



Thank you for subscribing to SmarterScience Teacher Edition in 2023.

Key features of the Physics “2023 HSC Comprehensive Revision Series” include:

- ~14 hours of cherry-picked HSC revision questions by topic
- Targeted at motivated students aiming for a Band 5 or 6 result
- Weighting toward more difficult examples
- Mark allocations of topic areas reflect their HSC exam allocations
- **Attempt, carefully review and annotate** this revision set in Term 3
- This question set provides the foundation of a concise and high-quality revision resource for the run into the HSC exam.

Our analysis on each topic, the common question types, past areas of difficulty and recent HSC trends all combine to create this revision set that ensures students cover a wide cross-section of the key areas.

IMPORTANT: If students have been exposed to questions in these worksheets during the year, we say great. Many top performing students attest to the benefits of doing quality questions 2-3 times before the HSC. This type of revision set is aimed at creating confidence and *speed through the exam*, with cherry picked questions that cover all important elements of revision while avoiding low percentage rabbit hole excursions.

HSC Final Study: M7 The Nature of Light

Light: Quantum Model (~9.8% historical contribution)

Key Areas addressed by this worksheet

- The *Quantum Model of Light* is the largest contributor to *M7 The Nature of Light*, appearing in two longer answer questions each new syllabus exam (except for 2022) as well as at least two multiple-choice.
- The *Photoelectric Effect* is the most commonly tested subtopic, attracting a multiple-choice question in each exam of the new syllabus, as well as high mark allocations in longer response questions in 2022 and 2019.
- *Experiments* which provide evidence for the quantum model of light have been the subject of regular testing and must be a revision focus. Specific attention should be given to *2021 HSC Q33* which attracted a substantial 9-mark allocation and proved very challenging.
- *Blackbodies* has also been examined frequently, appearing every year of the new syllabus, including two longer answer questions in 2020 with substantial mark allocations. *2020 HSC Q26* caused major problems and is a “must review” question in this area.
- *Energy calcs* is a concept which has been examined recently in *2021 HSC Q20* and *2022 HSC Q26b*. Challenging revision examples require cross-topic application of formulas to a photoelectric effect scenario.

“This resource is genuinely invaluable.”

*~ Frank Gonzalez,
Albion Park High School*

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Questions

1. PHYSICS, M7 2020 HSC 3 MC

What was the basis for Maxwell's prediction of the velocity of electromagnetic waves?

- A. Experiments using magnetic fields to accelerate particles
- B. Experiments using light and mirrors to establish the finite speed of light
- C. Equations showing how oscillating electric and magnetic fields propagate
- D. Equations showing how electromagnetic waves are affected by gravitational fields

2. PHYSICS M7 2022 HSC 9 MC

The radiation emitted by a black body has a peak wavelength of $5.8 \times 10^{-7} \text{ m}$.

What is its temperature?

- A. 3000 K
- B. 4500 K
- C. 5000 K
- D. 5500 K

3. PHYSICS, M7 2015 HSC 17 MC

Which row of the table correctly shows ideas that Planck and Einstein contributed to quantum theory?

	<i>Planck</i>	<i>Einstein</i>
(A)	Hot objects emit radiation in discrete amounts.	Light consists of packets of energy with specific values.
(B)	Planck's constant determines the energy of photons.	Objects emit energy that increases exponentially with frequency.
(C)	No energy is lost from black body radiators.	Energy is absorbed if the band gap is less than the photon energy.
(D)	The energy of photons decreases as the wavelength increases.	Photons have energy proportional to their frequency.

4. PHYSICS, M7 2016 HSC 13 MC

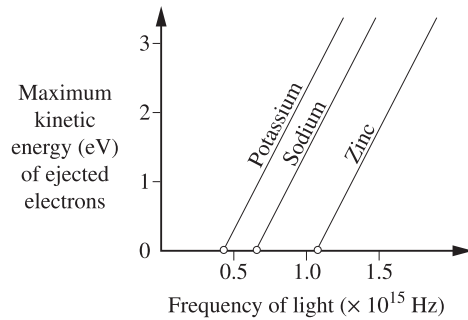
When light of a specific frequency strikes a metal surface, photoelectrons are emitted.

If the light intensity is increased but the frequency remains the same, which row of the table is correct?

