Write your name here

Surname: StemUp Model Solution

Other names:

Pearson Edexcel
Level 3 GCE

Centre Number:

Candidate Number:

Physics

Advanced Subsidiary
Paper 2: Core Physics II

Thursday 9 June 2016 – Afternoon
Time: 1 hour 30 minutes

Paper Reference
8PH0/02

You may need a ruler.

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions in Sections A and B.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- In questions 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 ▶

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SECTION A

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 statement about sound is correct?

☒ **A** Sound can travel through a solid.

☐ **B** Sound can travel through a vacuum.

☐ **C** Sound waves can travel as polarised waves.

☐ **D** Sound waves travel in a direction perpendicular to the direction of the oscillations.

(Total for Question 1 = 1 mark)

2 Which of the following is a correct unit for intensity of light?

☐ **A** $J m^{-2}$

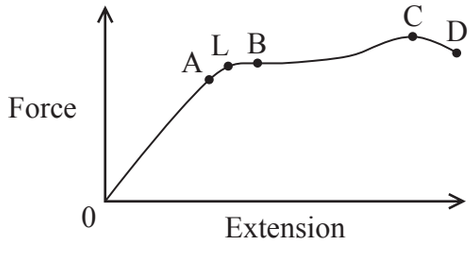
☐ **B** $W s^{-2}$

☒ **C** $W m^{-2}$

☐ **D** $J s^{-2}$

(Total for Question 2 = 1 mark)

3 The diagram shows a force-extension graph for a wire.



L is the elastic limit.

Which point represents the yield point?

☐ **A**

☒ **B**

☐ **C**

☐ **D**

(Total for Question 3 = 1 mark)

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4 A bubble of air is rising through a vertical column of water.

Which statement, about the motion of the bubble, is correct to a good approximation?

☒ **A** The bubble has a constant velocity because its weight equals the viscous drag.

☒ **B** The bubble has a constant velocity because the upthrust is equal to the viscous drag.

☒ **C** The bubble has an acceleration because its weight is greater than the upthrust.

☒ **D** The bubble has an acceleration because the viscous drag is greater than the upthrust.

(Total for Question 4 = 1 mark)

5 In an experiment a student is taking a measurement of a time interval in seconds.

He repeats the measurement and collects the following three readings:

3.2 s 3.2 s 3.3 s

Which one of the following is a correct statement?

☒ **A** The reading of 3.3 s is an error.

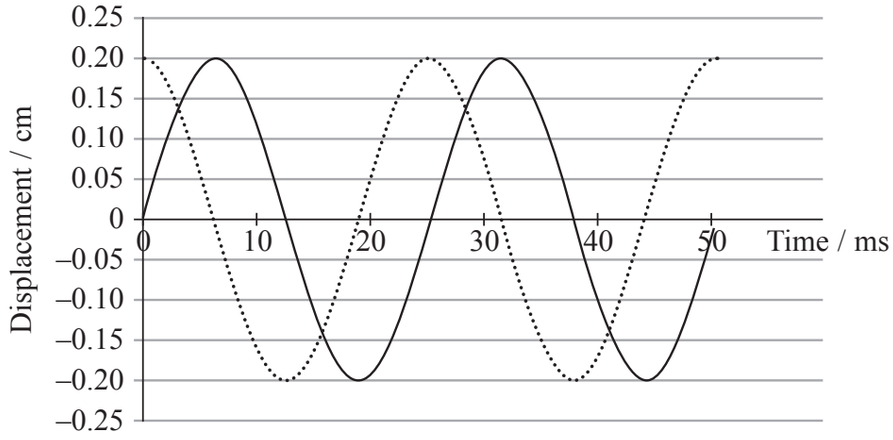
☒ **B** The average should be recorded as 3.23 s.

☒ **C** The uncertainty is 0.1 s.

☒ **D** The error is 0.1 s.

(Total for Question 5 = 1 mark)

6 The graph shows the variation of displacement with time for two waves.



What is the phase difference between these two waves?

