FOR OFFICIAL USE

National Qualifications 2026

Mark

X857/76/01

Physics Paper 2

THURSDAY, 21 MAY
10:15 AM – 12:30 PM

X8577601

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth
Day Month Year

Scottish candidate number

Total marks — 130

Attempt ALL questions.

You may use a calculator.

Reference may be made to the data sheet on *page 02* of this booklet and to the relationships sheet X857/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Do not remove any exam materials. You must leave this booklet on your desk; if you do not, you could lose all the marks for this paper.

Qualifications Scotland
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X857760101

Total marks — 130

Attempt ALL questions

1. A shot put competition takes place during an athletics meeting.

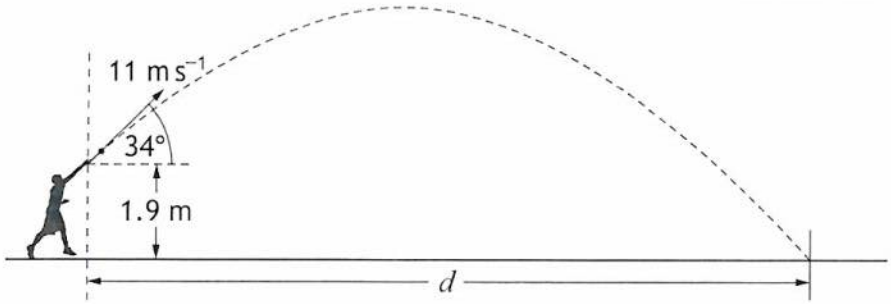
An athlete launches a metal ball, called a shot, with an initial velocity of 11 $m\,s^{-1}$ at an angle 34° to the horizontal.

The shot is released from a height of 1.9 m.

The horizontal distance travelled by the shot is d.

The effects of air resistance are negligible.

not to scale



(a) (i) Calculate:

(A) the horizontal component of the initial velocity of the shot — 1

Space for working and answer

(B) the vertical component of the initial velocity of the shot. — 1

Space for working and answer

1. (a) (continued)

(ii) Determine the maximum height of the shot above the ground. 4

Space for working and answer

(iii) Calculate the time taken for the shot to fall from the maximum height to the ground. 3

Space for working and answer

(iv) The shot hits the ground 1.52 s after it is released.

Calculate the horizontal distance d travelled by the shot. 3

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

1. (continued)

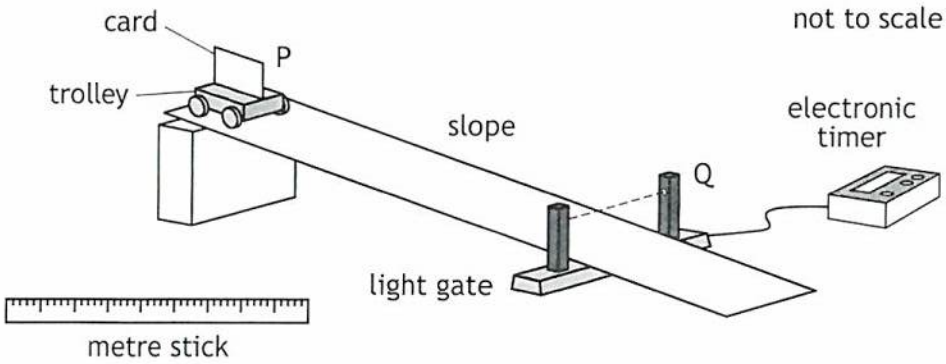
(b) A second, taller athlete releases the shot at a height of 2.2 m.

The initial speed and angle of launch of the shot are unchanged.

State what effect, if any, this has on the horizontal distance d travelled by the shot.

You must justify your answer. 2

2. A student carries out an experiment to determine the acceleration of a trolley down a slope, using the apparatus shown.



The trolley is placed at position P. The trolley is released from rest and accelerates down the slope.

The card attached to the trolley passes through the light gate at position Q. The electronic timer measures the time t for the card to pass through the light gate.

(a) Describe how the student would use **this** apparatus and analyse the data obtained to determine the value of the acceleration of the trolley down the slope. 3

2. (continued)

(b) The student releases the trolley 4 times from position P and records the following results from the timer:

13.9 ms, 13.1 ms, 11.0 ms, 12.4 ms

(i) Calculate the mean time for the card to pass through the light gate. 1

Space for working and answer

(ii) Calculate the approximate random uncertainty in this value. 2

Space for working and answer

(iii) A second student suggests that taking more measurements of the time for the card to pass through the light gate will improve the precision in the mean value for the time.

Explain why this student is correct. 1

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

2. (continued)

(c) The trolley is now placed at a position further down the slope and released from rest.