	<i>Number of photoelectrons emitted</i>	<i>Maximum kinetic energy of the photoelectrons</i>
(A)	Remains the same	Remains the same
(B)	Remains the same	Increases
(C)	Increases	Remains the same
(D)	Increases	Increases

5. PHYSICS, M7 2018 HSC 17 MC

The graph shows the maximum kinetic energy of electrons ejected from different metals as a function of the frequency of the incident light.



What can be deduced from this graph?

- A. The maximum kinetic energy of ejected electrons is proportional to the number of photons incident on the metal surface.
- B. More photons are required to cause an electron to be ejected from zinc than from potassium.
- C. Any photon that can eject an electron from the surface of zinc must also be able to cause an electron to be ejected from potassium.
- D. For any given frequency that causes electrons to be ejected from all three metals, the number of electrons ejected is always greatest for potassium.

6. PHYSICS, M7 2019 HSC 6 MC

Which graph correctly shows the relationship between the surface temperature of a black body (T) and the wavelength (λ) at which the maximum intensity of light is emitted?

- A.
- B.
- C.
- D.

7. PHYSICS, M7 2021 HSC 11 MC

What is the peak wavelength of electromagnetic radiation emitted by a person with a body temperature of 37°C (310 K)?

- A. 9.3×10^{-6} m
- B. 7.8×10^{-5} m
- C. 9.3×10^{-3} m
- D. 7.8×10^{-2} m

8. PHYSICS, M7 2019 HSC 13 MC

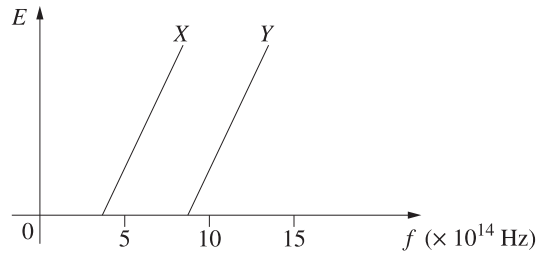
A laser has a power output of 30 mW and emits light with a wavelength of 650 nm.

How many photons does this laser emit per second?

- A. 4.6×10^{14}
- B. 9.8×10^{16}
- C. 3.1×10^{19}
- D. 9.3×10^{21}

9. PHYSICS, M7 EQ-Bank 17 MC

The graph shows the maximum kinetic energy (K) with which photoelectrons are emitted as a function of frequency (f) for two different metals X and Y .



The metals are illuminated with light of wavelength 450 nm.

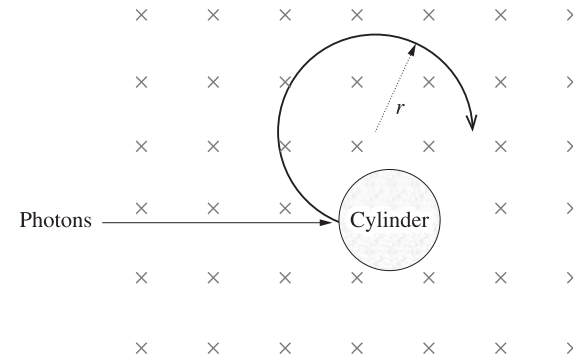
What would be the effect of doubling the intensity of this light without changing the wavelength?

- A. For metal X , the number of photoelectrons emitted would not change but the maximum kinetic energy would increase.
- B. For metal X , the number of photoelectrons emitted would increase but the maximum kinetic energy remains unchanged.
- C. For metals X and Y , the number of photoelectrons emitted would not change but the maximum kinetic energy would increase.
- D. For metals X and Y , the number of photoelectrons emitted would increase but the maximum kinetic energy remains unchanged.

10. PHYSICS, M7 2021 HSC 20 MC

A metal cylinder is located in a uniform magnetic field. The work function of the metal is ϕ .

Photons having an energy of 2ϕ strike the side of the cylinder, liberating photoelectrons which travel perpendicular to the magnetic field in a circular path. The maximum radius of the path is r .



If the photon energy is doubled, what will the maximum radius of the path become?

- A. $2r$
- B. $3r$
- C. $\sqrt{2}r$
- D. $\sqrt{3}r$

11. PHYSICS, M7 2017 HSC 21

A laser emits light of wavelength 550 nm.

- a. Calculate the frequency of this light. (2 marks)
- b. The electrons in a specific metal must absorb a minimum of 5×10^{-19} J in order to be ejected from its surface.

