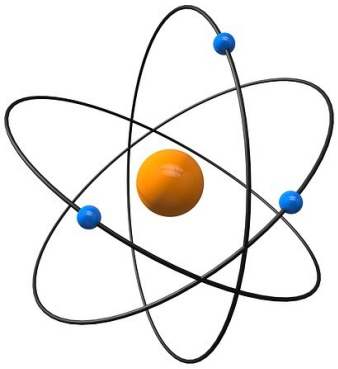
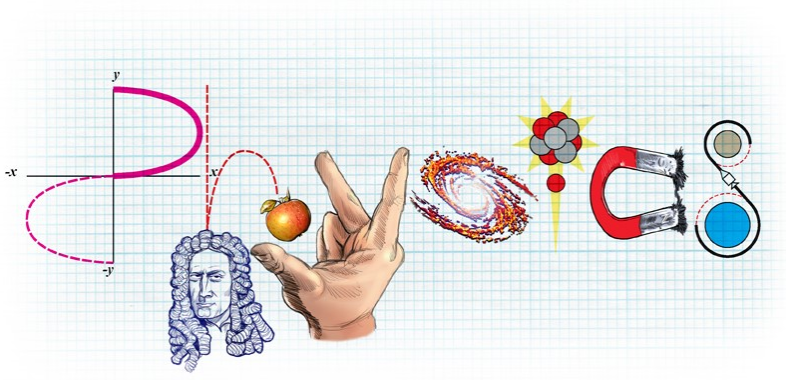
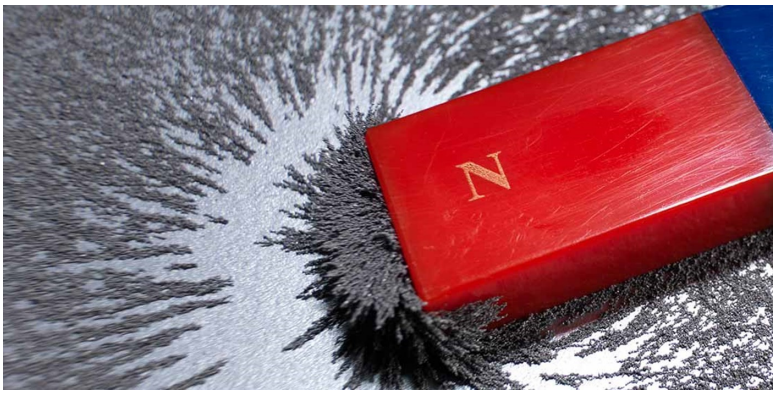
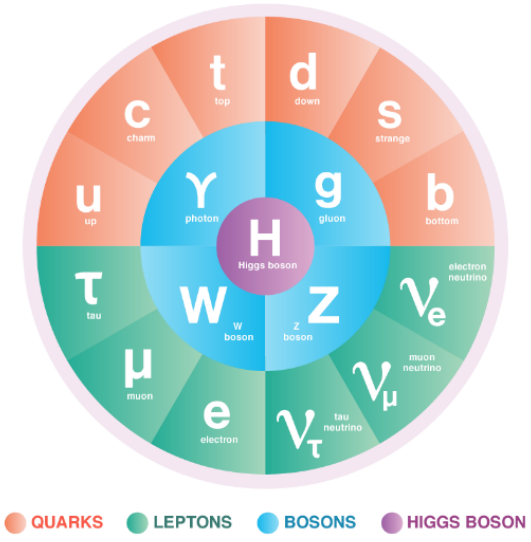


Higher Physics
Immersion Day
Challenging past paper questions







DATA SHEET

Speed of light in materials

Material	Speed in $m\,s^{-1}$
Air	3.0×10^8
Carbon dioxide	3.0×10^8
Diamond	1.2×10^8
Glass	2.0×10^8
Glycerol	2.1×10^8
Water	2.3×10^8

Gravitational field strengths

	Gravitational field strength on the surface in $N\,kg^{-1}$
Earth	9.8
Jupiter	23
Mars	3.7
Mercury	3.7
Moon	1.6
Neptune	11
Saturn	9.0
Sun	270
Uranus	8.7
Venus	8.9