☒ **A** 6 ms

☒ **B** 0.20 cm

☒ **C** π radians

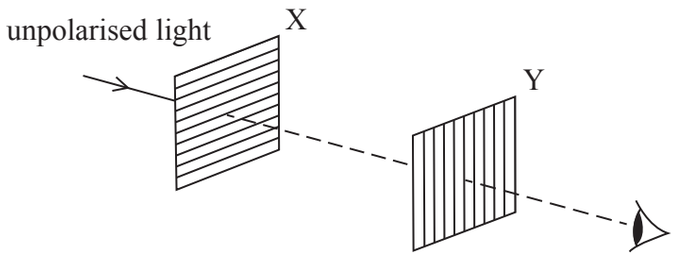
☒ **D** 90 degrees

(Total for Question 6 = 1 mark)

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7 A source of unpolarised light is viewed through two crossed polarising filters X and Y.



Which row in the table correctly describes the light emerging from the two filters?

	Light emerging from filter X	Light emerging from filter Y
☒ **A**	oscillates in every direction	oscillates in one direction
☒ **B**	oscillates in every direction	no light
☒ **C**	oscillates in one direction	oscillates in one direction
☒ **D**	oscillates in one direction	no light

(Total for Question 7 = 1 mark)

8 Sound waves are produced by a vibrating guitar string.

Which row in the table correctly describes the waves produced?

	Guitar string	Sound
☒ **A**	transverse	transverse
☒ **B**	longitudinal	longitudinal
☒ **C**	longitudinal	transverse
☒ **D**	transverse	longitudinal

(Total for Question 8 = 1 mark)

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9 A simple optical fibre consists of a core surrounded by cladding. The refractive index of the core is 1.56 and the refractive index of the cladding is 1.20.

(a) Show that the critical angle for light between these two media is about 50°.

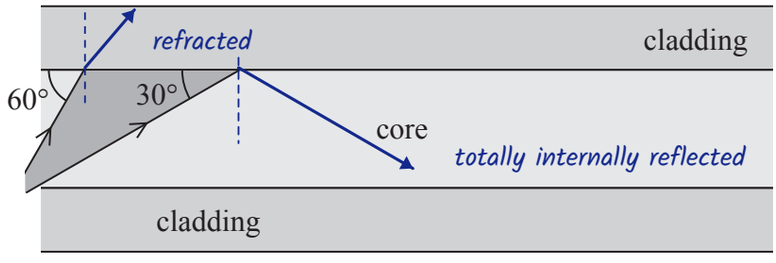
(3)

$n_1 \sin \theta_1 = n_2 \sin \theta_2$, and at the critical angle the angle in the cladding is 90°

$1.56 \times \sin C = 1.20 \times \sin 90°$

$\sin C = 1.20 \div 1.56 = 0.769$, so $C = 50.3°$, which is about 50°

(b) The diagram shows a diverging beam of light incident on the boundary between the core and the cladding. One side of the beam strikes the boundary at 60° and the other side at 30° as shown.



Three students each suggest a different outcome for the beam of light at the boundary.

Student A says "all the beam will totally internally reflect".

Student B says "all the beam will refract".

Student C says "some of the beam will totally internally reflect and some will refract".

State which student is correct, adding to the diagram to illustrate your answer.

(3)

Student C is correct: $i = 60° > C$ so TIR, but $i = 30° < C$ so it refracts.

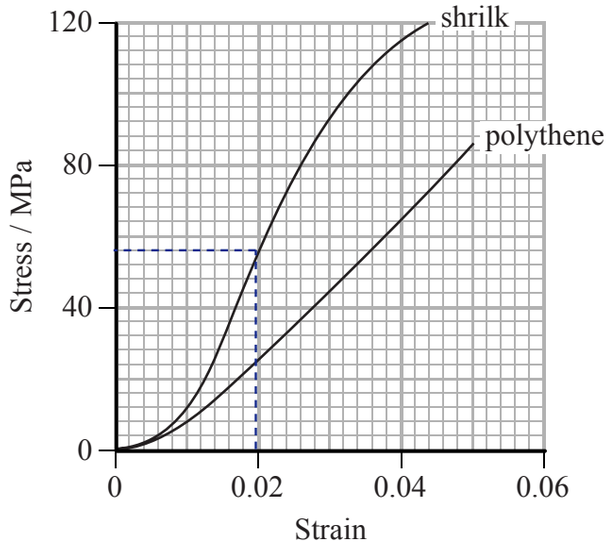
(Total for Question 9 = 6 marks)

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10 Shrilk is a new material made from discarded shrimp shells. It is biodegradable and is easily moulded into different shapes. Shrilk is an alternative to polythene and could be used to make waste bags in the future.