Explain why electrons will not be ejected from this metal when photons of wavelength 550 nm strike its surface. Support your answer with relevant calculations. (3 marks)

12. PHYSICS, M7 2021 HSC 26

A student performs an experiment to measure Planck's constant, h , using a device that emits specific frequencies of light when specific voltages are applied.

The voltage, V , needed to produce each frequency, f , is given by

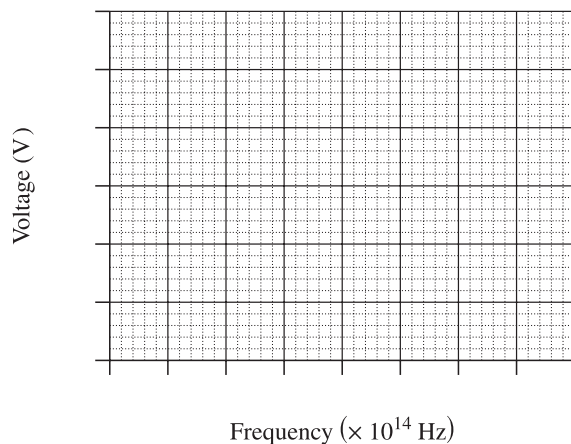
$$V = \frac{hf}{q_e}$$

where q_e is the charge on an electron.

Data from the experiment is shown.

Data point	Frequency ($\times 10^{14}$ Hz)	Voltage (V)
1	3.5	1.3
2	4.8	1.7
3	5.3	1.9
4	7.0	2.6

a. Graph this data on the axes provided. Include a line of best fit. (3 marks)



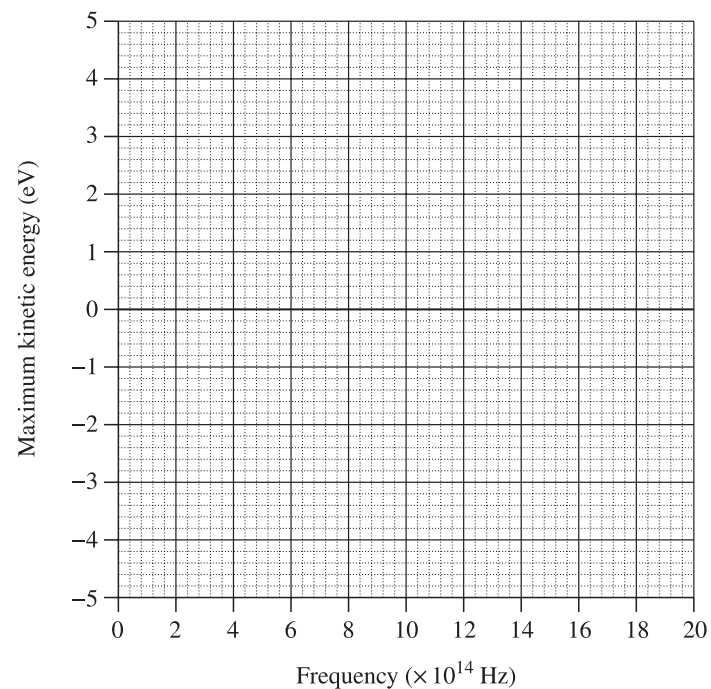
13. PHYSICS, M7 2019 HSC 23

A student investigated the photoelectric effect. The frequency of light incident on a metal surface was varied and the corresponding maximum kinetic energy of the photoelectrons was measured.

The following results were obtained.

Frequency ($\times 10^{14}$ Hz)	11.2	13.5	15.2	18.6	20.0
Maximum kinetic energy (eV)	0.6	1.3	2.3	3.3	4.2

Plot the results on the axes below and hence determine the work function of the metal in electron volts. (3 marks)



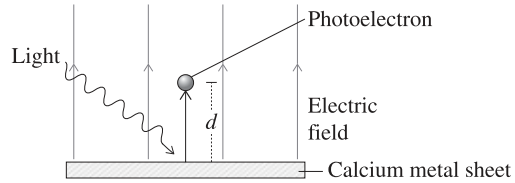
b. The student proposes using data point 1 to calculate a value for Planck's constant.