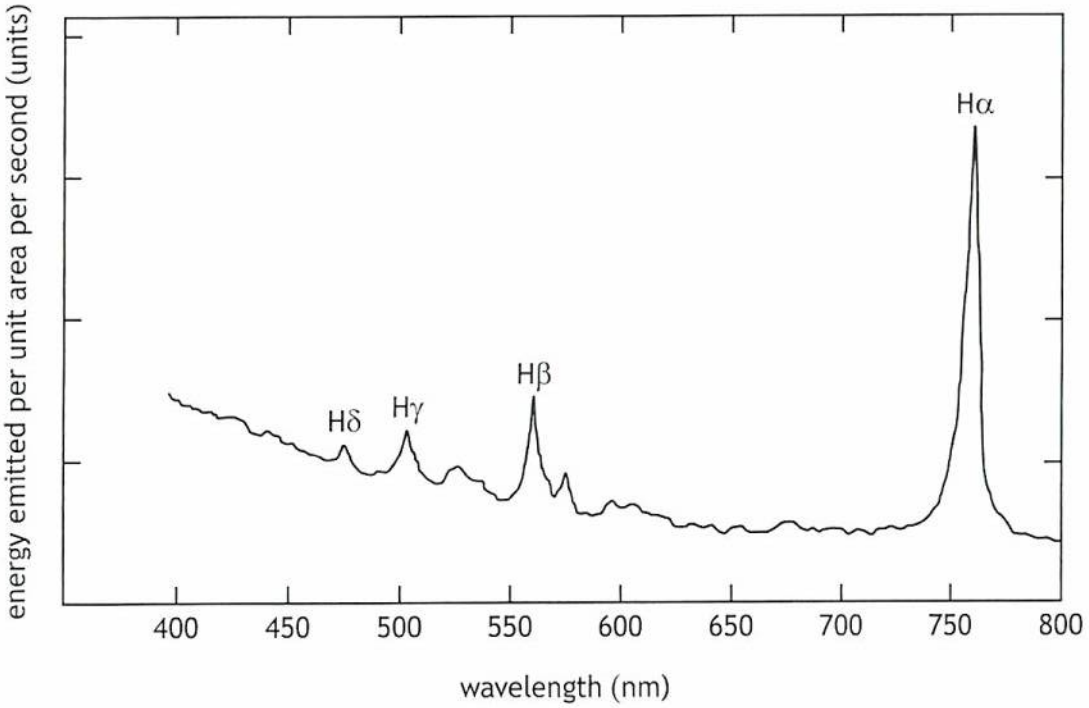
State whether the acceleration of the trolley is greater than, the same as, or less than the acceleration when released from position P.

You must justify your answer. 2

3. Some galaxies have a very bright object at their centre called a quasar. Quasars emit energy.

The graph shows the energy emitted per unit area per second and the corresponding wavelength of the radiation observed from a distant quasar.

The peaks on the graph correspond to lines on the hydrogen emission spectrum.



(a) When viewed from Earth, the peak from the quasar corresponding to the Hγ line is observed at a wavelength of 503 nm.

When viewed in a laboratory, the corresponding peak is observed at 434 nm.

(i) Show that the redshift of the radiation from the quasar is 0.159. 2

Space for working and answer

3. (a) (continued)

(ii) Calculate the approximate distance from Earth to this quasar. 5

Space for working and answer

(b) A second line on the hydrogen spectrum when measured in a laboratory has a wavelength of 486 nm.

Determine which peak on the graph this line corresponds to.

Justify your answer by calculation. 3

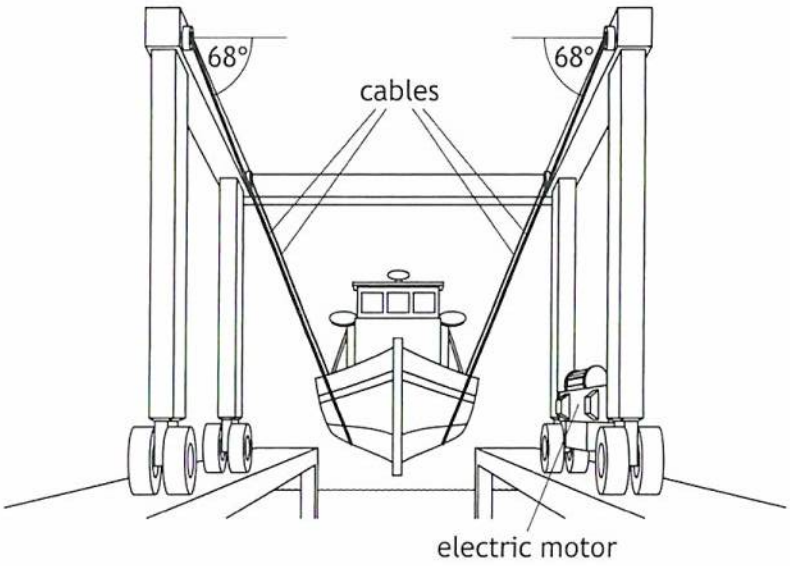
Space for working and answer

(c) State the name of the law that allows the age of the Universe to be estimated. 1

MARKS | DO NOT WRITE IN THIS MARGIN

4. A boat lift is used to raise a boat from the sea.

The lift has **four** cables, which attach to straps placed under the boat. The ends of the cables are attached to an electric motor that is used to raise the boat.



Each cable makes an angle of 68° to the horizontal.

The mass of the boat is 1400 kg.

