}$
- [x] **B** $\frac{F}{2}$ ✓
- [ ] **C** F
- [ ] **D** $2F$

$$F_1 = k\frac{q_1 q_2}{r^2}$$

$$F_2 = k\frac{(2q_1)q_2}{(2r)^2} = \frac{2}{4}k\frac{q_1 q_2}{r^2} = \frac{F_1}{2}$$

(Total for Question 5 = 1 mark)

6 A square coil has sides of length l and carries a current I, as shown. The plane of the coil is parallel to a magnetic field of flux density B.



Which row of the table gives the magnetic force on the named side of the coil?

		Named side	Magnetic force
☐	**A**	PQ	BIl to the left
☐	**B**	QR	BIl to the right
☒	**C**	RS	BIl upwards
☐	**D**	SP	BIl downwards

(Total for Question 6 = 1 mark)

7 A length of wire has a non-uniform cross-sectional area. There is an electric current in the wire.

Which of the following is **not** constant along the length of this wire?

- ☐ **A** electric current
- ☐ **B** electron charge
- ☒ **C** electron drift velocity
- ☐ **D** number of free electrons per unit volume

(Total for Question 7 = 1 mark)

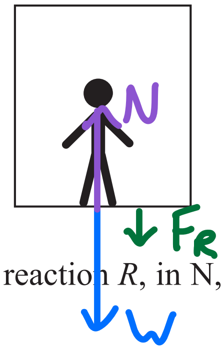
8 A roundabout completes 5.0 revolutions in 20 s.

Which of the following is the angular velocity of the roundabout?

- ☒ **A** 1.6 rad s^{-1}
- ☐ **B** 16 rad s^{-1}
- ☐ **C** 25 rad s^{-1}
- ☐ **D** 630 rad s^{-1}

(Total for Question 8 = 1 mark)

9 A person of mass 70 kg is standing on the floor of a lift, as shown. The lift is accelerating downwards at 1.5 m s^{-2}.



$F_R = ma$

and $F_R = W - N$

$N = W - F_r$

$N = mg - ma$

$N = (70 \times 9.81) - (70 \times 1.5)$

Which of the following gives the normal reaction R, in N, acting on the person?

- ☐ **A** $R = 70 \times 9.81$
- ☐ **B** $R = 70 \times 1.5$
- ☐ **C** $R = (70 \times 9.81) + (70 \times 1.5)$
- ☒ **D** $R = (70 \times 9.81) - (70 \times 1.5)$ ✓

(Total for Question 9 = 1 mark)

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10 An object was thrown so that it followed the path shown. Assume drag forces were negligible.

The object was thrown with an initial vertical component of velocity u. The time taken to reach maximum height is t.

Which of the following could **not** be used to determine the maximum vertical height s reached by the object?

- ☐ **A** $s = ut - \frac{1}{2}gt^2$
- ☒ **B** $s = ut$ ✓
- ☐ **C** $s = \frac{1}{2}ut$
- ☐ **D** $s = \frac{u^2}{2g}$

↑ $s = s$
$u = u$
$v = 0$
$a = -g$
$t = t$

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

$s = ut - gt^2$

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

$v^2 = u^2 + 2as$

(Total for Question 10 = 1 mark)

$u^2 - 2gs = 0 \quad s = \frac{u^2}{2g}$

11 A film involves a gang of bank robbers making a getaway on a bus loaded with gold bars. The bus spins out of control and ends up balancing on the edge of a cliff, as shown.

(Source: © maforche/Shutterstock)

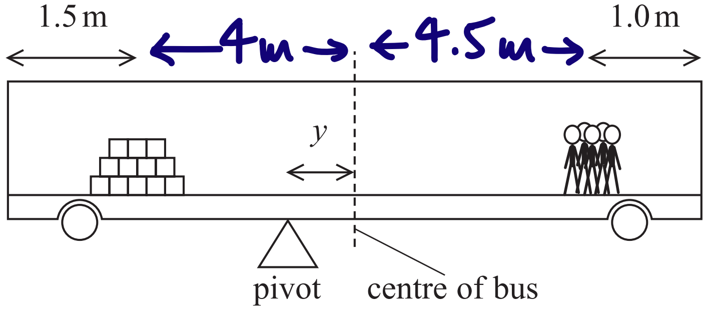
(a) State what is meant by the moment of a force about a point.

