8 A monochromatic source of light with a power P emits light with a wavelength λ.

Which of the following expressions gives the number of photons per unit time?

- ☒ **A** $\frac{hc}{P\lambda}$
- ☒ **B** $\frac{P\lambda}{hc}$
- ☒ **C** $\frac{Pc}{h\lambda}$
- ☒ **D** $\frac{h\lambda}{Pc}$

(Total for Question 8 = 1 mark)

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9 In 1924 de Broglie suggested that electrons have wave properties.
The de Broglie equation states:

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

Which of the following is correct?

- ☒ **A** The de Broglie wavelength is independent of the mass of the particle.
- ☒ **B** The de Broglie equation can be used to calculate the momentum of a photon.
- ☒ **C** The term p represents the mass of an electron multiplied by the speed of light.
- ☒ **D** The value of h depends on the particle involved.

(Total for Question 9 = 1 mark)

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9: When monochromatic light is incident on the surface of a metal, photoelectrons are emitted.

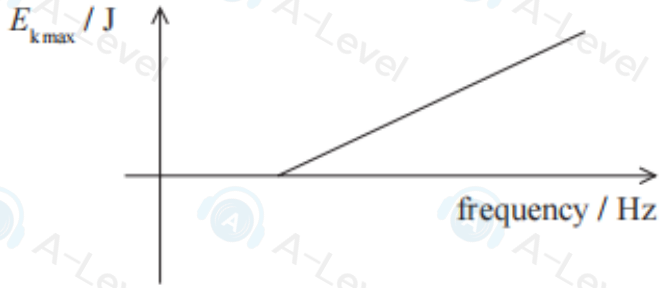
Which of the following statements is correct?

- ☒ **A** The maximum kinetic energy of the photoelectrons depends on the intensity of the incident light.
- ☒ **B** The number of photoelectrons emitted per second depends on the frequency of the incident light.
- ☒ **C** The maximum kinetic energy of the photoelectrons depends on the frequency of the incident light.
- ☒ **D** The number of photoelectrons emitted per second depends on the work function of the metal.

(Total for Question 9 = 1 mark)

9 Light of varying frequency is incident on a metal electrode and the maximum kinetic energy of the electrons emitted is determined.

The maximum kinetic energy of the electrons varies with the frequency of the incident light as shown.



Which of the following is the numerical value of the gradient?

☒ **A** 6.63×10^{-34}

☒ **B** 9.11×10^{-31}

☒ **C** 1.60×10^{-19}

☒ **D** 3.00×10^{8}

(Total for Question 9 = 1 mark)

4 Which of the following is evidence that electrons can behave like waves?

☒ **A** Electrons are attracted towards positively charged objects.

☒ **B** Electrons can absorb photons and move between energy levels in an atom.

☒ **C** Electrons can be diffracted when passing through a thin sheet of graphite.

☒ **D** Electrons can be released by photons in the photoelectric effect.

(Total for Question 4 = 1 mark)

6 When the photoelectric effect occurs, light incident on the surface of a metal releases electrons.

Which of the following is an experimental observation of the photoelectric effect?

☒ **A** Electrons are only released after light has been incident for a long time.

☒ **B** Increasing the frequency of the light increases the maximum kinetic energy of the released electrons.

☒ **C** Increasing the intensity of the light increases the maximum kinetic energy of the released electrons.

☒ **D** Only light with a wavelength above a threshold value releases electrons.

(Total for Question 6 = 1 mark)

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4 Which of the following has the largest de Broglie wavelength?

☒ **A** an electron travelling at $3.0 \times 10^5\ m\ s^{-1}$

☒ **B** an electron travelling at $4.0 \times 10^5\ m\ s^{-1}$

☒ **C** a neutron travelling at $3.0 \times 10^5\ m\ s^{-1}$

☒ **D** a neutron travelling at $4.0 \times 10^5\ m\ s^{-1}$

(Total for Question 4 = 1 mark)

7 Particle X of mass m is moving with velocity v and has a de Broglie wavelength λ.

Particle Y has a de Broglie wavelength 0.25λ.

Which row of the table could give the mass and velocity of particle Y?