(a) (i) Calculate the weight of the boat. 3

Space for working and answer

(ii) Determine the tension in **each** cable. 3

Space for working and answer

4. (continued)

(b) The boat is raised 1.3 m in a time of 49 s.

Determine the minimum power output of the electric motor. 4

Space for working and answer

(c) As the boat is raised the angle between each cable and the horizontal decreases.

State whether the tension in each cable decreases, stays the same, or increases.

You must justify your answer. 2

MARKS | DO NOT WRITE IN THIS MARGIN

5. A stunt was carried out during the making of a film.

An actor rode a motorcycle off a ramp at the edge of a cliff of height 1.3 km. The actor then jumped off the motorcycle mid-air and parachuted onto a moving train in the valley below.

Using your knowledge of physics, comment on the challenges involved in carrying out the stunt successfully. 3

MARKS | DO NOT WRITE IN THIS MARGIN

6. A plutonium nucleus emits an alpha particle $^{4}_{2}He$ to produce nucleus X.
The following statement represents this nuclear reaction.

$$^{240}_{94}Pu \rightarrow X + {}^{4}_{2}He$$

(a) (i) Identify element X. 1

(ii) The energy released by this reaction is 8.5500×10^{-13} J.
The table shows the masses of two of the particles.

Particle	Mass (kg)
$^{240}_{94}Pu$	398.626×10^{-27}
$^{4}_{2}He$	6.6447×10^{-27}

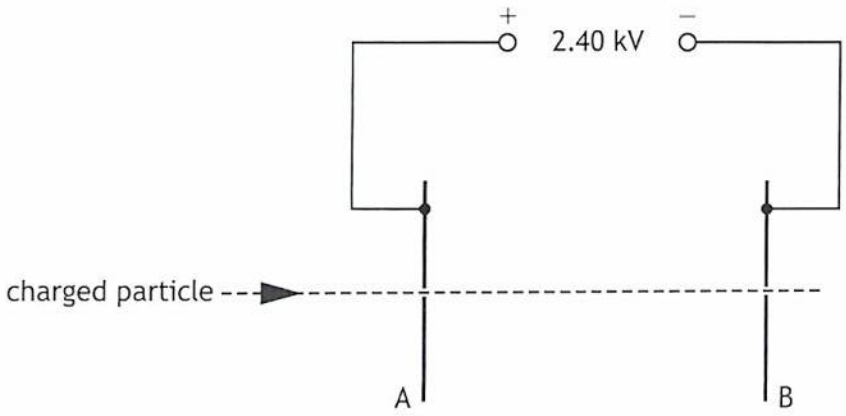
Calculate the mass of nucleus X. 4

Space for working and answer

6. (continued)

(b) A positively charged particle is accelerated by an electric field between metal plates A and B, in a vacuum.

Part of the apparatus used is shown.



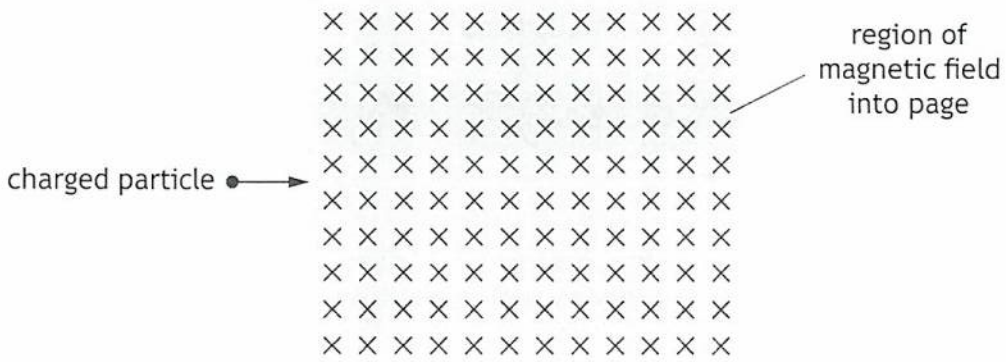
The kinetic energy gained by the particle as it travels from plate A to plate B is 7.68×10^{-13} J.

Calculate the magnitude of the charge on the particle. 3

Space for working and answer

6. (continued)

(c) After leaving the electric field at plate B, the positively charged particle enters a region of uniform magnetic field as shown.



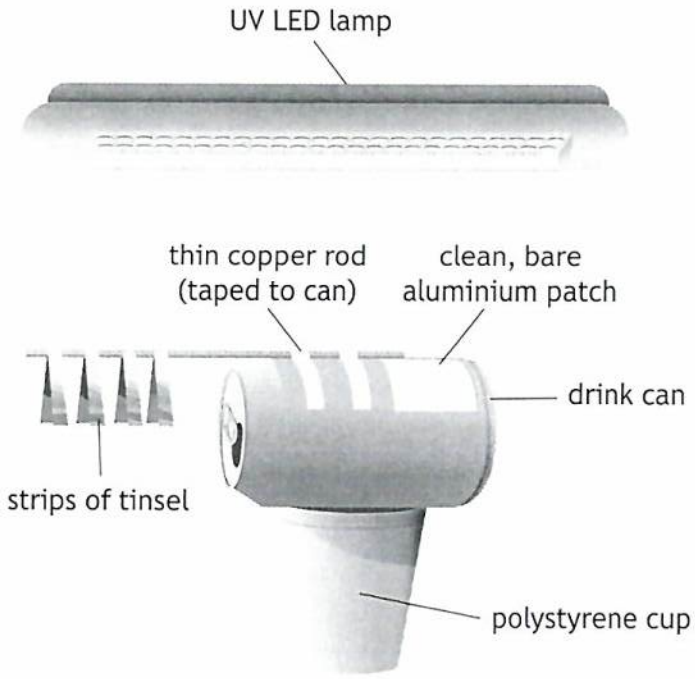
Determine the direction of the force exerted by the magnetic field on the particle as it enters the field. 1