The graph shows a stress-strain curve for a 25.0 cm length of shrilk and for a similar length of polythene, up to breaking point.



(a) (i) Calculate the force applied to the shrilk at a strain of 0.02

cross-sectional area = 1.2×10^{-6} m^2

(3)

From the graph, at a strain of 0.02 the stress σ = 56 MPa

σ = F/A so F = σA

$F = 56 \times 10^6$ Pa $\times$ 1.2×10^{-6} m^2

F = 67.2 N

Force = *67 N*

(ii) Determine the extension of the shrilk at a strain of 0.04

(2)

ε = Δx / x so Δx = εx

Δx = 0.04 × 25.0 cm

Δx = 1.0 cm

Extension = *1.0 cm*

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(b) Deduce whether shrilk or polythene is better for making waste bags.

(3)

Shrilk is better for making waste bags.

For the same stress, shrilk has a smaller strain than polythene, so shrilk is stiffer and does not stretch as much for a given force (load).

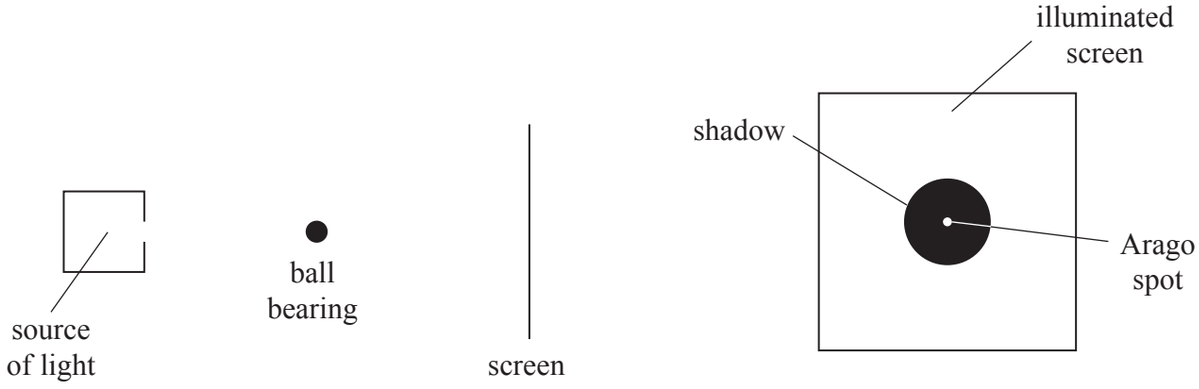
Shrilk also breaks at a higher stress (about 120 MPa compared with about 85 MPa), so it is stronger and can withstand a greater load (weight of rubbish) before breaking.

(Total for Question 10 = 8 marks)

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11 The diagram shows a coherent beam of light incident on a metal ball bearing.

A dark shadow is seen on a screen behind the ball bearing. There is a small spot of light in the centre of the shadow. This spot of light is known as the Arago spot.



Experimental set-up

Appearance on screen

(a) Use Huygens' construction to explain the behaviour of light as it travels past the edge of the ball bearing.

(2)

The light is diffracted as it passes the edge of the ball bearing.

Every point on a wavefront acts as a source of secondary wavelets; the wavelets from points near the edge spread into the shadow, and the new wavefront is the envelope of the wavelets.

(b) Explain why a spot of light is produced at the centre of the shadow.

(3)

Light diffracts around every part of the edge of the ball bearing.

The centre of the shadow is the same distance from every point on the edge, so the path lengths are equal and the path difference at the spot is zero.

The waves therefore arrive in phase (phase difference zero), so they superpose constructively (constructive interference), giving a bright spot.

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(c) François Arago first demonstrated this experiment in 1818 for a group of eminent scientists, to show the behaviour of light.

State the model for the behaviour of light that this experiment demonstrated and explain why the scientific community accepted this model.

(3)

It demonstrated the wave model of light.

Diffraction and interference are wave behaviours, so the bright spot provided experimental evidence for the wave model and supported previous evidence (e.g. Young's double slit).

The demonstration was reproducible: others could repeat it and see the same spot, so the model was accepted.

(d) The ball bearing shown in the experimental set-up has a diameter of about 1 cm.

Describe how the diameter could be measured accurately.

(2)

Use a micrometer screw gauge (or vernier callipers), checking for zero error.

Measure the diameter in several different places (different orientations) and calculate the mean.