Justify a better method to calculate Planck's constant from the experimental data provided. (3 marks)

14. PHYSICS M7 2022 HSC 26

Light of frequency $7.5 \times 10^{14} \text{ Hz}$ is incident on a calcium metal sheet which has a work function of 2.9 eV . Photoelectrons are emitted.

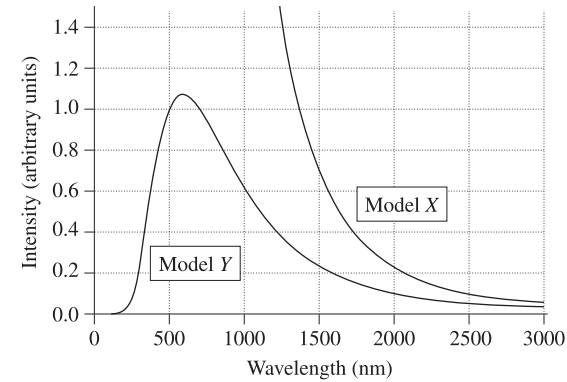
The metal is in a uniform electric field of 5.2 NC^{-1} , perpendicular to the surface of the metal, as shown.



- Show that the maximum kinetic energy of an emitted photoelectron is $3.2 \times 10^{-20} \text{ J}$. (3 marks)
- Calculate the maximum distance, d , an emitted photoelectron can travel from the surface of the metal. (3 marks)

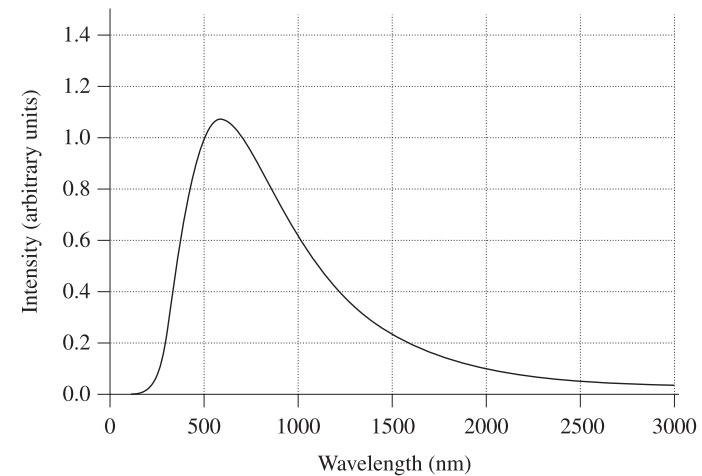
15. PHYSICS, M7 2020 HSC 26

- Describe the difference between the spectra of the light produced by a gas discharge tube and by an incandescent lamp. (2 marks)
- The graph shows the curves predicted by two different models, **X** and **Y**, for the electromagnetic radiation emitted by an object at a temperature of 5000 K.



Identify an assumption of EACH model which determines the shape of its curve. (2 marks)

- The diagram shows the radiation curve for a black body radiator at a temperature of 5000 K.



On the same diagram, sketch a curve for a black body radiator at a temperature of 4000 K and explain the differences between the curves. (4 marks)

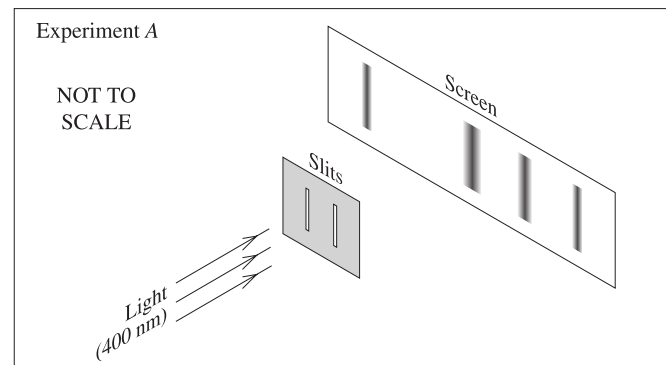
16. PHYSICS, M7 2016 HSC 27b

Explain how the result of ONE investigation of the photoelectric effect changed the scientific understanding of the nature of light. (4 marks)