(d) Explain why a neutron that enters the magnetic field would not be deflected. 2

[Turn over

7. A teacher uses a 'drink can and tinsel' electroscope to demonstrate the photoelectric effect with an ultraviolet (UV) LED lamp.

The teacher uses sandpaper to remove the outer layer of the can, so that a small patch of clean, bare aluminium is exposed.



The teacher charges the aluminium can negatively, causing the ends of the strips of tinsel to rise.

(a) The teacher switches on the UV lamp and shines it onto the clean, bare aluminium patch on the can.

The electroscope now discharges, and the ends of the strips of tinsel fall slowly.

The work function of aluminium is 6.56×10^{-19} J.

(i) State what is meant by a *work function of* 6.56×10^{-19} *J.* 1

7. (a) (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

(ii) The lamp emits UV radiation with a frequency of 1.15×10^{15} Hz.

Calculate the energy of a photon of this UV radiation. 3

Space for working and answer

(iii) Determine the maximum kinetic energy of an electron released from the surface of the clean, bare aluminium. 1

Space for working and answer

(iv) The UV lamp has a power rating of 1.5 W.

Determine the maximum number of photons of UV radiation the lamp emits in a time of 12 s. 4

Space for working and answer

7. (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

(b) The teacher repeats the procedure with the same setup as before but this time the area of the clean, bare aluminium patch is made much larger.

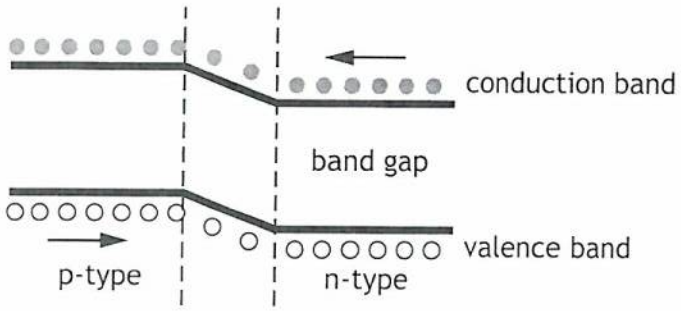
State what effect, if any, this change has on the rate at which the ends of the tinsel fall.

Justify your answer. 2

(c) The UV lamp used during the demonstration contains several LEDs.

An LED is made from doped semiconductor materials to create a p-n junction.

The diagram represents the band structure of an LED.



(i) State what is meant by a *doped semiconductor*. 1

(ii) A voltage is applied across the LED so that it is forward biased and emits light.

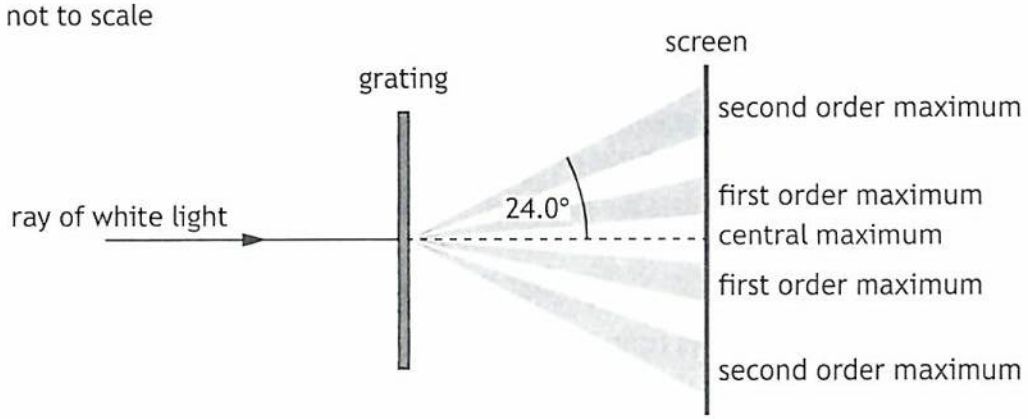
Using **band theory**, explain how the LED emits light. 3

MARKS | DO NOT WRITE IN THIS MARGIN

8. A student carries out an experiment to investigate the interference of light.

(a) A ray of white light is incident on a grating.

not to scale



(i) Explain, in terms of waves, how a maximum is formed. 1

(ii) Explain, in terms of path difference, why the central maximum is white. 1

(iii) The angle between the central maximum and the second order maximum for red light is 24.0°.