(Total for Question 11 = 10 marks)

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12 A student carries out an experiment using a guitar string. She investigates the effect of varying the tension in the guitar string on the frequency of sound produced when the string is plucked.

(a) Describe a method of varying and measuring the tension in the string.

(2)

Fix one end of the string and pass the other end over a pulley at the edge of the bench, then hang a set of masses (weights) on it.

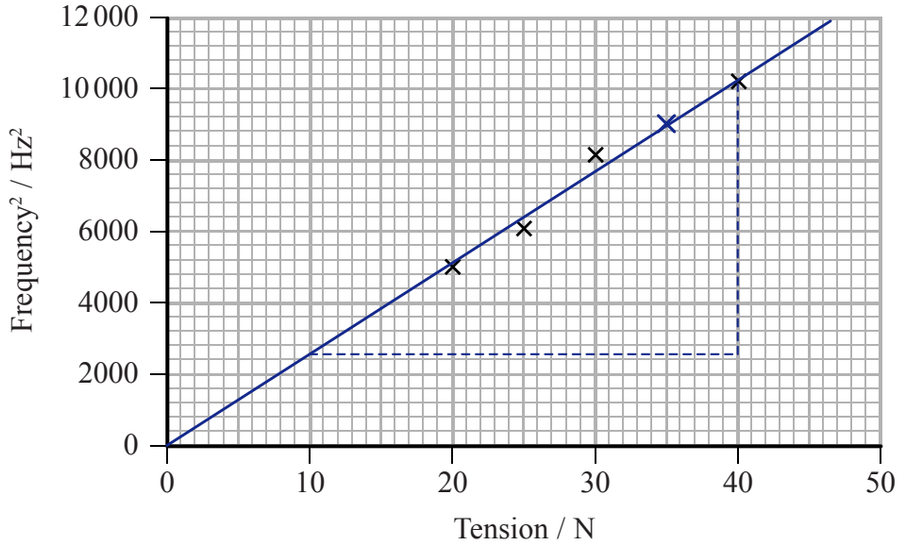
Vary the tension by adding masses: tension = weight of the masses, T = mg, with m measured on a balance and g = 9.81 N kg^{-1}.

(b) The student records the following data and plots a graph.

Tension / N	20	25	30	35	40
Frequency / Hz	70	78	90	95	101
Frequency^2 / Hz^2	4900	6084	8100	9025	10 201

Complete the table and graph.

(3)



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(c) The student reads that guitar strings have a mass per unit length of between 0.4×10^{-3} kg m^{-1} and 7×10^{-3} kg m^{-1}.

Determine whether the guitar string used in this experiment lies within this range.

length of string vibrating = 0.40 m

(5)

gradient = $\Delta(f^2) / \Delta T$ = (10 240 − 2560) Hz^2 / (40 − 10) N = 256 $Hz^2\ N^{-1}$

$v = f\lambda$ and $v = \sqrt{(T/\mu)}$. For the fundamental, $\lambda = 2L = 2 \times 0.40\ m = 0.80\ m$

so $f = (1/\lambda)\sqrt{(T/\mu)}$, giving $f^2 = T / (\lambda^2\mu)$, so gradient = $1 / (\lambda^2\mu)$

$\mu = 1 / (\lambda^2 \times \text{gradient}) = 1 / (0.80^2 \times 256)$

$\mu = 6.1 \times 10^{-3}\ kg\ m^{-1}$

This is between $0.4 \times 10^{-3}\ kg\ m^{-1}$ and $7 \times 10^{-3}\ kg\ m^{-1}$, so the guitar string used does lie within this range.

(Total for Question 12 = 10 marks)

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13 An electron beam is directed onto crystalline graphite. A fluorescent screen on the other side of the crystal shows the pattern in Figure 1. The brighter areas correspond to higher electron intensity.

The speed of the electrons is increased and the resulting pattern is shown in Figure 2.