(1)

The force multiplied by the perpendicular distance from the pivot (to the line of action of the force). ✓

(b) The bus is balanced on a pivot that is a distance y from the centre of the bus.

The centre of mass of the gold is 1.5 m from one end of the bus. The centre of mass of the bank robbers is 1.0 m from the other end of the bus, as shown.

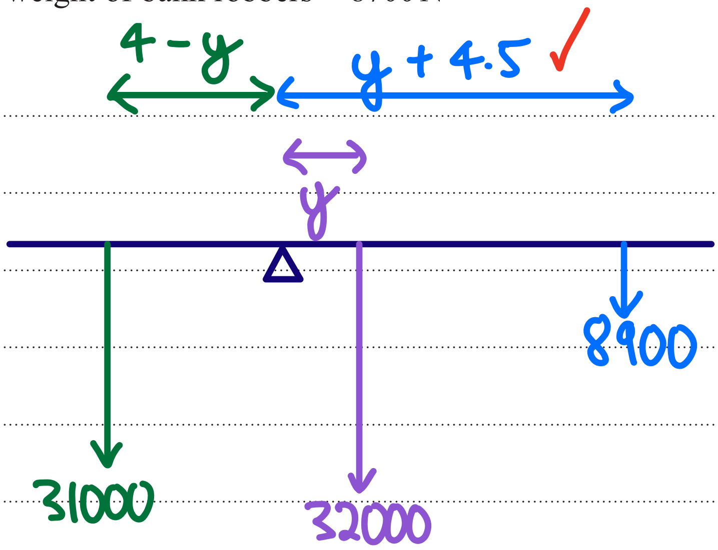


The unloaded bus can be treated as a uniform body with a weight of 32 000 N.

Calculate the distance y when the bus is balanced.

length of bus = 11.0 m
weight of gold bars = 31 000 N
weight of bank robbers = 8700 N

(4)



$\overleftarrow{M} = \overrightarrow{M}$

$y =$ 1.18 m

(Total for Question 11 = 5 marks)

$31000 \times (4 - y) = (32000 \times y) + ((y + 4.5) \times 8700)$

$124\,000 - 31000y = 32000y + 8700y + 39150$

$124 - 39.15 = y(31 + 32 + 8.7)$

$y = 84.85/71.7 = 1.183$

P74468A0724

12 Electrical power is transmitted from Norway to Britain using a cable laid under the North Sea.

The following information is published on a website.

> The cable has a diameter of 15 cm and a length of 720 km.
>
> It is made of copper of resistivity $1.7 \times 10^{-8}\,\Omega\,m$.
>
> The electrical power transmitted from Norway is 1400 MW and the transmission potential difference is 1100 kV.
>
> The efficiency of this process is almost 100%.

Deduce, by calculation, whether the claim for efficiency is correct.

$$R = \frac{\rho l}{A} = \frac{4\rho l}{\pi d^2} = \frac{4 \times 1.7\times10^{-8} \times 720\times10^{3}}{\pi \times 0.15^2} = 0.6926\,\Omega$$

$$I = P/V = 1400\times10^{6} / 1100\times10^{3} = 1272.7\text{ A}$$

$$P_{lost} = I^2 R = 1272.7^2 \times 0.6926 = 1.12\times10^{6}\text{ W}$$

$$\frac{1.12}{1400} \times 100 = 0.08$$ Inefficiencies ∴ 99.92% efficient

Claim is correct.

(Total for Question 12 = 6 marks)

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13 Beams of antiprotons are often used in particle physics experiments.

(a) Show that the rest mass of an antiproton is about 900 MeV/c^2.