The grating has a slit separation of 3.33×10^{-6} m.

Calculate the wavelength of this red light. 3

Space for working and answer

DO NOT WRITE IN THIS MARGIN

8. (continued)

(b) The student now replaces the grating with a different grating of unknown slit separation.

The student places a colour filter in front of the grating.

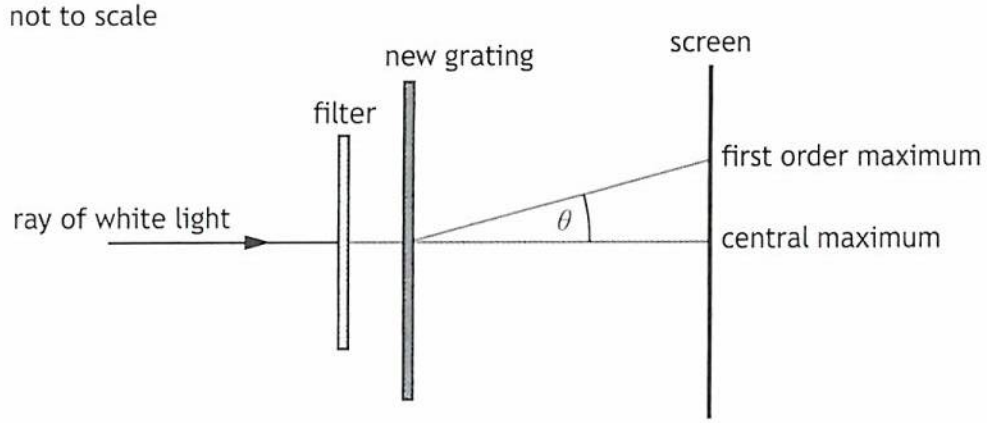
The student measures the angle θ between the central maximum and the first order maximum for this colour of light.

The student repeats these measurements several times and calculates the mean value of θ.

This procedure is repeated with different colours of filter.

Each colour filter allows light of a specific wavelength to pass through.

not to scale



The following results are obtained.

Colour filter	Wavelength (nm)	Mean θ (°)
Red	650	23.0
Orange	600	21.0
Yellow	580	20.5
Green	550	19.0
Blue	450	15.5

MARKS | DO NOT WRITE IN THIS MARGIN

8. (b) (continued)

(i) Suggest how the student should process these results to obtain a reliable value for the slit separation of this grating. 2

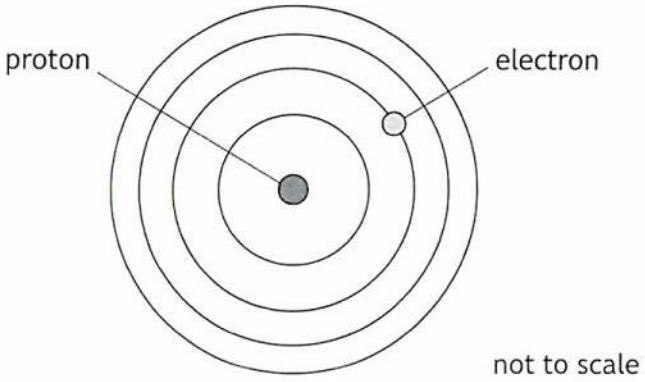
(ii) The student determines the slit separation of the grating to be 1.6×10^{-6} m.

Determine the number of lines **per millimetre** on this grating. 1

Space for working and answer

[Turn over

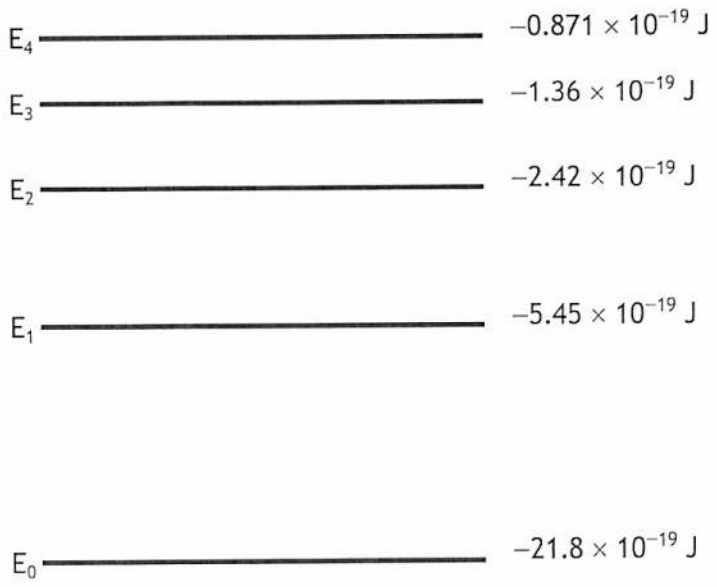
9. The Bohr model of the hydrogen atom can be represented by the diagram shown.



(a) State **two** features of the Bohr model of the hydrogen atom. 2

9. (continued)

(b) Some of the energy levels of the hydrogen atom are shown.



(i) An electron is in the ground state of a hydrogen atom.