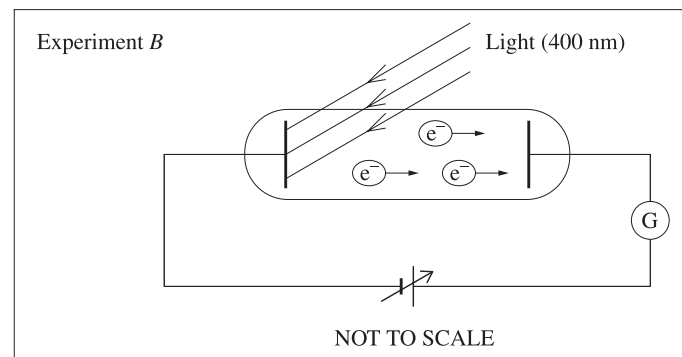
17. PHYSICS, M7 2021 HSC 33

Two experiments are performed with identical light sources having a wavelength of 400 nm.

In experiment **A**, the light is incident on a pair of narrow slits 5.0×10^{-5} m apart, producing a pattern on a screen located 3.0 m behind the slits.



In experiment **B**, the light is incident on different metal samples inside an evacuated tube as shown. The kinetic energy of any emitted photoelectrons can be measured.



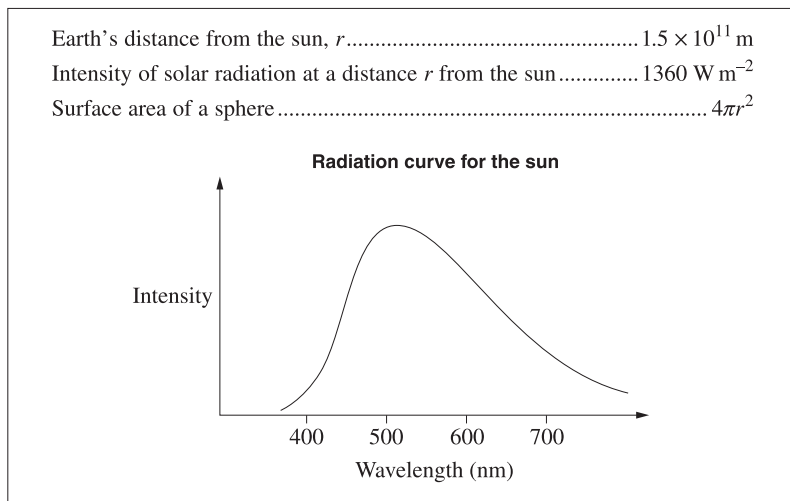
Some results from experiment **B** are shown.

Metal sample	Work function (J)	Photoelectrons observed?
Nickel	8.25×10^{-19}	No
Calcium	4.60×10^{-19}	Yes

How do the results from Experiment **A** and Experiment **B** support TWO different models of light? In your answer, include a quantitative analysis of each experiment. (9 marks)

18. PHYSICS, M8 2019 HSC 34

Use the following information to answer this question.



Describe both the production and radiation of energy by the sun. In your answer, include a quantitative analysis of both the power output and the surface temperature of the sun. (9 marks)

Worked Solutions

1. PHYSICS, M7 2020 HSC 3 MC

Maxwell used equations to show interactions between electric and magnetic fields.

⇒ C

2. PHYSICS M7 2022 HSC 9 MC

$$\lambda_{\max} = \frac{b}{T}$$

$$T = \frac{b}{\lambda_{\max}}$$

$$= \frac{2.898 \times 10^{-3}}{5.8 \times 10^{-7}}$$

$$\approx 5000 \text{ K}$$

⇒ C

3. PHYSICS, M7 2015 HSC 17 MC

By Elimination:

- Statements of both scientists are incorrect in B and C.
- In D, Planck's experiments did not look at photons (eliminate D).

⇒ A

4. PHYSICS, M7 2016 HSC 13 MC

- An increase in light intensity increases the number of photons striking the metal surface.
- This increases the number of photoelectrons emitted.
- Since no change in frequency, the energy of photons striking metal surface remains constant.
- Maximum kinetic energy of emitted photoelectrons remains the same.

⇒ C

5. PHYSICS, M7 2018 HSC 17 MC

→ The graph shows that zinc has a greater work function than potassium.

→ So, any photon with sufficient energy to eject a photon from the surface of zinc will also have sufficient energy to overcome the work function of potassium and eject a photon from its surface.