(4)

$E = mc^2 = 1.673 \times 10^{-27} \times (3.00 \times 10^8)^2 = 1.506 \times 10^{-10}$ J ✓

Convert to eV $1.506 \times 10^{-10} \div 1.60 \times 10^{-19} = 9.41 \times 10^8$ eV ✓

941×10^6 eV/c^2 ✓

≈ 900 MeV/c^2

(b) Antiprotons can be produced by accelerating and colliding two protons moving in opposite directions. A website suggests a possible outcome for a collision between these protons is described by the nuclear equation:

$$p + p \rightarrow p + p + p + \bar{p}$$

Deduce, by using conservation laws, whether it should be possible to produce an antiproton in this way.

(4)

	p	+ p	→ p	+ p	+ p	+ $\bar{p}$	
Q:	1	1	1	1	1	−1	✓ ✓
B:	1	1	1	1	1	−1	✓ ✓
L:	0	0	0	0	0	0	✓
S:	0	0	0	0	0	0	✓

p: Momentum is conserved if the momentum before is equal to the momentum afterwards.

E: Energy required to produce a proton and an antiproton is at least 2×941

(Total for Question 13 = 8 marks)

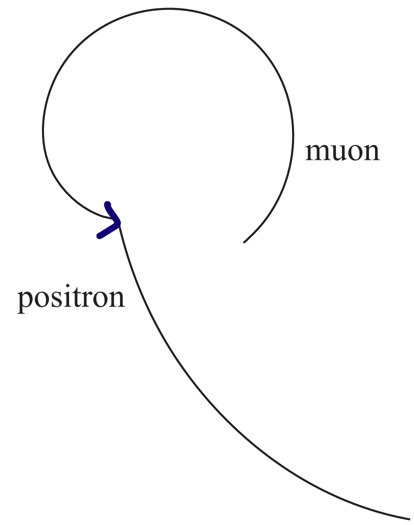
= 1882 MeV ✓

This energy comes from the E_K of the initial moving protons. ✓

P 7 4 4 6 8 A 0 9 2 4

Turn over ▶

14 The decay of a positive muon produced a positron, an electron neutrino and a muon antineutrino. The diagram shows the tracks formed in a particle detector.



(a) A muon belongs to a family of particles called leptons.

State two features that all particles in the lepton family have in common.

(2)

• Fundamental particles. ✓
• Interact by the weak force. ✓

(b) Write a nuclear equation for the decay of the muon (μ) described above.

(2)

$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$ ✓✓

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(c) Describe the role of the magnetic field in a particle detector.

(3)

To provide a force on moving charged particles ✓, causing a circular track in the particle detector. The size and direction of which allows the charge ✓ and momentum ✓ of the particle to be determined.

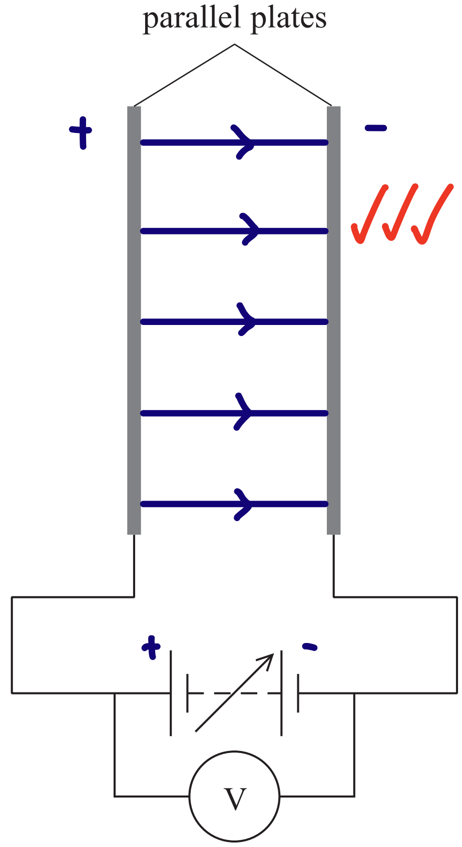
(d) Explain how the diagram gives evidence that a particle or particles, other than the positron, were produced in this decay.