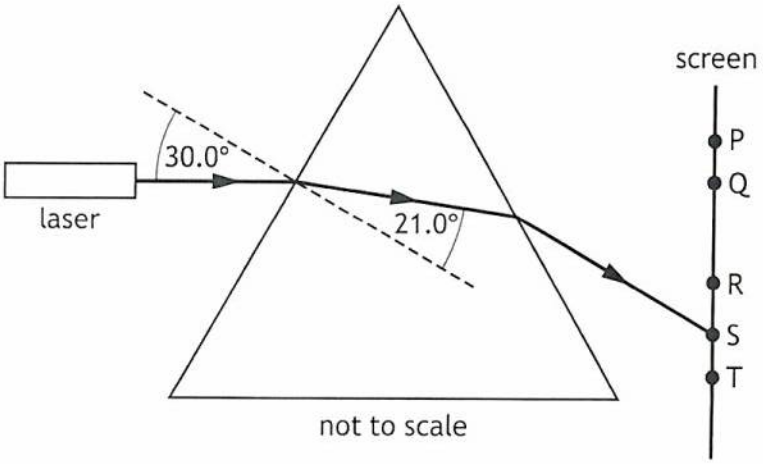
State the minimum energy of an incident photon required to ionise this atom. 1

(ii) Determine the highest frequency of photon emitted for the energy levels shown for this atom. 3

Space for working and answer

10. A student carries out an experiment to investigate the path of a ray of light through a prism.

(a) A laser produces a ray of green light of wavelength 532 nm. The ray is incident on a glass prism as shown.



(i) State what is meant by the term *absolute refractive index*. 1

(ii) Calculate the absolute refractive index of the glass for this light. 3

Space for working and answer

10. (a) (continued)

(iii) Calculate the frequency of this light inside the prism. 3

Space for working and answer

(b) The laser is now replaced by a laser that emits red light.

No other changes are made to the experimental set-up.

State at which point, P, Q, R, S, or T, red light would be observed on the screen.

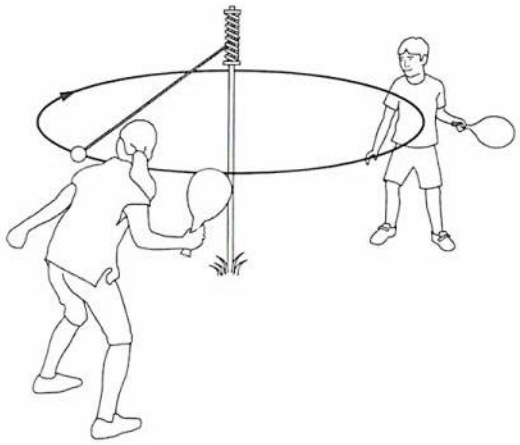
Justify your answer. 3

[Turn over

11. The use of analogies from everyday life can help improve the understanding of physics concepts.

Swingball is an outdoor game in which a ball is attached to a string connected to a vertical pole as shown. Two players try to hit the ball in the opposite direction to each other.

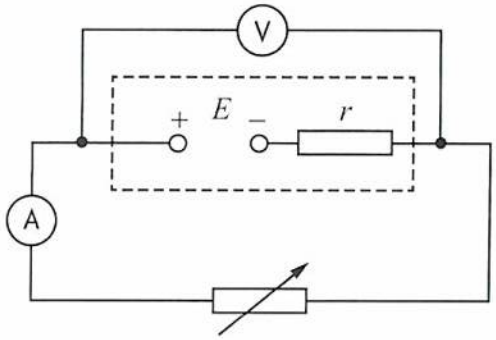
A student states Swingball is like current in an electric circuit.



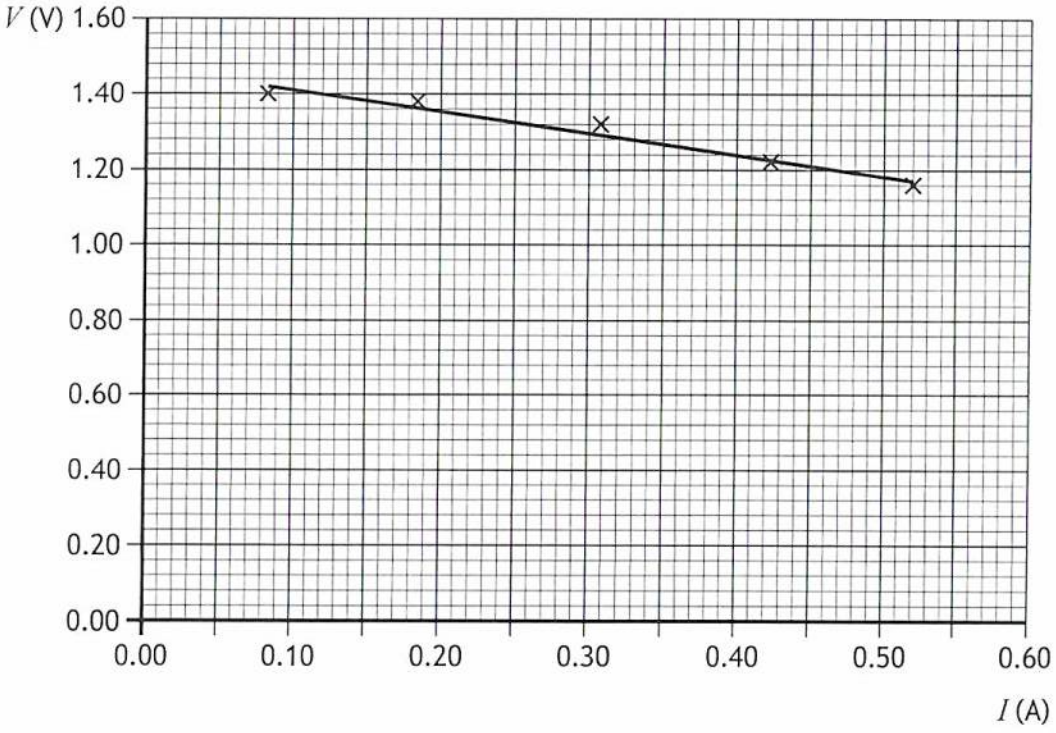
Using your knowledge of physics, comment on this analogy. 3

