

AS PHYSICS (7407/1)

Paper 1

Specimen 2014

Morning

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- a pencil
- a ruler
- a calculator
- a data and formulae booklet.

Instructions

- Answer **all** questions.
- Show **all** your working.

Information

- The maximum mark for this paper is 70.

Please write clearly, in block capitals, to allow character computer recognition.

Centre number

Candidate number

Surname

Forename(s)

Candidate signature

Answer **all** questions.

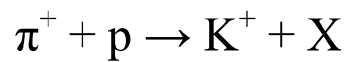
- 0 1** . **1** Complete **Table 1** comparing some of the properties of the positive pion, π^+ , and the proton.

[5 marks]

Table 1

Name	π^+	Proton
Relative charge	+1	<i>+1</i>
Baryon number	<i>0</i>	<i>+1</i>
Quark composition	<i>$u \bar{d}$</i>	<i>uud</i>

- 0 1** . **2** When a positive pion interacts with a proton, a kaon can be produced, along with another strange particle, as shown in this equation



Circle the type of interaction shown in this equation.

[1 mark]

Electromagnetic

Gravitational

Strong Nuclear

Weak Nuclear

- 0 1** . **3** Deduce the relative charge, baryon number and strangeness of particle X.

[3 marks]

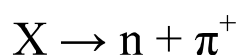
Charge: $(+1) + (+1) = (+1) + Q$, so $Q = +1$

Baryon number: $0 + 1 = 0 + B$, so $B = +1$

Strangeness: $0 + 0 = (+1) + S$, so $S = -1$

X has relative charge +1, baryon number +1, strangeness -1

- 0 1 . 4 Particle X can decay to produce a neutron and positive pion as shown in this equation



Circle the type of interaction shown in this equation.

[1 mark]

Electromagnetic

Gravitational

Strong Nuclear

Weak Nuclear

- 0 1 . 5 Explain your answer.

[2 marks]

X has strangeness -1, but the neutron and the pion both have strangeness 0, so strangeness changes from -1 to 0 in the decay.

Strangeness can only change in weak interactions, so this must be a weak interaction.

- 0 1 . 6 The neutron and positive pion will then decay. The positive pion can decay into a positron and an electron neutrino.

Write down the equation for the decay of the neutron.

[2 marks]



(proton, electron (β^-) and electron antineutrino)

- 0 1 . 7 Explain why no further decays occur.

[2 marks]

The only particles remaining are electrons, positrons, neutrinos and antineutrinos, which are leptons and are stable.

The other particle is a proton, which is the only stable baryon, so it does not decay.

0 2

The photoelectric effect can be demonstrated by illuminating a negatively charged plate, made from certain metals, with ultraviolet (UV) light and showing that the plate loses its charge.

0 2

. 1

Explain why, when ultraviolet light is shone on a **positively** charged plate, no charge is lost by the plate.

[2 marks]

The photoelectric effect involves the ejection (emission) of electrons from the plate, and electrons are negatively charged.

Any electrons ejected from a positive plate will only make the positive charge greater (and they are attracted back by it), so the plate does not lose its charge.

0 2

. 2

Threshold frequency and work function are important ideas in the study of the photoelectric effect.

Tables 2 and 3 summarise the work functions of three metals and photon energies of three UV light sources.

Table 2

Metal	Work function/ eV
Zinc	4.3
Iron	4.5
Copper	4.7

Table 3

Light source	Photon energy/ eV
1	4.0
2	4.4
3	5.0

Discuss the combinations of metal and UV light source that could best be used to demonstrate the idea of threshold frequency and the idea of work function.

[6 marks]

Threshold frequency: keep the metal the same and vary the light source, e.g. use zinc (work function 4.3 eV) with light sources 1 and 3.

Source 1 photons have energy 4.0 eV, less than the work function of zinc, so (from $E = hf$) their frequency is below the threshold frequency and no electrons are emitted: no charge is lost with source 1.

Source 3 photons have energy 5.0 eV, greater than the work function, so their frequency is above the threshold frequency and photoelectrons are emitted: the plate loses its charge with source 3.

This shows emission only happens when the frequency is above the threshold frequency. (Sources 1 and 3 work with any of the three metals, since 4.0 eV is below and 5.0 eV is above all three work functions.)

Work function: keep the light source the same and vary the metal. Use light source 2 (photon energy 4.4 eV) with each metal in turn.