(4)

There is a sharp change in direction and a different radius of path. ✓ This indicates a change in momentum of the new charged particle ✓ As momentum is conserved ✓, it means another particle(s) must have been created ✓ (that has no charge).

(Total for Question 14 = 11 marks)

15 A teacher demonstrates the electric field produced between two parallel metal plates. The plates are connected to a variable power supply, as shown. The power supply has a very large internal resistance and includes a voltmeter that indicates its output.



(a) (i) Add to the diagram to show the electric field between the two plates.

(3)

(ii) Explain why the reading on the voltmeter indicates the e.m.f. of the power supply.

(2)

Current is zero. ✓ $\varepsilon = V + Ir$ ∴ $\varepsilon = V$ when $I = 0$
Terminal PD is equal to the EMF as there is no PD across the internal resistance ✓ (no 'lost volts').

(b) The power supply output is increased until sparks are heard and are seen in the gap between the plates. Sparks form in air when the electric field strength exceeds $3.0 \times 10^6\,V\,m^{-1}$ and the air becomes conducting for a short time.

(i) Calculate the minimum potential difference across the plates for sparks to be created.

distance between parallel plates = 2.0 mm

(2)

$E = \frac{V}{d}$ $V = Ed$ ✓ $= 3.0\times10^6 \times 2.0\times10^{-3} = 6.0\times10^3$

Minimum potential difference = 6.0×10^3 V ✓

(ii) Explain why the voltmeter reading decreases significantly whenever sparks are produced.

(3)

When there is a spark, there is a current in the circuit, ✓ this reduces the terminal PD ✓ as $V = \mathcal{E} - Ir$ and there is a PD across the internal resistance of the supply. ✓

(Total for Question 15 = 10 marks)

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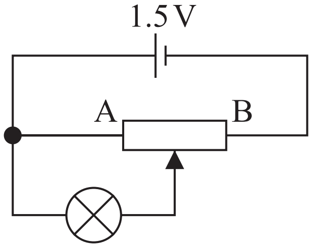
16 A student is investigating circuits that include a filament bulb. The filament bulb is labelled '1.5 V, 0.50 W'.

(a) Show that the resistance of the filament bulb when operating normally is about 5 Ω.

(2)

$P = V^2/R \quad R = V^2/P = 1.5^2/0.50 = 4.50 \approx 5\ \Omega$

*(b) The student wishes to control the brightness of the filament bulb using a potentiometer. The student connects the circuit shown. The total resistance of the potentiometer is very much larger than the resistance of the filament bulb.



Explain how the brightness of the filament bulb changes as the potentiometer slider is moved from A to B.

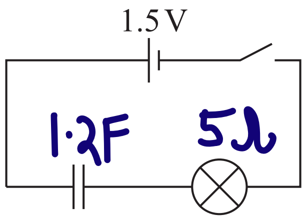
(6)

At A, the bulb is not lit as the PD across it is zero. At B it is at its brightest, as the PD across it is now 1.5V.
As the slider moves from A to B, the brightness increases as the PD increases and it has a greater current through it, as the resistance between A and the slider increases as it moves towards B.

P 7 4 4 6 8 A 0 1 4 2 4

(c) The student connects the filament bulb in the circuit shown below. The capacitor is initially uncharged and has a capacitance of 1.2 F.

The resistance of the filament bulb is 5 Ω.



Explain how the brightness of the filament bulb will vary as the switch is closed.

(4)

When the switch is first closed, the PD across the capacitor is zero, and the PD across the bulb is 1.5V. ✓ The current through the bulb is a maximum. This means the bulb will be the brightest. ✓ As the PD across the capacitor increases and the current decreases exponentially ✓, the brightness of the bulb decreases. ✓

(Total for Question 16 = 12 marks)

17 Over one hundred years ago, Rutherford supervised a series of experiments using a source of alpha particles and thin gold foil.