MARKS | DO NOT WRITE IN THIS MARGIN

12. A student uses the circuit shown to determine the EMF E and the internal resistance r of a power supply.



The student uses readings of current I and terminal potential difference V from this circuit to produce the graph shown.



(a) State what is meant by the term *electromotive force (EMF)*. 1

12. (continued)

(b) Using information from the graph, determine:

(i) the EMF E of the power supply 1

(ii) the internal resistance r of the power supply. 3

Space for working and answer

(c) Calculate the short circuit current for the power supply. 3

Space for working and answer

[Turn over

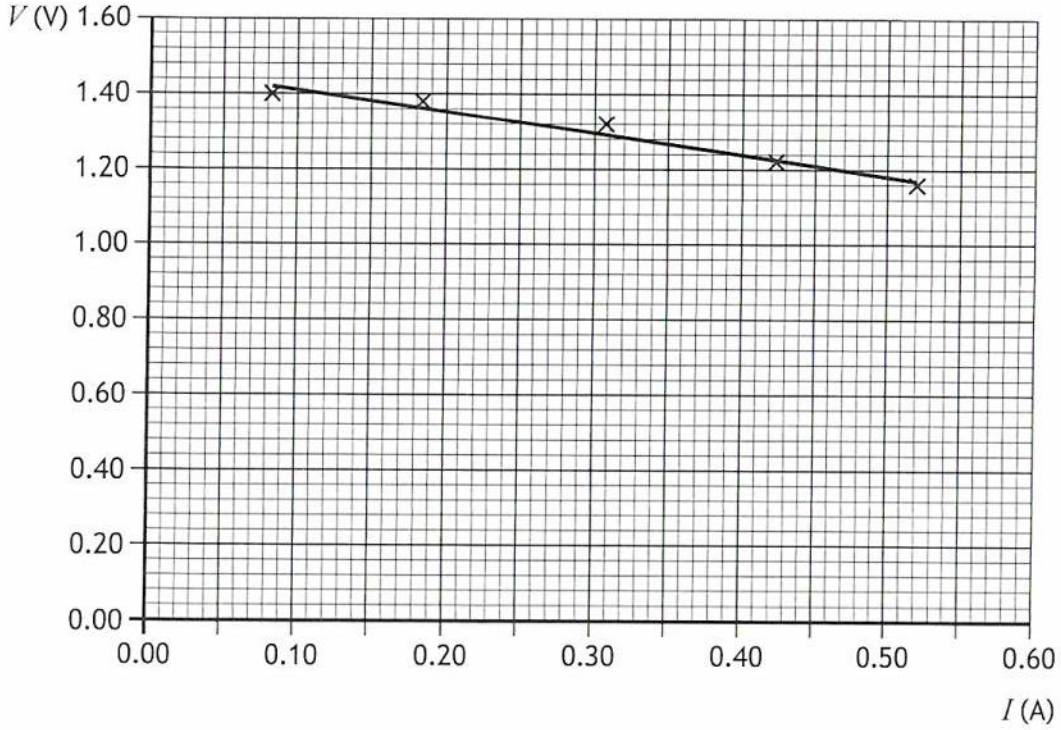
MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

(d) The student now repeats the experiment with a different power supply that has a smaller EMF and a greater internal resistance.

On the graph below, add a line to show how the results of this experiment compare with the original experiment. 2

(An additional graph, if required, can be found on *page 45*.)