⇒ **C**

6. PHYSICS, M7 2019 HSC 6 MC

Since $\lambda_{\max} = \frac{b}{T}$, $\lambda \propto \frac{1}{T}$ (Wien's Displacement Law)

⇒ **A**

7. PHYSICS, M7 2021 HSC 11 MC

$$\begin{aligned}\lambda &= \frac{b}{T} \\ &= \frac{2.898 \times 10^{-3}}{310} \\ &= 9.3 \times 10^{-6}\end{aligned}$$

⇒ **A**

8. PHYSICS, M7 2019 HSC 13 MC

$$\begin{aligned}E &= hf \\ &= \frac{hc}{\lambda} \\ &= \frac{(6.626 \times 10^{-34})(3 \times 10^8)}{6.5 \times 10^{-7}} \\ &= 3.1 \times 10^{-19} \text{ J}\end{aligned}$$

♦ Mean mark 43%.

$$\begin{aligned}\text{Photons} &= \frac{P}{E} \\ &= \frac{30 \times 10^{-3}}{3.1 \times 10^{-19}} \\ &= 9.8 \times 10^{16}\end{aligned}$$

⇒ **B**

9. PHYSICS, M7 EQ-Bank 17 MC

→ Calculating the frequency of incident light:

$$\begin{aligned}v &= f\lambda \\ f &= \frac{c}{\lambda}, \quad (v = c) \\ &= \frac{3 \times 10^8}{4.5 \times 10^{-7}} \\ &= 6.67 \times 10^{14} \text{ Hz}\end{aligned}$$

→ This is greater than the work function of metal **X**, but less than the work function of metal **Y**. So, when the light is incident upon both metals, photoelectron emission will occur for **X** but not **Y**.

→ Increasing the intensity of the light increases the rate at which photons strike the surface of metal **X**. This increases the rate of photoelectron emission.

→ The only way to increase the maximum kinetic energy is to increase the frequency of incident light. So, the maximum kinetic energy of photoelectrons remains unchanged.

⇒ **B**

10. PHYSICS, M7 2021 HSC 20 MC

$$K_{\max} = \frac{1}{2}mv_{\max}^2$$

$$v_{\max} = \sqrt{\frac{2K_{\max}}{m}} \dots (1)$$

$$r = \frac{mv}{qB}$$

Substitute into (1):

$$r = \frac{m}{qB} \sqrt{\frac{2K_{\max}}{m}}$$

$$r \propto \sqrt{K_{\max}}$$

When the photon energy is 2ϕ , $K_{\max} = \phi$.

When the photon energy is doubled to 4ϕ , $K_{\max} = 3\phi$.

\therefore As $r \propto \sqrt{K_{\max}}$ the radius increases by a factor of $\sqrt{3}$.

$\Rightarrow D$

♦ Mean mark 24%.

11. PHYSICS, M7 2017 HSC 21

a. $v = f\lambda$

$$f = \frac{v}{\lambda}$$

$$= \frac{3 \times 10^8}{550 \times 10^{-9}}$$

$$= 5.45 \times 10^{14} \text{ Hz}$$

b. $E = hf$

$$= 6.62 \times 10^{-34} \times 5.46 \times 10^{14}$$

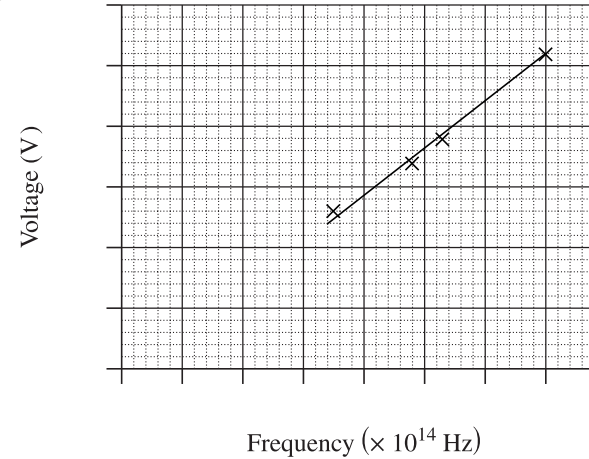
$$= 3.63 \times 10^{-19} \text{ J}$$

\rightarrow The work function of the metal sample is $5 \times 10^{-19} \text{ J}$.

\rightarrow Since the incident photon energy of $3.63 \times 10^{-19} \text{ J}$ is less than $5 \times 10^{-19} \text{ J}$, they are unable to eject electrons from the metal.