Specific latent heat of fusion of materials

Material	Specific latent heat of fusion in $J\,kg^{-1}$
Alcohol	0.99×10^5
Aluminium	3.95×10^5
Carbon Dioxide	1.80×10^5
Copper	2.05×10^5
Iron	2.67×10^5
Lead	0.25×10^5
Water	3.34×10^5

Specific latent heat of vaporisation of materials

Material	Specific latent heat of vaporisation in $J\,kg^{-1}$
Alcohol	11.2×10^5
Carbon Dioxide	3.77×10^5
Glycerol	8.30×10^5
Turpentine	2.90×10^5
Water	22.6×10^5

Speed of sound in materials

Material	Speed in $m\,s^{-1}$
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Specific heat capacity of materials

Material	Specific heat capacity in $J\,kg^{-1}\,°C^{-1}$
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Ice	2100
Iron	480
Lead	128
Oil	2130
Water	4180

Melting and boiling points of materials

Material	Melting point in °C	Boiling point in °C
Alcohol	–98	65
Aluminium	660	2470
Copper	1077	2567
Lead	328	1737
Iron	1537	2737
Water	–	100

Radiation weighting factors

Type of radiation	Radiation weighting factor
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3
X-rays	1

$$d = vt$$

$$d = \bar{v}t$$

$$s = vt$$

$$s = \bar{v}t$$

$$a = \frac{v-u}{t}$$

$$F = ma$$

$$W = mg$$

$$E_w = Fd$$

$$E_p = mgh$$

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

$$Q = It$$

$$V = IR$$

$$V_2 = \left(\frac{R_2}{R_1 + R_2} \right) V_S$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

$$R_T = R_1 + R_2 + \ldots$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$

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

$$P = IV$$

$$P = I^2R$$

$$P = \frac{V^2}{R}$$

$$E_h = cm\Delta T$$

$$E_h = ml$$

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

$$p_1V_1 = p_2V_2$$

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{pV}{T} = \text{constant}$$

$$f = \frac{N}{t}$$

$$v = f\lambda$$

$$T = \frac{1}{f}$$

$$A = \frac{N}{t}$$

$$D = \frac{E}{m}$$

$$H = Dw_r$$

$$\dot{H} = \frac{H}{t}$$

1. A hot air balloon is moving vertically.

At a height of 50 m a sandbag is released.

The sandbag takes 3.0 s to reach the ground.

The effects of air resistance can be ignored.

The initial velocity of the sandbag on release is

A $2.0\ \text{m s}^{-1}$ upwards

B $2.0\ \text{m s}^{-1}$ downwards

C $17\ \text{m s}^{-1}$ upwards

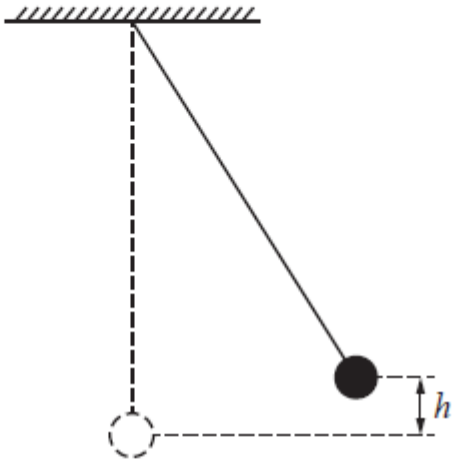
D $17\ \text{m s}^{-1}$ downwards

E $31\ \text{m s}^{-1}$ upwards.

H 2023 S1 Q2

2. A pendulum bob of mass m is released from rest at height h.

The bob reaches a speed v at the lowest point of its swing.



Neglecting air resistance, the speed of the bob at its lowest point is doubled by

A changing the height to $4h$

B changing the height to $2h$

C changing the height to $\frac{h}{2}$

D changing the mass of the bob to $2m$

E changing the mass of the bob to $\frac{m}{2}$.

H 2023 S1 Q4

3. A satellite of mass 620 kg is placed into an Earth orbit of radius 23 000 km.

The mass of the Earth is 6.0×10^{24} kg.