		Mass	Velocity
☒	**A**	$0.25m$	v
☒	**B**	$0.5m$	$8v$
☒	**C**	m	$2v$
☒	**D**	$2m$	$4v$

(Total for Question 7 = 1 mark)

4 Electromagnetic radiation can be described in terms of a photon model.

Which of the following demonstrates the photon model of light?

☒ **A** diffraction patterns

☒ **B** Huygens' construction

☒ **C** photoelectric effect

☒ **D** plane polarisation

(Total for Question 4 = 1 mark)

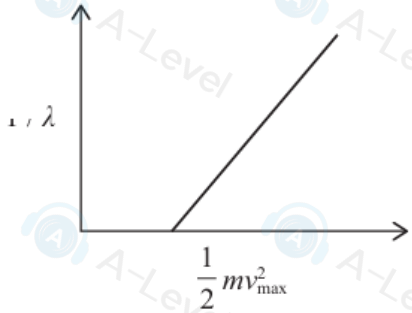
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10 Light of wavelength λ travelling at speed c is incident on a metal surface.

Photoelectrons are emitted from the surface with a maximum kinetic energy $\frac{1}{2}mv_{max}^2$.

The graph shows the relationship between $1/\lambda$ and $\frac{1}{2}mv_{max}^2$.



Which of the following shows how the gradient of the graph can be used to determine the Planck constant h?

☒ **A** $h = \frac{1}{\text{gradient}}$

☒ **B** $h = \frac{1}{\text{c} \times \text{gradient}}$

☒ **C** $h = \frac{\text{c}}{\text{gradient}}$

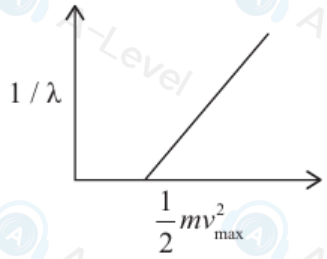
☒ **D** $h = \text{gradient}$

(Total for Question 10 = 1 mark)

10 Light of wavelength λ travelling at speed c is incident on a metal surface.

Photoelectrons are emitted from the surface with a maximum kinetic energy $\frac{1}{2}mv^2_{max}$

The graph shows the relationship between 1 / λ and $\frac{1}{2}mv^2_{max}$



Which of the following shows how the gradient of the graph can be used to determine the Planck constant h?

A $h = \frac{1}{\text{gradient}}$

B $h = \frac{1}{\text{c} \times \text{gradient}}$

C $h = \frac{\text{c}}{\text{gradient}}$

D $h = \text{gradient}$

(Total for Question 10 = 1 mark)

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3 An electron has a de Broglie wavelength of 3.5×10^{-10} m.

Which of the following expressions gives the velocity of the electron in m s^{-1}?

☒ **A** $\frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 3.5 \times 10^{-10}}$

☒ **B** $\frac{6.63 \times 10^{-34}}{3.5 \times 10^{-10}}$

☒ **C** $\frac{9.11 \times 10^{-31} \times 3.5 \times 10^{-10}}{6.63 \times 10^{-34}}$

☒ **D** $\frac{3.5 \times 10^{-10}}{6.63 \times 10^{-34}}$

(Total for Question 3 = 1 mark)

5 An electron has a de Broglie wavelength of 1.55×10^{-9} m.

Which of the following gives the speed, in $m\,s^{-1}$, of this electron?

☒ **A** $\dfrac{9.11 \times 10^{-31}}{6.63 \times 10^{-34} \times 1.55 \times 10^{-9}}$

☒ **B** $\dfrac{1.55 \times 10^{-9} \times 9.11 \times 10^{-31}}{6.63 \times 10^{-34}}$

☒ **C** $\dfrac{6.63 \times 10^{-34} \times 1.55 \times 10^{-9}}{9.11 \times 10^{-31}}$

☒ **D** $\dfrac{6.63 \times 10^{-34}}{1.55 \times 10^{-9} \times 9.11 \times 10^{-31}}$

(Total for Question 5 = 1 mark)

4 An electron has a velocity of $2 \times 10^{7}\,m\,s^{-1}$.

Which of the following expressions gives the de Broglie wavelength of the electron in metres?