(a) Describe the model of the atom that Rutherford proposed as a result of this series of experiments.

(3)

Atoms are mainly empty space. The majority of the mass is concentrated in the nucleus which is positively charged and tiny compared to the size of the atom.

(b) The initial kinetic energy of an alpha $\left({}^{4}_{2}\alpha\right)$ particle is 7.3×10^{-13} J.

(i) In a textbook, it states that an alpha particle with this energy would be brought to rest when it reached a distance of 5.0×10^{-14} m from the centre of the gold nucleus $\left({}^{197}_{79}\text{Au}\right)$.

Deduce whether this statement is correct.

(4)

$$W = \frac{qQ}{4\pi\varepsilon_0 r}$$

$$r = \frac{qQ}{4\pi\varepsilon_0 W} = \frac{(2 \times 1.60 \times 10^{-19}) \times (79 \times 1.60 \times 10^{-19})}{4\pi \times 8.85 \times 10^{-12} \times 7.3 \times 10^{-13}}$$

$$r = 4.982 \times 10^{-14}\ \text{m} \approx 5.0 \times 10^{-14}$$

$\therefore$ Statement is correct.

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(ii) Determine the initial momentum of the alpha particle.

(3)

$E_K = \frac{p^2}{2m}$ ✓ $p = \sqrt{2mE_K} = \sqrt{2 \times 1.661 \times 10^{-27} \times 4 \times 7.3 \times 10^{13}}$ ✓

$p = 9.849 \times 10^{-20}$ kg ms^{-1}

Initial momentum = 9.8×10^{-20} kg ms^{-1} ✓

(c) An alpha particle moves along a path directly towards a gold nucleus, as shown.

(i) An elastic interaction occurs and the alpha particle recoils.

State what is meant by an elastic interaction.

(1)

The total kinetic energy is conserved. ✓

(ii) State what happens to the atoms in the gold foil as a result of these interactions.

(1)

The gold nuclei (and therefore the atom) recoils. ✓

(Total for Question 17 = 12 marks)

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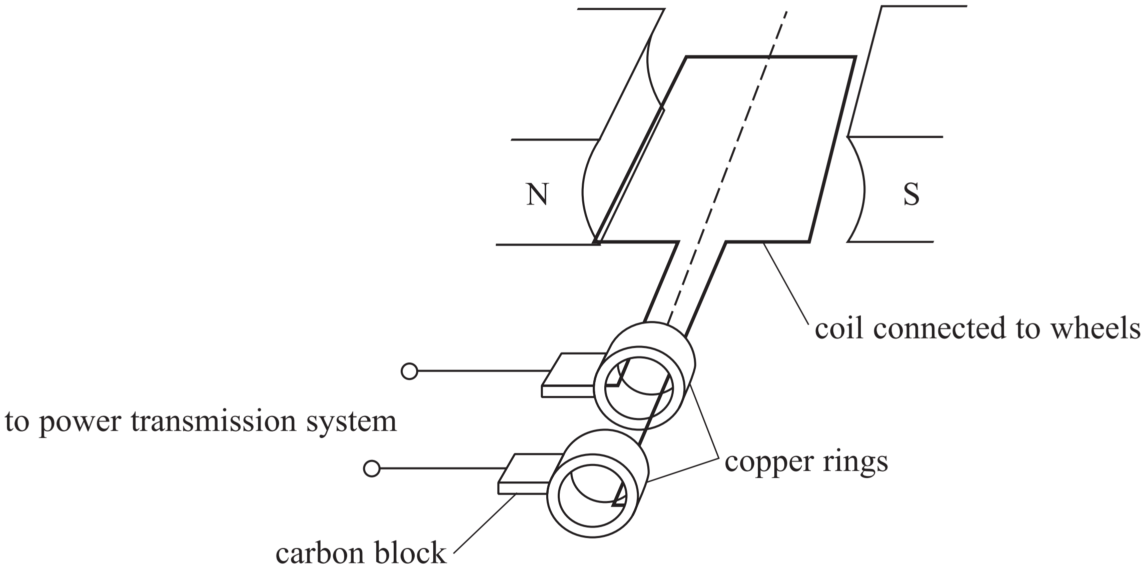
18 Regenerative braking supplies a current back to the power transmission system whilst slowing a vehicle. The arrangement shown can be used as a regenerative braking system on a train.