The zinc plate loses its charge because 4.4 eV is greater than its work function (4.3 eV), but iron (4.5 eV) and copper (4.7 eV) do not lose their charge because the photon energy is less than their work functions.

This shows the work function is the minimum energy needed to remove an electron from the metal surface, and that it is different for different metals, so each metal has its own threshold frequency ($f_0 = \phi/h$).

Light source 2 should be used for this because the other two sources would cause either all three metals to lose their charge (source 3) or none of the metals to lose their charge (source 1).

- 0 2 . 3** Calculate the maximum kinetic energy, in J, of the electrons emitted from a zinc plate when illuminated with ultraviolet light.

work function of zinc = 4.3 eV
 frequency of ultraviolet light = 1.2×10^{15} Hz

[3 marks]

$$\phi = 4.3 \times 1.6 \times 10^{-19} = 6.88 \times 10^{-19} \text{ J}$$

$$hf = 6.63 \times 10^{-34} \times 1.2 \times 10^{15} = 7.96 \times 10^{-19} \text{ J}$$

$$hf = \phi + E_{k(max)} \text{ so } E_{k(max)} = hf - \phi$$

$$E_{k(max)} = 7.96 \times 10^{-19} - 6.88 \times 10^{-19} = 1.08 \times 10^{-19} \text{ J}$$

maximum kinetic energy 1.1×10^{-19} J

- 0 2 . 4** Explain why your answer is a maximum.

[1 mark]

The work function is the minimum energy needed to remove an electron from the zinc surface, so only surface electrons get the maximum KE; deeper electrons leave with less.

Turn to page 8 for the next question

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED**

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0 3

Figure 1 and **Figure 2** show a version of Quincke's tube, which is used to demonstrate interference of sound waves.

Figure 1

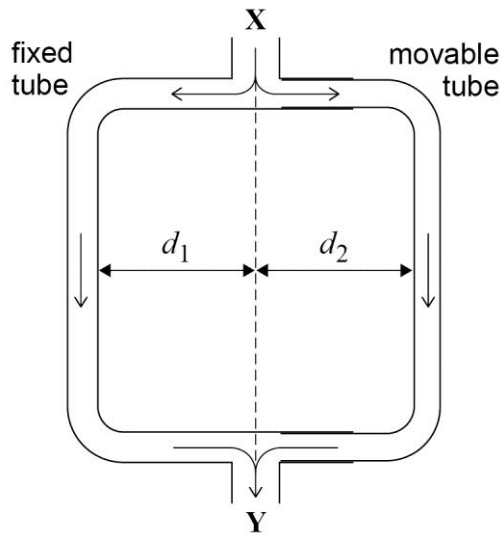
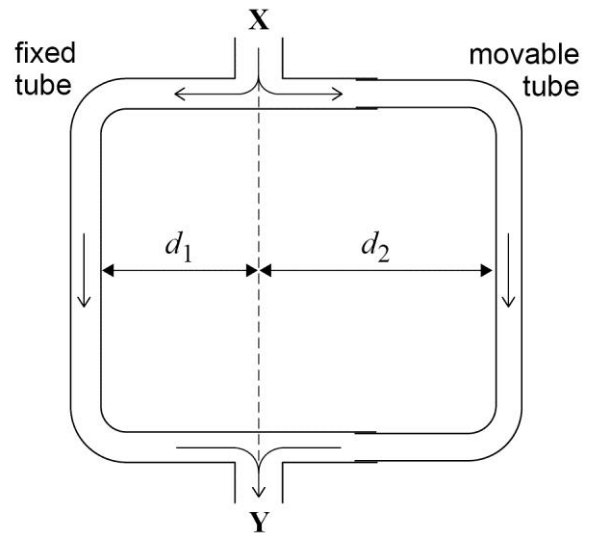


Figure 2



A loudspeaker at **X** produces sound waves of one frequency. The sound waves enter the tube and the sound energy is divided equally before travelling along the fixed and movable tubes. The two waves superpose and are detected by a microphone at **Y**.

0 3

. 1

The movable tube is adjusted so that $d_1 = d_2$ and the waves travel the same distance from **X** to **Y**, as shown in **Figure 1**. As the movable tube is slowly pulled out as shown in **Figure 2**, the sound detected at **Y** gets quieter and then louder.

Explain the variation in the loudness of the sound at **Y** as the movable tube is slowly pulled out.

[4 marks]

Initially the path difference is zero, so the two waves meet at Y in phase and the resultant displacement (loudness) is a maximum.