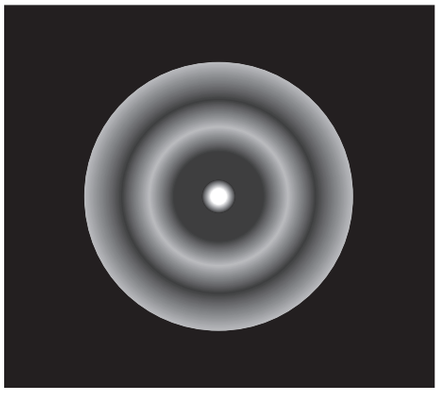


Figure 1

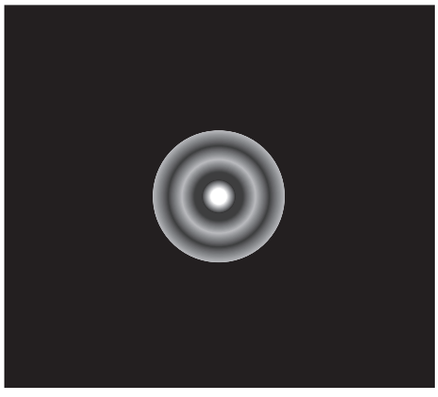


Figure 2

*(a) Discuss the conclusions that can be drawn from this information about the behaviour of electrons and the structure of graphite.

(6)

The rings form a diffraction pattern, with bright rings where the electron waves interfere constructively. Diffraction is a wave property, so this shows that electrons behave as waves, with a wavelength similar to the atomic spacing in graphite.

When the speed of the electrons is increased the rings get smaller, so the diffraction angle θ decreases. From $n\lambda = d \sin\theta$ with the spacing d fixed, a smaller θ means the wavelength λ has decreased.

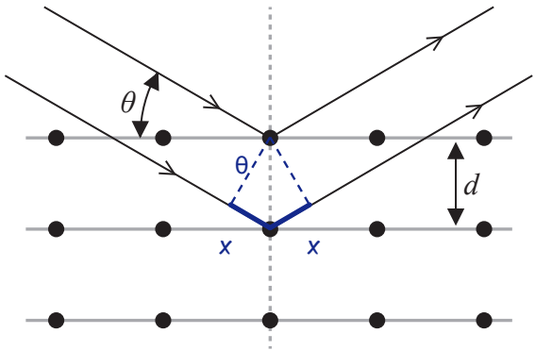
This agrees with the de Broglie equation $\lambda = h/p = h/mv$: as the speed and so the momentum increase, the wavelength decreases.

A clear pattern means graphite has a regular, layered crystal structure with small gaps at uniform distances acting like a grating; rings rather than spots show it is made of many small crystals.

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(b) An electron beam can be used to explore the structure of solid materials. The diagram shows an electron beam reflected by the top two layers of atoms within a material. The two layers are separated by a distance d.



(i) Show that the extra distance travelled by the electron beam reflecting off the second layer of atoms is given by $2d\sin\theta$.

θ is the angle between the beam and each layer of atoms.

You may add to the diagram.

(2)

Draw the wavefronts (dashed) from the top atom at right angles to the lower beam.

The extra distance is the two parts marked x.

The angle between d and each wavefront is θ, so x = d sinθ, and extra distance = 2x = 2d sinθ.

(ii) Give one reason why there is more than one ring shown in both Figure 1 and Figure 2.

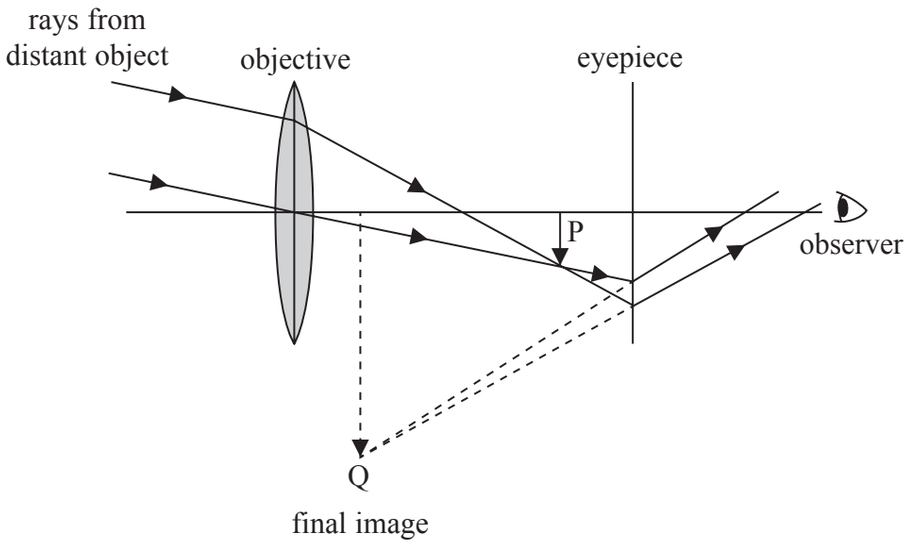
(1)

There is more than one order of diffraction: a ring occurs wherever the path difference is a whole number of wavelengths (λ for the 1st ring, 2λ for the 2nd ring).