The coil rotates with the wheels of the train. Two copper rings are connected to the ends of the coil. The rings rotate with the coil and two carbon blocks make electrical contact with the rings as they rotate.

(a) Describe how this arrangement can be used as a regenerative brake.

(4)

The turning coil causes a change in flux linkage. This induces an EMF that opposes the change that caused it.
This opposes the motion of the wheels, applying a force opposing their motion so it slows them down.

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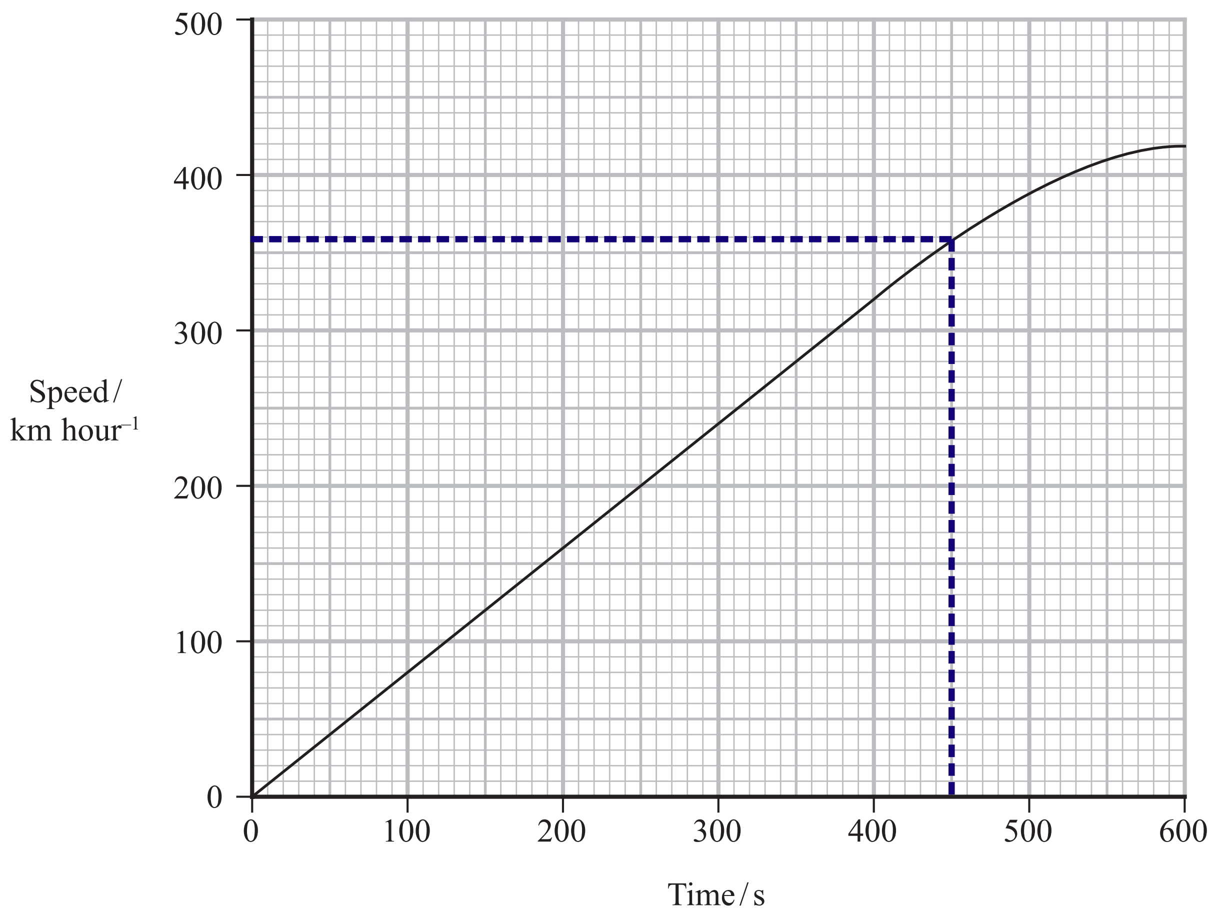
(b) A specification for a new train states that the train should be able to accelerate to a speed of 360 km hour^{-1} from rest, and that this acceleration should be completed within 40 km of level track.