The gravitational force that the satellite experiences from the Earth in this orbit is

A 4.7×10^{2} N

B 4.7×10^{8} N

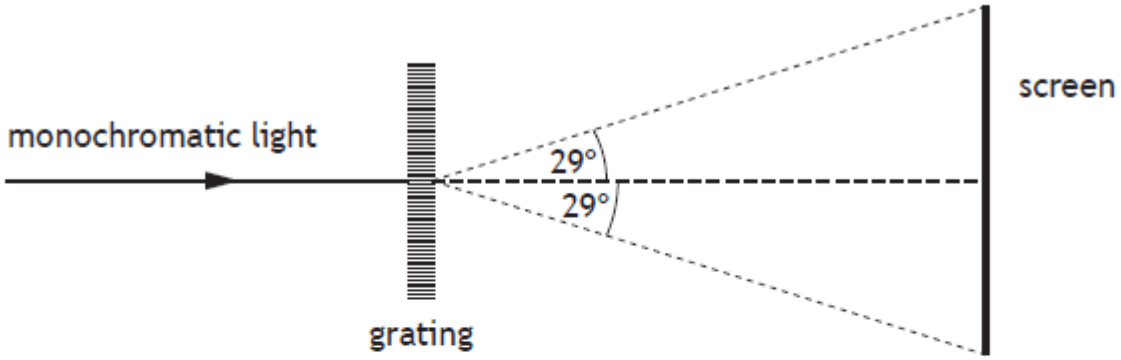
C 1.1×10^{10} N

D 1.1×10^{13} N

E 6.9×10^{13} N.

H 2023 S1 Q6

4. A ray of monochromatic light is incident on a grating. An interference pattern is observed on the screen.



The angle between the central maximum and the maximum observed at the edge of the screen is 29°.

The wavelength of the light is 605 nm.

The separation of the slits on the grating is 5.0×10^{-6} m.

The total number of maxima observed on the screen is

A 4

B 7

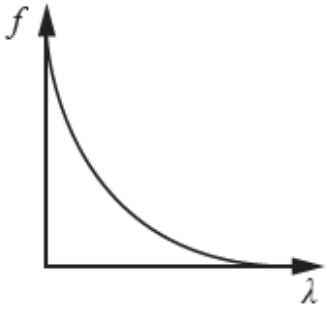
C 8

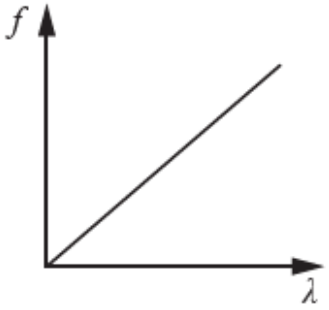
D 9

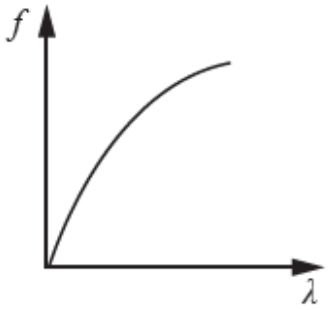
E 15.

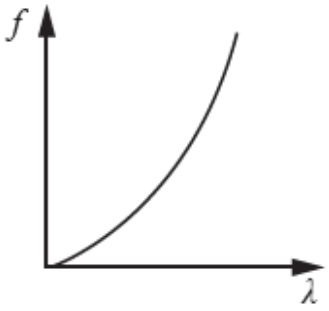
H 2023 S1 Q15

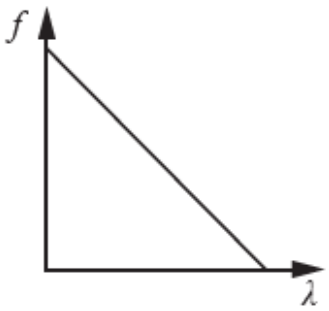
5. Which graph shows the relationship between frequency f and wavelength λ of photons of electromagnetic radiation?