(Total for Question 13 = 9 marks)

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14 A telescope consists of a convex lens (objective) of power 0.820 D and a second lens (eyepiece) as shown.



The objective produces an image at P. This image becomes the object of the eyepiece, which produces a final image at Q.

(a) Show that the focal length of the objective lens is about 1200 mm.

(2)

P = 1/f so f = 1/P

f = 1 ÷ 0.820 D = 1.22 m

f = 1220 mm, which is about 1200 mm

(b) Telescopes can be used to observe distant objects such as the Moon.

(i) Explain why the image of the Moon produced at P by the objective lens will be at a distance of about 1200 mm from this lens.

(2)

The Moon is very far away, so the rays from a point on the Moon reaching the lens are parallel.

Parallel rays converge to the principal focus, so the image forms at the focal point, a distance f ≈ 1200 mm from the lens.

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(ii) State the properties of the image at P.

(2)

The image at P is real, inverted (upside down) and diminished (smaller than the object).

(c) The eyepiece is at a distance of 100 mm from the image at P. To give a reasonable magnification, the final image at Q should be a virtual image at a distance of 300 mm from the eyepiece.

The following lenses are available:

diverging lens focal length 150 mm,
converging lens focal length 150 mm,
diverging lens focal length 100 mm,
converging lens focal length 100 mm.

Deduce which lens should be used for the eyepiece.

(3)

Using 1/u + 1/v = 1/f (real is positive), u = 100 mm and the virtual image has v = −300 mm

1/f = 1/100 mm − 1/300 mm = 3/300 mm − 1/300 mm = 2/300 mm

f = +150 mm

f is positive, so the converging lens of focal length 150 mm should be used.

(Total for Question 14 = 9 marks)

TOTAL FOR SECTION A = 60 MARKS

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SECTION B

Answer ALL questions.

15 Read the following extract and then answer the questions that follow.

Powdery dust, the by-product of fearsome meteor storms that pounded the Moon, coats much of the lunar surface. A build-up of this dust could damage sensitive machinery.

Scientists theorise that lunar dust must be electrostatically charged by ultraviolet solar radiation from the Sun. When ultraviolet radiation hits the Moon's "day side", the half that faces the Sun, it knocks electrons out of atoms in the lunar soil.

(a) Describe the particle model of ultraviolet radiation that explains how it can "knock electrons out of atoms".

(3)

Ultraviolet radiation consists of photons: discrete packets (quanta) of energy, each with energy $E = hf$, so the photon energy depends on the frequency.

One photon interacts with one electron, giving all its energy to that electron.

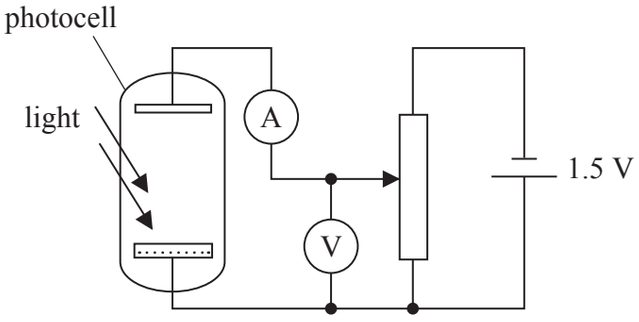
If the photon energy is greater than the work function (the frequency is above the threshold frequency), the electron gains enough energy to be removed, and any extra energy becomes kinetic energy.

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(b) A teacher uses the arrangement below to demonstrate that electrons can be knocked out of a metal surface in a photocell by visible light.

The arrangement can also be used to measure the maximum kinetic energy of these electrons.



(i) Explain how the potential divider circuit can produce a range of values from 0 to 1.5 V on the voltmeter.

(3)

The variable resistor is connected across the 1.5 V cell as a potential divider, with the voltmeter between the slider and the bottom end.

The 1.5 V is split between the parts of the resistor either side of the slider, in the ratio of their resistances, so moving the slider changes the resistance the voltmeter is across.