12. PHYSICS, M7 2021 HSC 26

a.

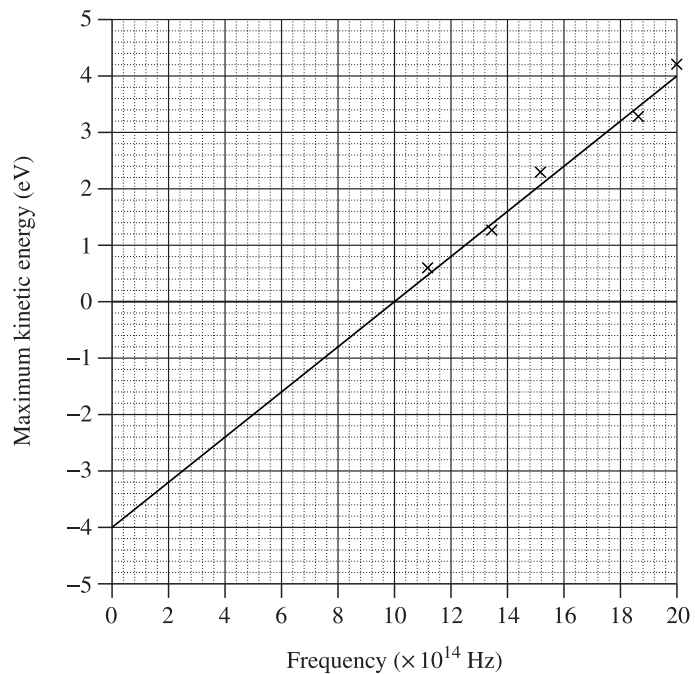


b. The gradient of the line of best fit should be determined using the graph $V = \frac{hf}{q_e}$.

The gradient is equal to $\frac{V}{f}$, and h can be calculated as $h = \text{gradient} \times q_e$.

This method increases the accuracy by taking more data points into account.

13. PHYSICS, M7 2019 HSC 23



The metal has a work function of 4 eV (this is the negative of the y -intercept).

14. PHYSICS M7 2022 HSC 26

a. $K_{\max} = hf - \Phi$

$$= 6.626 \times 10^{-34} \times 7.5 \times 10^{14} - 2.9 \times 1.602 \times 10^{-19}$$

$$= 3.2 \times 10^{-20} \text{ J}$$

b. Maximum Distance:

→ The electric field will do 3.2×10^{-20} J of work to stop the electron.

♦ Mean mark (b) 51%.

$$W = qEd$$

$$3.2 \times 10^{-20} = 1.602 \times 10^{-19} \times 5.2 \times d_{\max}$$

$$\therefore d_{\max} = \frac{3.2 \times 10^{-20}}{1.602 \times 10^{-19} \times 5.2}$$

$$= 0.038 \text{ m.}$$

15. PHYSICS, M7 2020 HSC 26

a. Differences:

- The spectra of light produced by a gas discharge tube will consist of lines only at a few discrete wavelengths.
- The spectra of light produced by an incandescent lamp will be a continuous spectrum.

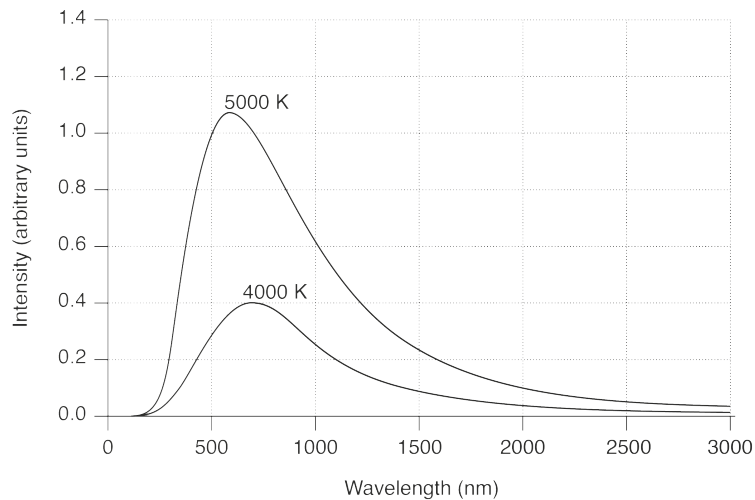
◆ Mean mark (a) 39%.

b. Assumptions of EACH model:

- Model **X** black bodies absorb and emit energy continuously.
- Model **Y** assumes that black bodies absorb and emit energy in discrete quantities.