☒ **A** $\dfrac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 2 \times 10^{7}}$

☒ **B** $\dfrac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 2 \times 10^{7}}$

☒ **C** $\dfrac{9.11 \times 10^{-31} \times 2 \times 10^{7}}{6.63 \times 10^{-34}}$

☒ **D** $\dfrac{1.67 \times 10^{-27} \times 2 \times 10^{7}}{6.63 \times 10^{-34}}$

(Total for Question 4 = 1 mark)

6 Which of the following describes threshold frequency?

☒ **A** The frequency of light that causes photoelectrons to have maximum kinetic energy.

☒ **B** The frequency of light emitted when excited electrons fall to the ground state.

☒ **C** The minimum frequency of light that can cause an electron to leave a surface.

☒ **D** The maximum frequency of light which excites an electron in the ground state.

(Total for Question 6 = 1 mark)

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18: Some types of glue can be hardened by exposure to ultraviolet (UV) light.

(a) One type of UV lamp contains mercury atoms in an evacuated glass tube. When a large potential difference is applied between two electrodes in the tube, electrons move between the two electrodes. These electrons collide with the mercury atoms in the tube.
These mercury atoms then emit photons.

Explain why the mercury atoms emit photons.

(2)

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(a) One type of UV lamp contains mercury atoms in an evacuated glass tube. When a large potential difference is applied between two electrodes in the tube, electrons move between the two electrodes. These electrons collide with the mercury atoms in the tube.
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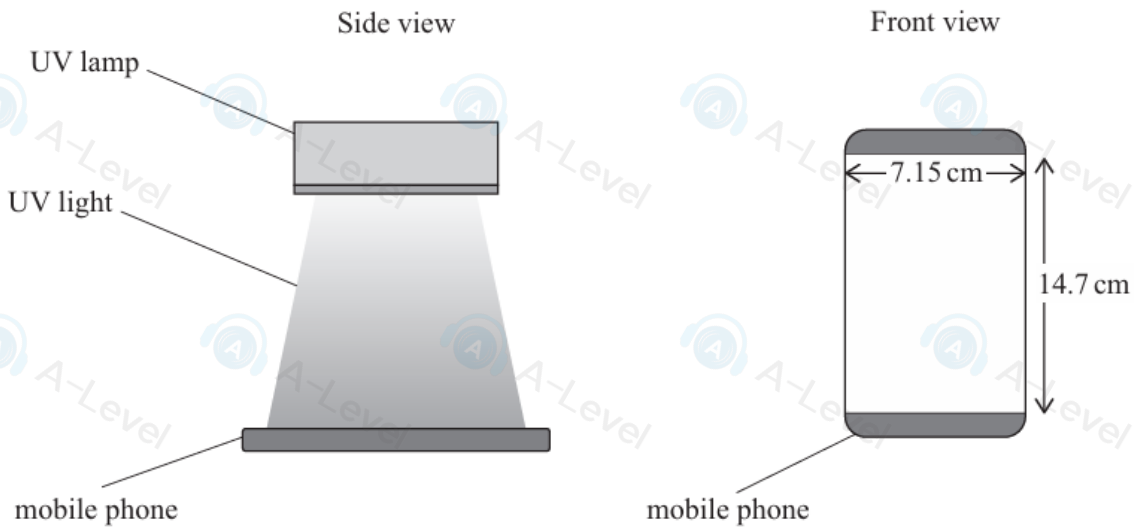
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(b) A technician is replacing the screen on a mobile phone. He spreads a layer of glue over the phone surface and attaches the glass screen. The glue is then hardened when exposed to UV light.

The equipment used and screen dimensions are as shown in the following diagram.



The intensity of the UV light received on the screen is 50 mW cm^{-2}.

The glue takes 25 s to harden.