With the slider at the bottom this resistance is zero, so the reading is 0 V; with the slider at the top it is the maximum resistance, so the reading is 1.5 V.

(ii) The potential difference on the voltmeter is increased until the ammeter reading is zero.
The voltmeter reads 0.6 V at this instant.
State the maximum kinetic energy of the electrons in eV.

(1)

Maximum kinetic energy = *0.6* eV

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(c) Discuss whether the photocell arrangement in part (b) gives a valid demonstration of how dust particles become charged on the Moon.

(4)

Valid: both the demonstration and the theory use the photoelectric effect, with photons knocking out electrons so the material becomes positively charged. Both happen in a vacuum (the photocell is evacuated and the Moon has no atmosphere).

Not valid: the demonstration uses visible light but on the Moon it is ultraviolet, so the wavelengths are different. The photocell has a metal surface, but on the Moon it is dust, a different material. The metal plate is fixed, but dust particles are free to move.

On the Moon UV removes electrons from individual atoms, which could be ionisation rather than the photoelectric effect.

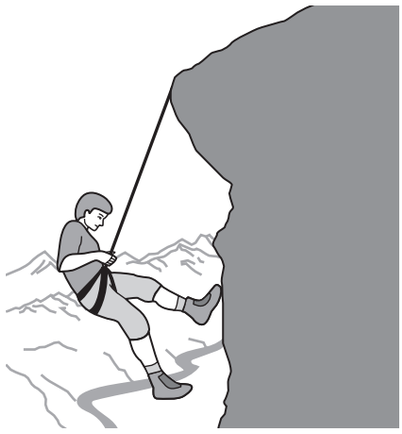
So the photocell only partly models how lunar dust becomes charged.

(Total for Question 15 = 11 marks)

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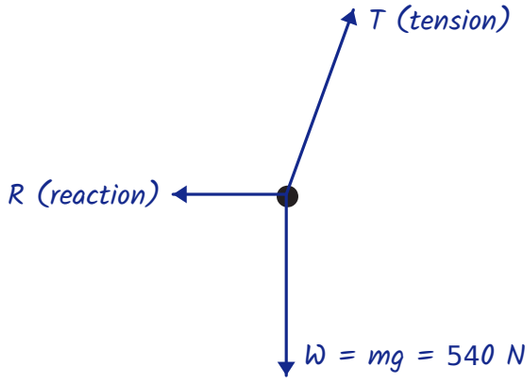
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16 The diagram shows a rock climber of mass 55 kg. She is hanging on a rope with one foot in contact with a rock face. She uses this foot to push herself horizontally away from the rock face. The rope is inclined at 20° to the vertical.



(a) Complete the free-body force diagram below to represent the forces acting on the climber.

(3)



(b) (i) Show that the tension in the rope is about 600 N.

(3)

The reaction force is horizontal, so vertically the forces balance:

$T \cos 20° = mg$

$T = mg \div \cos 20° = (55\ kg \times 9.81\ N\ kg^{-1}) \div \cos 20°$

$T = 539.6\ N \div 0.940 = 574\ N$, which is about 600 N

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(ii) The rope extends by 2.5 cm when used as shown.

Calculate the energy stored within the rope.

(2)

$E = \frac{1}{2} F \Delta x$

$E = \frac{1}{2} \times 574\ N \times 2.5 \times 10^{-2}\ m$

$E = 7.2\ J$

Energy stored = 7.2 J

(iii) State one assumption made in this calculation.

(1)

The rope obeys Hooke's law: extension is proportional to force (limit of proportionality not exceeded).

(Total for Question 16 = 9 marks)

TOTAL FOR SECTION B = 20 MARKS
TOTAL FOR PAPER = 80 MARKS

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List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
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 field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	

Mechanics

Kinematic equations of motion

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

$v = u + at$

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

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

Forces

$\Sigma F = ma$

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

$W = mg$

$moment\ of\ force = Fx$

Momentum

$p = mv$

Work, energy and power

$\Delta W = F\Delta s$

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

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

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

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

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

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

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

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

$I = nqvA$

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Materials

Density

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

Stokes' law

$F = 6\pi\eta r v$

Hooke's law

$F = k\Delta x$

Pressure

$$p = \frac{F}{A}$$

Young modulus

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

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

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

Elastic strain energy

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

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

$hf = \phi + \frac{1}{2} m v_{max}^2$

de Broglie wavelength

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

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