◆ Mean mark (b) 44%.

c.



$$\text{Using } \lambda_{\max} = \frac{b}{T} \Rightarrow \lambda \propto \frac{1}{T}$$

Therefore, the 4000 K curve will have a peak wavelength greater than the 5000 K curve. The area under the curve and the intensity at all wavelengths will be less for the 4000 K curve, as the total power output of a black body decreases as its temperature decreases.

16. PHYSICS, M7 2016 HSC 27b

→ One investigation of the photoelectric effect showed that the kinetic energy of emitted photoelectrons increased when the frequency of incident light increased, but did not increase with increased light intensity.

◆ Mean mark 40%.

→ This could only be explained by a particle, or photon model of light.

→ The photon model considers light to consist of discrete packets of energy, where the energy of a photon is proportional to its frequency.

→ Thus, higher frequency light → greater photon energy → greater kinetic energy of emitted photoelectrons.

→ The scientific understanding of light was changed from a wave model where light existed only as transverse waves of different wavelengths to a wave-particle duality.

17. PHYSICS, M7 2021 HSC 33

Experiment A supports the wave model of light as it demonstrates light undergoing diffraction as well as constructive and destructive interference, which are wave properties.

◆ Mean mark 52%.

When light is incident upon the slits, it diffracts and causes the slit to act as a source of wavefronts. When light from the slits arrives at the screen, bright bands are produced when light waves arrive in phase and undergo constructive interference. Dark bands are produced when light waves arrive at the screen out of phase and undergo destructive interference.

The spacing between adjacent bright bands can be calculated:

$$d \sin \theta = m \lambda$$

$$5 \times 10^{-5} \sin \theta = 1 \times 400 \times 10^{-9}$$

$$\theta = 0.46^\circ$$

$$s = 3 \times \tan(0.46) = 0.024 \text{ m}$$

Experiment B supports Einstein's particle, or photon model of light. This model can calculate the photon energy of incident light and explain why photons are emitted from calcium but not nickel:

$$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8}{400 \times 10^{-9}} = 7.50 \times 10^{14} \text{ Hz}$$

$$E = hf = 6.626 \times 10^{-34} \times 7.50 \times 10^{14} = 4.97 \times 10^{-19} \text{ J}$$

This energy is greater than the work function of calcium, explaining why one photon has enough energy to liberate a photoelectron from the calcium sample. However, this energy is less than the work function of nickel, explaining why no photoelectrons were observed from the nickel sample.

These observations support the particle model of light. Applying the particle model, the kinetic energy of photoelectrons emitted from calcium can be calculated:

$$K_{\max} = hf - \phi = 4.97 \times 10^{-19} - 4.60 \times 10^{-19} = 3.70 \times 10^{-20} \text{ J}$$

18. PHYSICS, M8 2019 HSC 34

Production of the sun's energy is predominantly done through the proton-proton chain. Four protons react in the sun's core to produce one helium atom. The mass of one helium atom is less than the mass of four protons, so mass is converted into energy through Einstein's mass-energy equivalence, $E = mc^2$.

◆◆ Mean mark 38%.

The sun acts as a black body and so radiates its energy in the form of black body radiation. It radiates energy as light with a variety of wavelengths, as shown in the black body curve above. It peaks at a specific wavelength which can be used to calculate its temperature:

$$\lambda_{\max} = 5.0 \times 10^{-7} \text{ m (see graph above)}$$

$$\lambda_{\max} = \frac{b}{T}$$

$$T = \frac{2.898 \times 10^{-3}}{5.0 \times 10^{-7}}$$

$$= 5796 \text{ K}$$

$$= 5800 \text{ K}$$

Energy radiated from the sun spreads out over a sphere as it travels away from the sun. The intensity of radiated energy decreases at distances further from the sun, consistent with the inverse square law.

Using the intensity of the sun's radiation at earth, its power output can be calculated:

$$P = IA$$

$$= I \times 4\pi r^2$$

$$= 1360 \times 4 \times 3.142 \times (1.5 \times 10^{11})^2$$

$$= 3.85 \times 10^{26} \text{ W}$$