The graph shows the performance of the train on a test run.



(i) Calculate the acceleration of the train as it accelerates to a speed of 360 km hour^{-1}.

(3)

$a = \frac{\Delta v}{\Delta t} = \frac{100}{450} = 0.222$

$\Delta v = \frac{360 \times 1000}{3600} = 100\ ms^{-1}$

Acceleration of train = $0.22\ ms^{-2}$

(ii) Deduce whether the performance of the train met the specification on this test run.

(3)

Area = displacement ✓ = $\frac{1}{2} \times 450 \times 1000 = 22500$ ✓

22.5 km < 40 km ∴ It met the specification ✓

(c) On curved tracks there is a maximum safe speed for the train.

(i) Explain why there is a maximum safe speed for a train travelling on a curved track.

(4)

When the track is curved then a centripetal force is required ✓, provided by a reaction force between the wheels and rails. ✓ $F_c = mv^2/r$ ✓ ∴ there is a maximum speed at which the track can no longer provide this force ✓ ($F_c \propto v^2$).

(ii) When the train travels at 200 km hour^{-1}, the minimum safe radius of curvature of the track is 1800 m.

Calculate the minimum safe radius of curvature for a speed of 360 km hour^{-1}.

(2)

$F = \frac{mv^2}{r}$ F ∝ m constant ∴ $\frac{v^2}{r} = k$

$\frac{v_1^2}{r_1} = \frac{v_2^2}{r_2}$ ✓ $r_2 = r_1 \frac{v_2^2}{v_1^2} = 1800 \times \frac{360^2}{200^2} = 5832$

Minimum safe radius of curvature = 5830 m ✓

(Total for Question 18 = 16 marks)

TOTAL FOR PAPER = 90 MARKS

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Pearson Edexcel Level 3 GCE

Friday 24 May 2024

Morning (Time: 1 hour 45 minutes)

Paper reference	9PH0/01

Physics

Advanced

PAPER 1: Advanced Physics I

Data, Formulae and Relationships Booklet
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Pearson

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$	
Coulomb law constant	$k = \dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{N m}^2\ \text{C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19}\ \text{C}$	
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27}\ \text{kg}$	