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(i) Show that the total energy incident on the glass screen during this time is

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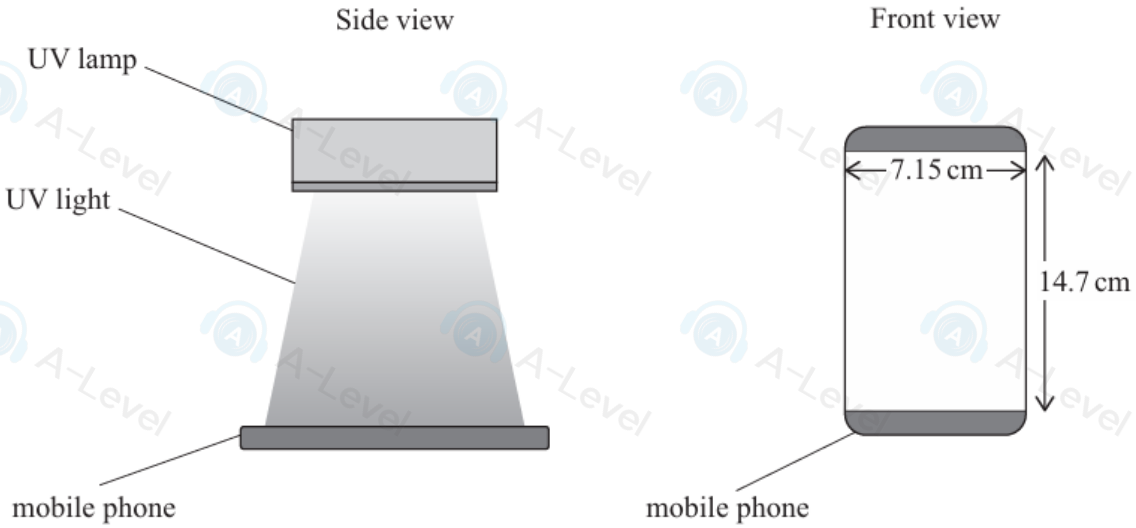
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(2)

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(i) Show that the total energy incident on the glass screen during this time is

(c) The potential difference applied between the electrodes in the UV lamp is increased.

Explain the effect this would have on the frequency of the UV light produced by the lamp.

(2)

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18: Some types of glue can be hardened by exposure to ultraviolet (UV) light.

(a) One type of UV lamp contains mercury atoms in an evacuated glass tube. When a large potential difference is applied between two electrodes in the tube, electrons move between the two electrodes. These electrons collide with the mercury atoms in the tube.
These mercury atoms then emit photons.

Explain why the mercury atoms emit photons.

(2)

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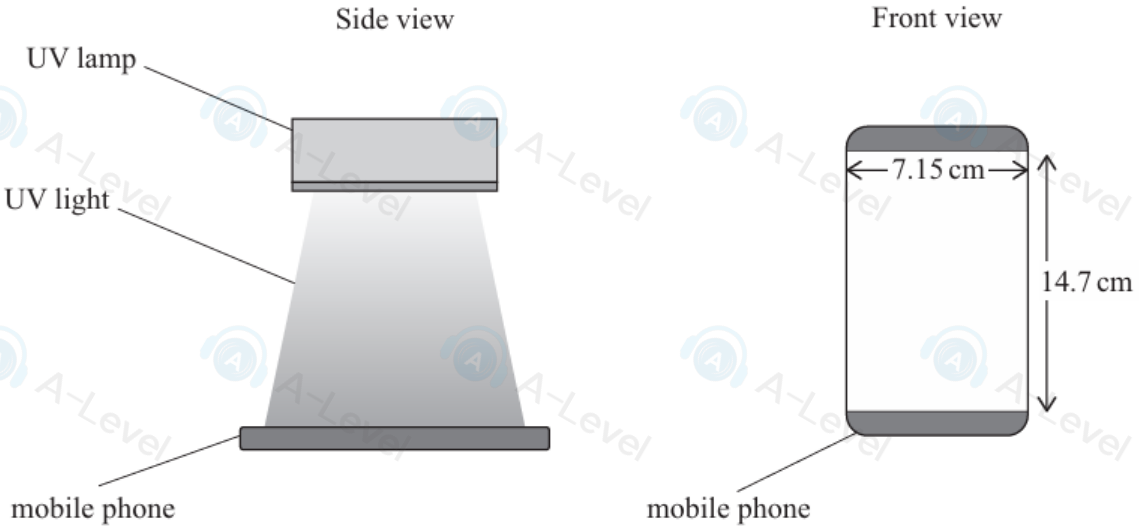
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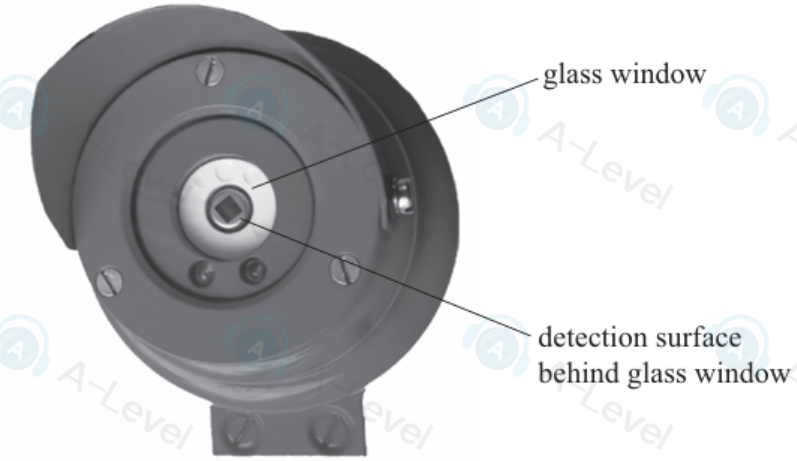
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The glue takes 25 s to harden.