As the tube is pulled out the path difference increases, the waves are no longer in phase, so the displacement and loudness decrease.

At a path difference of half a wavelength the waves are in antiphase and the sound is quietest. As it increases further, the waves become more in phase and the sound gets louder again.

0 3 . 2 The tube starts in the position shown in **Figure 1**.

Calculate the minimum distance moved by the movable tube for the sound detected at **Y** to be at its quietest.

frequency of sound from loud speaker = 800 Hz
speed of sound in air = 340 m s⁻¹

[3 marks]

$$\lambda = v / f = 340 / 800 = 0.425 \text{ m}$$

$$\text{quietest when path difference} = \lambda/2 = 0.2125 \text{ m}$$

$$\text{path difference} = 2(d_2 - d_1) = 2 \times (\text{distance moved by tube})$$

$$\text{distance moved} = 0.2125 / 2 = 0.106 \text{ m}$$

minimum distance moved = 0.106 m

0 3 . 3 Quincke's tube can be used to determine the speed of sound.

State and explain the measurements you would make to obtain a value for the speed of sound using Quincke's tube and a sound source of known frequency.

[4 marks]

Start with $d_1 = d_2$ (sound loudest at Y). Pull the movable tube out

slowly and use a ruler to measure the distance moved by the tube at

each successive minimum and maximum of loudness.

Each change in distance between a maximum and the next minimum is

equal to one quarter of a wavelength (the path difference changes by

$\lambda/2$).

Continue until the tube is at its greatest distance, or repeat readings for

decreasing distance back to the start, and average to find λ .

Then use speed = frequency $\times$ wavelength ($v = f\lambda$).

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0 4

Spectacle lenses can be tested by dropping a small steel ball onto the lens, as shown in **Figure 3**, and then checking the lens for damage.

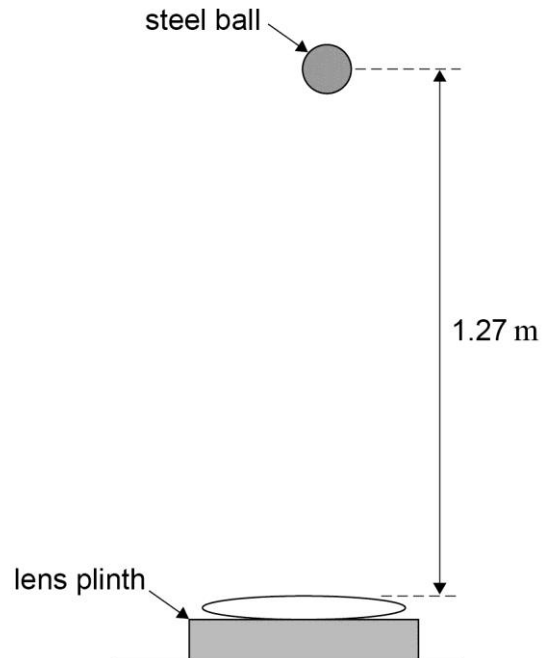
Figure 3

A test requires the following specifications:

diameter of ball = 16 mm

mass of ball = 16 g

height of drop = 1.27 m



0 4

. 1

Calculate the density of the steel used for the ball.

[3 marks]

$$m = 16 \text{ g} = 0.016 \text{ kg}, \quad r = 8 \text{ mm} = 0.008 \text{ m}$$

$$V = \frac{4}{3} \pi r^3 = \frac{4}{3} \times \pi \times (0.008)^3 = 2.14 \times 10^{-6} \text{ m}^3$$

$$\rho = m / V = 0.016 / 2.14 \times 10^{-6}$$

$$\rho = 7.46 \times 10^3 \text{ kg m}^{-3}$$

$$\text{density} = \underline{7.5 \times 10^3} \text{ kg m}^{-3}$$

0 4

. 2

In a test the ball bounced back to a height of 0.85 m.

Calculate the speed of the ball just before impact.

[2 marks]

$$v^2 = u^2 + 2as = 0 + 2 \times 9.81 \times 1.27 = 24.9$$

$$v = \sqrt{24.9} = 4.99 \text{ m s}^{-1}$$

$$\text{speed} = \underline{5.0} \text{ m s}^{-1}$$

- 0 4** . **3** Calculate the speed of the ball just after impact.