Mechanics

Kinematic equations of motion

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

$$v = u + at$$

$$s = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

moment of force $= Fx$

Momentum

$$p = mv$$

Work, energy and power

$$\Delta W = F\Delta s$$

$$E_k = \tfrac{1}{2}mv^2$$

$$\Delta E_{grav} = mg\Delta h$$

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Electric circuits

Potential difference

$$V = \frac{W}{Q}$$

Resistance

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

Electrical power and energy

$$P = VI$$

$$P = I^2R$$

$$P = \frac{V^2}{R}$$

$$W = VIt$$

Resistivity

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

Current

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

$$I = nqvA$$

Materials

Density

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

Stokes' law

$$F = 6\pi\eta rv$$

Hooke's law

$$\Delta F = k\Delta x$$

Young modulus

$$\text{Stress } \sigma = \frac{F}{A}$$

$$\text{Strain } \varepsilon = \frac{\Delta x}{x}$$

$$E = \frac{\sigma}{\varepsilon}$$

Elastic strain energy

$$\Delta E_{el} = \tfrac{1}{2}F\Delta x$$

Waves and particle nature of light

Wave speed

$$v = f\lambda$$

Speed of a transverse wave on a string

$$v = \sqrt{\frac{T}{\mu}}$$

Intensity of radiation

$$I = \frac{P}{A}$$

Power of a lens

$$P = \frac{1}{f}$$

$$P = P_1 + P_2 + P_3 + \ldots$$

Thin lens equation

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

Magnification for a lens

$$m = \frac{\text{image height}}{\text{object height}} = \frac{v}{u}$$

Diffraction grating

$$n\lambda = d\sin\theta$$

Refractive index

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

$$n = \frac{c}{v}$$

Critical angle

$$\sin C = \frac{1}{n}$$

Photon model

$$E = hf$$

Einstein's photoelectric equation

$$hf = \phi + \tfrac{1}{2}mv^2_{max}$$

de Broglie wavelength

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

Further mechanics

Impulse

$$F\Delta t = \Delta p$$

Kinetic energy of a non-relativistic particle

$$E_k = \frac{p^2}{2m}$$

Motion in a circle

$$v = \omega r$$

$$T = \frac{2\pi}{\omega}$$

$$F = ma = \frac{mv^2}{r}$$

$$a = \frac{v^2}{r}$$

$$a = r\omega^2$$

$$F = mr\omega^2$$

Fields

Coulomb's law

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Electric field strength

$$E = \frac{F}{Q}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{V}{d}$$

Electric potential

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

Capacitance

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

Energy stored in a capacitor

$$W = \tfrac{1}{2}QV$$

$$W = \tfrac{1}{2}CV^2$$

$$W = \tfrac{1}{2}\frac{Q^2}{C}$$

Capacitor discharge

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

$$I = I_0 e^{-t/RC}$$

$$V = V_0 e^{-t/RC}$$

$$\ln Q = \ln Q_0 - \frac{t}{RC}$$

$$\ln I = \ln I_0 - \frac{t}{RC}$$

$$\ln V = \ln V_0 - \frac{t}{RC}$$

In a magnetic field

$$F = BIl \sin \theta$$

$$F = Bqv \sin \theta$$

Faraday's and Lenz's laws

$$\mathscr{E} = \frac{-d(N\phi)}{dt}$$

Root-mean-square values

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

Nuclear and particle physics

In a magnetic field

$$r = \frac{p}{BQ}$$

Thermodynamics

Heating

$$\Delta E = mc\Delta\theta$$

$$\Delta E = L\Delta m$$

Molecular kinetic theory

$$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$$

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

Ideal gas equation

$$pV = NkT$$

Stefan-Boltzmann law

$$L = \sigma A T^4$$

$$L = 4\pi r^2 \sigma T^4$$

Wien's law

$$\lambda_{max} T = 2.898 \times 10^{-3}\ \mathrm{m\ K}$$

Space

Intensity

$$I = \frac{L}{4\pi d^2}$$

Redshift of electromagnetic radiation

$$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$

Cosmological expansion

$$v = H_0 d$$

Nuclear radiation

Mass-energy

$$\Delta E = c^2 \Delta m$$

Radioactive decay

$$A = \lambda N$$

$$\frac{dN}{dt} = -\lambda N$$

$$\lambda = \frac{\ln 2}{t_{½}}$$

$$N = N_0\, e^{-\lambda t}$$

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

Gravitational fields

Gravitational force

$$F = \frac{Gm_1 m_2}{r^2}$$

Gravitational field strength

$$g = \frac{Gm}{r^2}$$

Gravitational potential

$$V_{grav} = \frac{-Gm}{r}$$

Oscillations

Simple harmonic motion

$$F = -kx$$

$$a = -\omega^2 x$$

$$x = A\cos\omega t$$

$$v = -A\omega\sin\omega t$$

$$a = -A\omega^2\cos\omega t$$

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$

$$\omega = 2\pi f$$

Simple harmonic oscillator

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

$$T = 2\pi\sqrt{\frac{l}{g}}$$

END OF DATA, FORMULAE AND RELATIONSHIPS LIST

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