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(i) Show that the total energy incident on the glass screen during this time is about 130 J

15 The photograph shows a 'flame detector'. The flame detector uses the photoelectric effect to detect ultraviolet radiation from fires.



(Source: © Fisenko Evgeny/Shutterstock)

(a) Explain how electrons are released in the photoelectric effect.

(4)

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(b) A fire emits photons of ultraviolet radiation with a wavelength of 380 nm.

17 The diagram shows the energy levels for an atom of hydrogen.



An electron is in the −13.6 eV (ground state) level of this atom.

(a) A photon interacts with this electron.

Explain why this interaction causes the emission of another photon.

(2)

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(b) A photon has a wavelength of 218 nm.

(i) Determine the energy, in eV, of this photon.

(4)

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Photon energy = ... eV

(ii) Explain whether the atom of hydrogen could emit a photon with this energy.

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17 Ultraviolet light of wavelength 20.0 nm is incident on a metal surface. The metal has a work function of 3.68 eV. Electrons are released by the photoelectric effect.

(a) Calculate the maximum speed of the electrons as they are released from the metal surface.

(5)

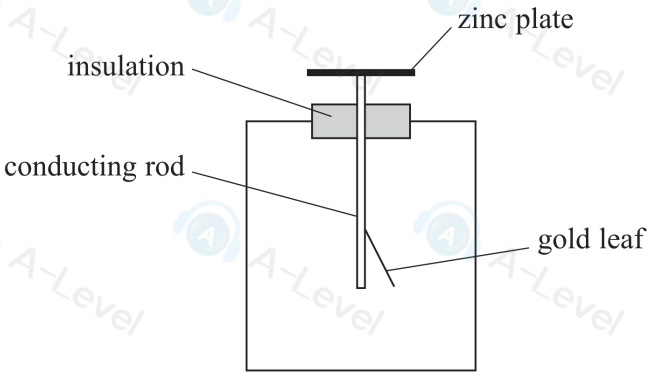
Maximum speed = ...

(b) A student suggests that if the wavelength and intensity of the light used are both increased, the maximum speed of the electrons released from the metal surface also increases.

Explain whether the student's suggestion is correct.

(4)

19 A gold leaf electroscope is a device that can be used to detect charge. The deflection of the gold leaf depends on the amount of charge on the zinc plate and the conducting rod.



In a demonstration of the photoelectric effect, a teacher charged the zinc plate with a negative charge and the gold leaf was deflected.

When ultraviolet radiation of frequency 2.0×10^{15} Hz was shone onto the zinc plate, the deflection of the gold leaf reduced.

(a) (i) Explain why the deflection of the gold leaf reduced. Your answer should include a calculation.

(4)

work function for zinc = 6.9×10^{-19} J

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(ii) Explain what would be observed with the gold leaf electroscope if ultraviolet radiation of the same frequency but with a lower intensity was used.

(4)

(b) In the early 20th century, the wave model was generally accepted as an explanation of the nature of light.

Explain why the wave model cannot explain the photoelectric effect.

(3)

(Total for Question 19 = 11 marks)

TOTAL FOR SECTION B = 70 MARKS
TOTAL FOR PAPER = 80 MARKS

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