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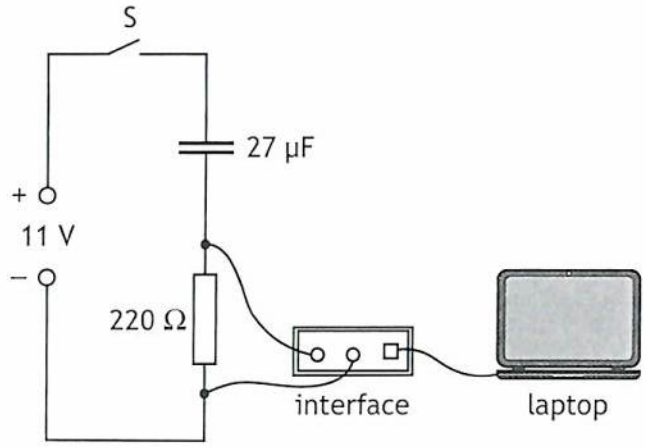
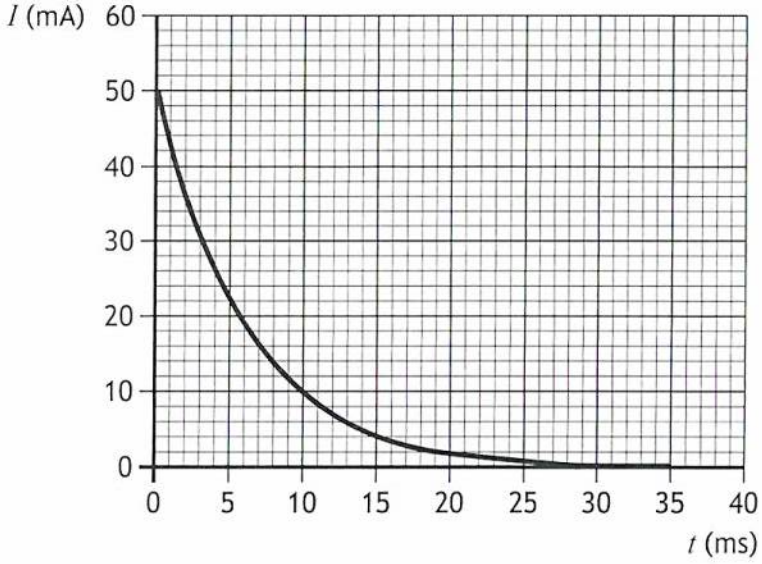
13. A student investigates the charging of a capacitor.

The student sets up the circuit shown.



The capacitor is initially uncharged. Switch S is now closed. A laptop connected to an interface displays a graph of current against time as the capacitor charges, as shown.



The capacitor is fully charged at 30 ms.

13. (continued)

(a) Determine the potential difference across the capacitor at a time of 7.0 ms. 4

Space for working and answer

(b) Calculate the energy stored by the capacitor when it is fully charged. 3

Space for working and answer

(c) Switch S is opened, and the capacitor is discharged.

The resistor is now replaced with one that has a greater resistance.

Switch S is again closed and the capacitor charges.

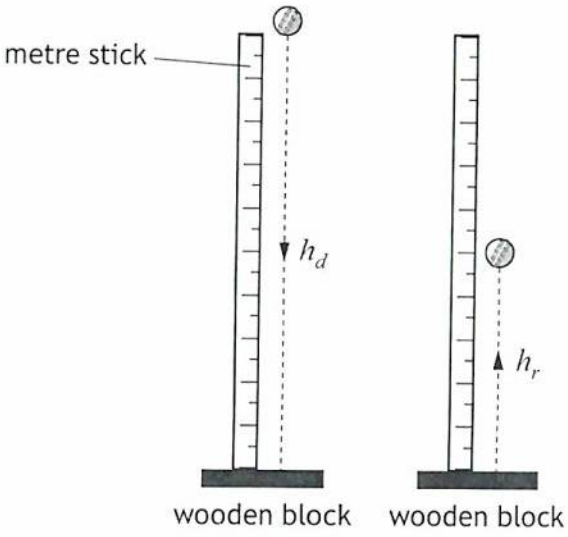
State whether the time for the capacitor to fully charge is greater than, equal to, or less than 30 ms.

Justify your answer. 2

DO NOT WRITE IN THIS MARGIN

14. A student carries out an investigation to determine the coefficient of restitution e of a cricket ball on a wooden block.

The coefficient of restitution is a measure of how close a collision is to being elastic. An elastic collision will give a coefficient of restitution equal to 1.00.



The cricket ball is dropped from rest from a height h_d, collides with the wooden block, and rebounds to a height h_r.

The student uses video analysis to record the motion of the cricket ball and measure h_d and h_r.

The student repeats the procedure for a range of different drop heights h_d.

The results are shown in the table.

h_d (m)	h_r (m)
0.100	0.080
0.300	0.180
0.400	0.220
0.600	0.325
0.700	0.390

(a) The coefficient of restitution e can be determined using

$$h_r = e^2 h_d$$

MARKS | DO NOT WRITE IN THIS MARGIN

14. (a) (continued)

(i) Using the square-ruled paper on *page 42*, draw a graph of h_r against h_d. 3

(The table of results is also shown on *page 43*, opposite the square-ruled paper.)

(ii) Calculate the gradient of the line of best fit on your graph. 2

Space for working and answer

(iii) Using the gradient of the line of best fit, determine the coefficient of restitution e for the collision between the cricket ball and the wooden block. 2

Space for working and answer

(b) The student now drops the cricket ball from a height of 2.250 m onto the wooden block.

Determine the rebound height. 2

Space for working and answer

[END OF QUESTION PAPER]