A 

B 

C 

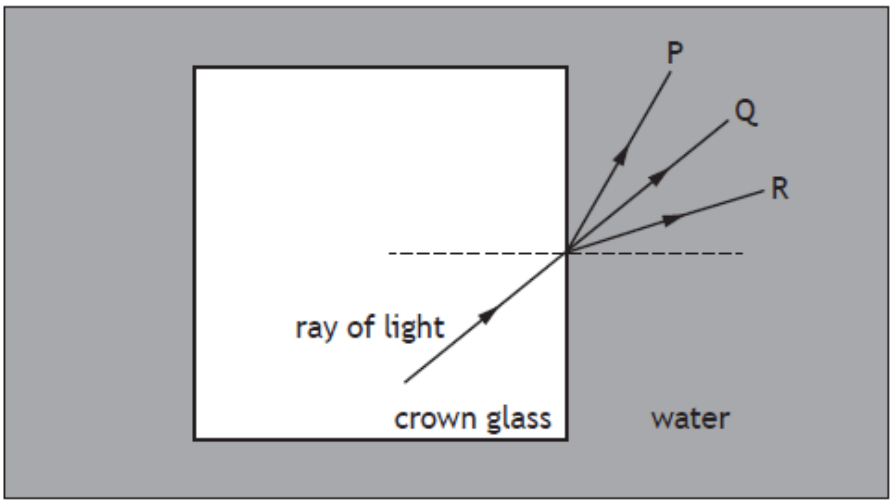
D 

E 

H 2023 S1 Q17

6. A ray of monochromatic light travels from a crown glass block into water.

The diagram shows three paths P, Q, and R for the ray of light in the water.

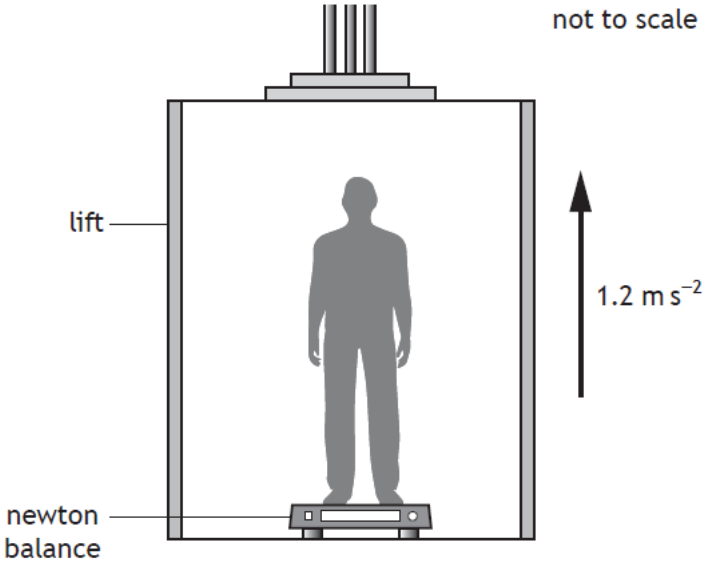


Which row in the table shows what happens to the speed and the wavelength, and the path the ray of light follows in the water?

	Speed	Wavelength	Path
A	decreases	decreases	R
B	decreases	decreases	P
C	stays the same	stays the same	Q
D	increases	increases	R
E	increases	increases	P

H 2023 S1 Q18

7. During an experiment a student inside a lift stands on a newton balance.



The mass of the student is 50.0 kg.

The lift accelerates upwards at 1.2 m s^{-2}.

The reading on the newton balance is:

A 60 N
B 430 N
C 490 N
D 550 N
E 590 N.

H 2022 S1 Q5

8. A proton consists of two up quarks and a down quark.

A student makes the following statements about protons:

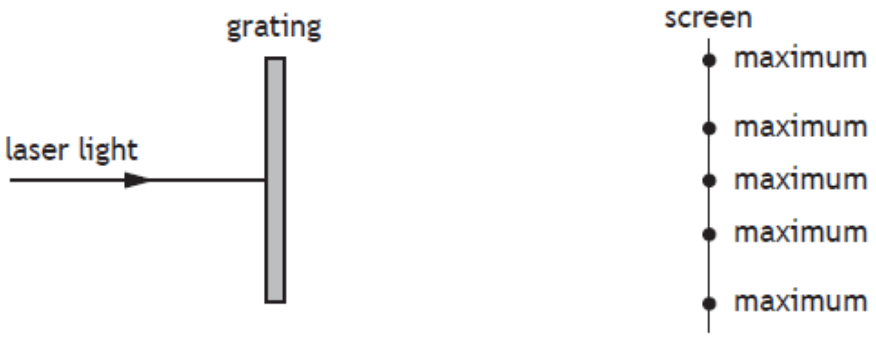
I Protons are baryons.
II Protons are hadrons.
III Protons are fermions.