[2 marks]

$$v^2 = u^2 + 2as \text{ (ball rises to 0.85 m, final } v = 0)$$

$$0 = u^2 + 2 \times (-9.81) \times 0.85$$

$$u^2 = 16.7, \quad u = 4.08 \text{ m s}^{-1}$$

$$\text{speed} = \underline{4.1} \text{ m s}^{-1}$$

- 0 4** . **4** Calculate the change in momentum of the ball due to the impact.

[2 marks]

$$\text{velocity reverses, so } \Delta p = mv - (-mu) = mv + mu$$

$$\Delta p = 0.016 \times 5.0 + 0.016 \times 4.1$$

$$\Delta p = 0.146 \text{ kg m s}^{-1}$$

$$\text{momentum} = \underline{0.15} \text{ kg m s}^{-1}$$

- 0 4** . **5** The time of contact was 40 ms. Calculate the average force of the ball on the lens during the impact.

[2 marks]

$$F = \Delta p / \Delta t = 0.146 / (40 \times 10^{-3})$$

$$F = 3.64 \text{ N}$$

$$\text{average force} = \underline{3.6} \text{ N}$$

- 0 4** . **6** Explain, with reference to momentum, why the test should also specify the material of the plinth the lens sits on.

[2 marks]

Impact time can be increased if the plinth material is not stiff (it deforms on impact).

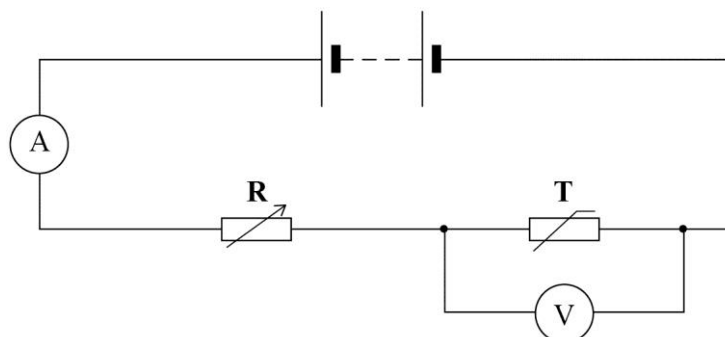
A longer impact time for the same change in momentum (smaller rate of change of momentum) would reduce the force of the impact.

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0 5

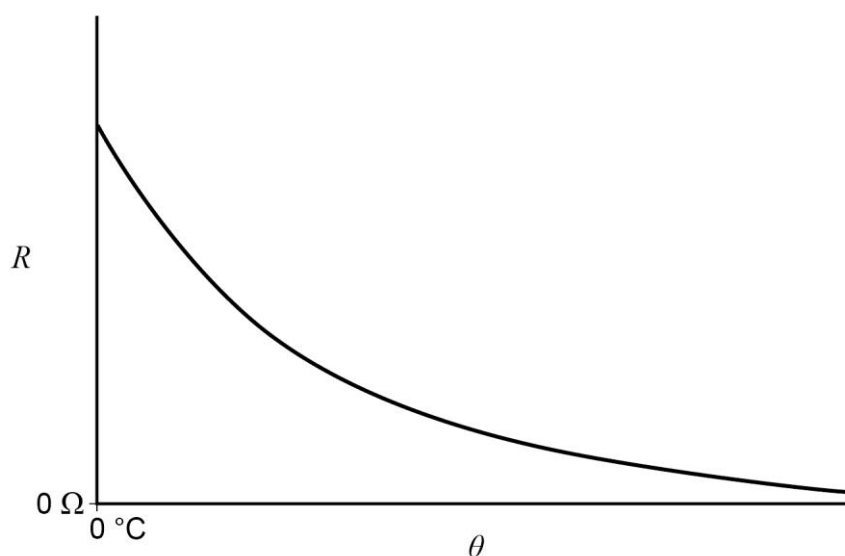
Figure 4 shows a circuit including a thermistor **T** in series with a variable resistor **R**. The battery has negligible internal resistance.

Figure 4



The resistance–temperature (R - θ) characteristic for **T** is shown in **Figure 5**.

Figure 5



0 5

. 1

The resistor and thermistor in **Figure 4** make up a potential divider.

Explain what is meant by a potential divider.

[1 mark]

A combination of resistors in series connected across a voltage source, which splits the source pd to produce a required pd across one of them.

- 0 5 . 2** State and explain what happens to the voltmeter reading when the resistance of **R** is increased while the temperature is kept constant.