Which of these statements is/are correct?

A I only
B II only
C III only
D I and II only
E I, II and III

H 2022 S1 Q12

9. Light from a laser is incident on a grating as shown.



A series of interference maxima are observed on the screen.

A student makes the following statements about the interference pattern observed on the screen:

I Increasing the distance between the grating and the screen increases the distance between the observed maxima.

II Increasing the distance between the laser and the grating increases the distance between the observed maxima.

III Decreasing the distance between the slits on the grating decreases the distance between the observed maxima.

Which of the statements is/are correct?

A I only

B II only

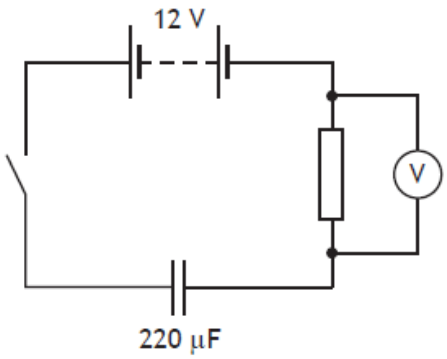
C I and III only

D II and III only

E I, II and III

H 2022 S1 Q16

10. A circuit is set up as shown.



The battery has negligible internal resistance.

The capacitor is initially uncharged.

The switch is now closed.

When the reading on the voltmeter is 7.0 V, the charge stored on the capacitor is:

A 3.1×10^{-5} C

B 4.4×10^{-5} C

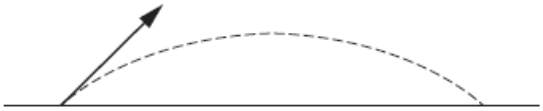
C 1.1×10^{-3} C

D 1.5×10^{-3} C

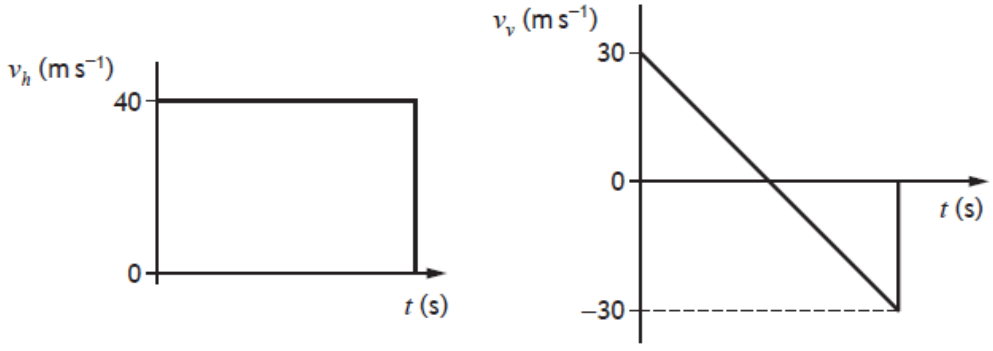
E 2.6×10^{-3} C.

H 2022 S1 Q16

11. A golfer strikes a golf ball, which then moves off at an angle to the ground. The ball follows the path shown.



The graphs show how the horizontal component of the velocity v_h and the vertical component of the velocity v_v of the ball vary with time t.



The speed of the ball just before it hits the ground is

A 10 m s^{-1}

B 30 m s^{-1}

C 40 m s^{-1}

D 50 m s^{-1}

E 70 m s^{-1}.

H 2019 S1 Q3

12 A student makes the following statements about an elastic collision.

I Total momentum is conserved.

II Total kinetic energy is conserved.

III Total energy is conserved.

Which of these statements is/are correct?

A I only

B II only

C I and II only

D I and III only

E I, II and III

H 2019 S1 Q6

13. A student makes the following statements about the Universe.

I The force due to gravity acts against the expansion of the Universe.

II Measurements show the rate of expansion of the Universe is increasing.

III The mass of a galaxy can be estimated by the orbital speed of the stars within the galaxy.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I, II and III

H 2019 S1 Q10

14. A student makes the following statements about the Standard Model.

I Every particle has an antiparticle.

II Alpha decay is evidence for the existence of the neutrino.

III The W-boson is associated with the strong nuclear force.

Which of these statements is/are correct?

A I only

B II only

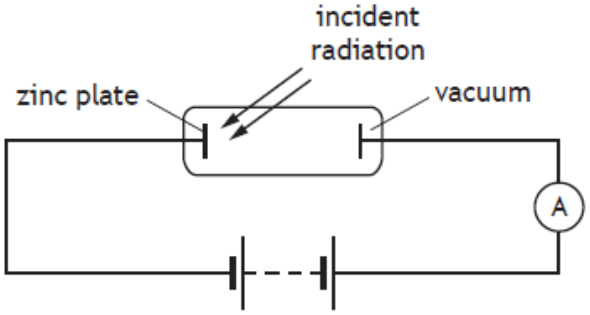
C III only

D I and II only

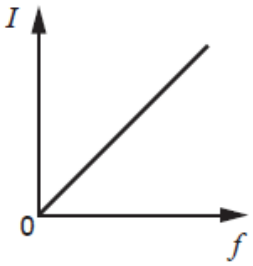
E I and III only

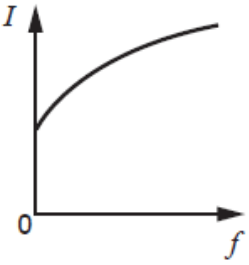
H 2019 S1 Q13

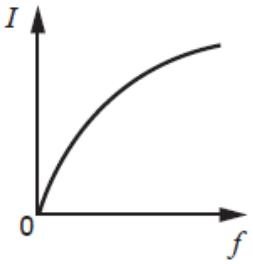
15. The diagram shows an experiment set up to investigate the photoelectric effect.
The frequency of the incident radiation is varied and the current in the circuit is measured.

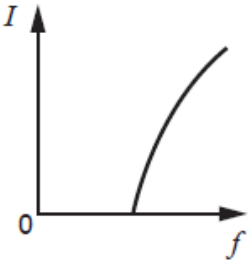


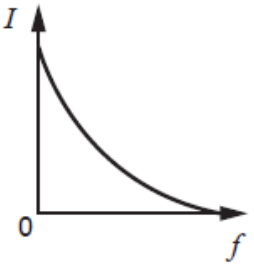
Which graph shows the relationship between the current I in the circuit and the frequency f of the incident radiation?

A


D


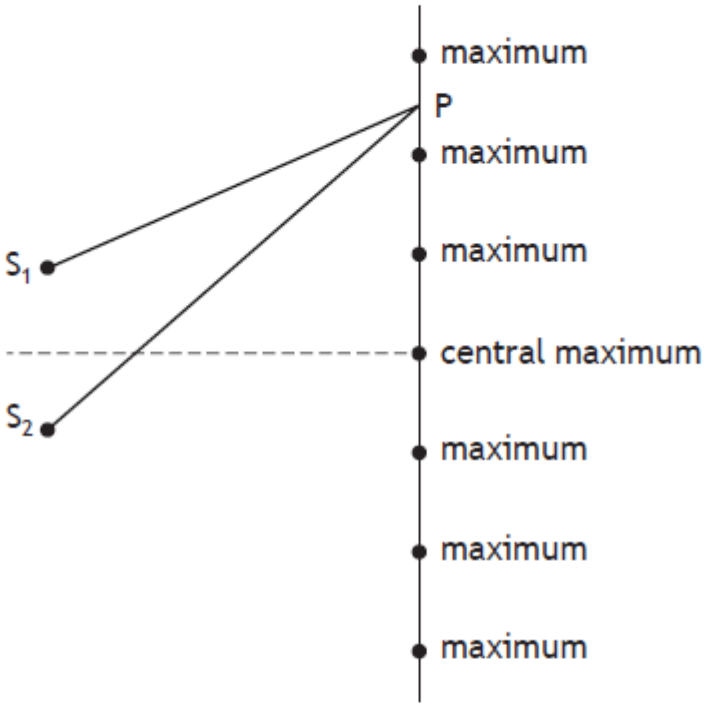
B


E


C


H 2019 S1 Q15

16. Waves from two coherent sources, S_1 and S_2, produce an interference pattern. Maxima are detected at the positions shown.