[3 marks]

The voltmeter reading decreases.

When R increases, R takes a larger share of the supply pd, so the pd across R increases.

The pd across R + the pd across T = the supply pd (constant, as internal resistance is negligible), so the pd across T , the voltmeter reading, decreases.

- 0 5 . 3** State and explain what happens to the ammeter reading when the temperature of the thermistor increases.

[2 marks]

The ammeter reading increases. At a higher temperature the resistance of T is lower, so the total circuit resistance is lower and the current increases.

- 0 5 . 4** The battery has an emf of 12.0 V. At a temperature of 0 °C the resistance of the thermistor is $2.5 \times 10^3 \Omega$.

The voltmeter is replaced by an alarm that sounds when the voltage across it exceeds 3.0 V.

Calculate the resistance of R that would cause the alarm to sound when the temperature of the thermistor is lowered to 0 °C.

[2 marks]

alarm sounds when pd across T = 3.0 V, $R_T = 2500 \Omega$

$I = V / R = 3.0 / 2500 = 1.2 \times 10^{-3} \text{ A}$

pd across R = $12.0 - 3.0 = 9.0 \text{ V}$

$R = V / I = 9.0 / 1.2 \times 10^{-3} = 7500 \Omega$

resistance = 7500 Ω

Turn over ►

- 0 5** . **5** State **one** change that you would make to the circuit so that instead of the alarm coming on when the temperature falls, it comes on when the temperature rises above a certain value.

[1 mark]

Connect the alarm across the variable resistor R instead of across the thermistor T .

0 6

If lengths of rail track are laid down in cold weather, they may deform as they expand when the weather becomes warmer. Therefore, when rails are laid in cold weather they are stretched and fixed into place while still stretched. This is called pre-straining.

The following data is typical for a length of steel rail:

Young modulus of steel =	$2.0 \times 10^{11} \text{ Pa}$
cross sectional area of a length of rail =	$7.5 \times 10^{-3} \text{ m}^2$
amount of pre-strain =	2.5×10^{-5} for each kelvin rise in temperature the rail is expected to experience.

A steel rail is laid when the temperature is 8°C and the engineer decides to use a pre-strain of 3.0×10^{-4} .

0 6

. 1

Calculate the tensile force required to produce the pre-strain in the rail required by the engineer.

[3 marks]

$$E = \text{tensile stress} / \text{tensile strain}$$

$$\text{stress} = E \times \text{strain} = 2.0 \times 10^{11} \times 3.0 \times 10^{-4} = 6.0 \times 10^7 \text{ Pa}$$

$$\text{stress} = F / A, \text{ so } F = \text{stress} \times A = 6.0 \times 10^7 \times 7.5 \times 10^{-3}$$

$$F = 4.5 \times 10^5 \text{ N}$$

$$\text{tensile force} = \underline{4.5 \times 10^5} \text{ N}$$

0 6

. 2

Calculate the elastic strain energy stored in a rail of unstressed length 45 m when pre-strained as in part 6.1.

[2 marks]

$$\text{strain} = \text{extension} / \text{original length}$$

$$\text{extension} = 3.0 \times 10^{-4} \times 45 = 1.35 \times 10^{-2} \text{ m}$$

$$\text{energy} = \frac{1}{2} \times F \times \text{extension} = \frac{1}{2} \times 4.5 \times 10^5 \times 1.35 \times 10^{-2}$$

$$\text{energy stored} = 3.04 \times 10^3 \text{ J}$$

$$\text{elastic strain energy} = \underline{3.04 \times 10^3} \text{ J}$$

Question 6 continues on the next page

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0 6 . 3 Calculate the temperature at which the steel rail becomes unstressed.

[2 marks]

$$\text{temperature change} = \text{pre-strain} / \text{pre-strain per K}$$

$$= 3.0 \times 10^{-4} / 2.5 \times 10^{-5} = 12 \text{ K}$$

$$\text{temperature} = 8 \text{ }^{\circ}\text{C} + 12 = 20 \text{ }^{\circ}\text{C}$$

temperature = 20 $^{\circ}\text{C}$

0 6 . 4 Explain why the engineer does not use the highest observed temperature at the location of the railway track to determine the amount of pre-strain to use.

[2 marks]

So that the rail is not always under stress (to reduce the average stress), as the rail spends little time at the highest temperature.

Then zero stress occurs closer to the average temperature: the rail is under tensile or compressive stress at different times.

END OF QUESTIONS