The wavelength of the waves is 28 mm.

For the third minimum at P the path difference ($S_2P - S_1P$) is

A 42 mm

B 56 mm

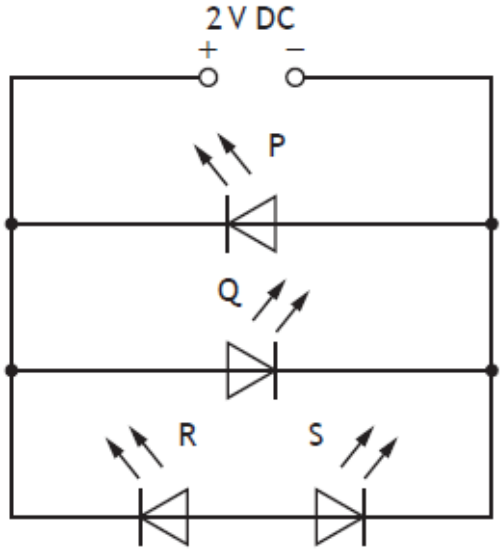
C 70 mm

D 84 mm

E 98 mm.

H 2019 S1 Q17

17. A student connects four identical light emitting diodes (LEDs) to a 2 V DC supply as shown.



Which of the LEDs P, Q, R, and S will light?

A P only
B Q only
C P and Q only
D P and R only
E Q and S only.

H 2019 S1 Q24

18. An adult with a child is cycling along a straight level path. The child is in a trailer, which is connected to the bike by a tow bar.

The combined mass of the bike and the adult is 85 kg.

The combined mass of the child and trailer is 28 kg.

The forward force on the bike and trailer is 125 N.

A frictional force of 45 N acts on the bike.

A frictional force of 15 N acts on the trailer.

(a) Show that the acceleration of the bike and trailer is 0.58 $m\,s^{-2}$. 2

(b) Determine the magnitude of the tension in the tow bar. 4

(c) As the speed of the bike and trailer increases, the friction forces on both the bike and the trailer increase.

The acceleration of the bike and trailer remains 0.58 $m\,s^{-2}$.

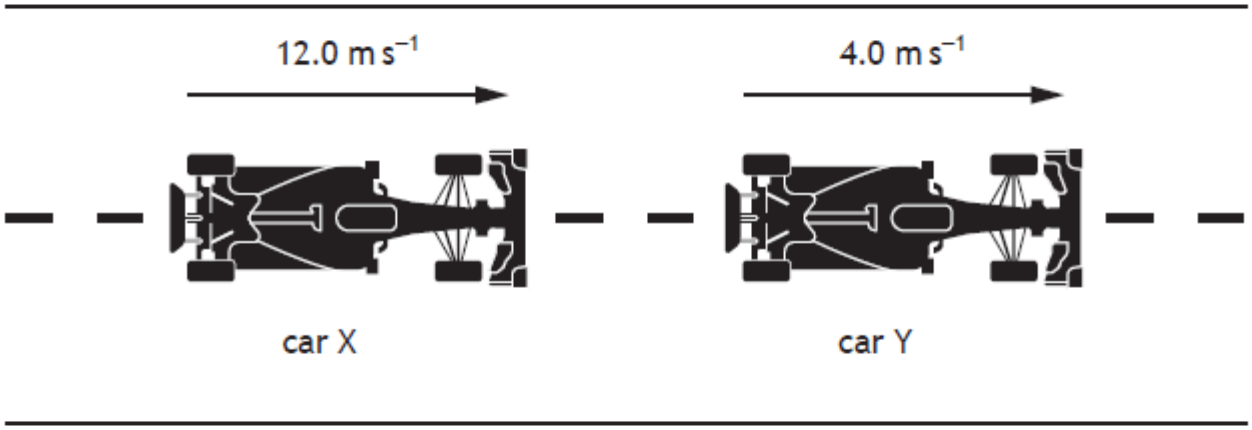
State whether the tension in the tow bar increases, decreases, or stays the same.

Justify your answer. 2

19 During a practice session for a Grand Prix, two Formula 1 cars collide in the pit lane.

Car X has a mass of 760 kg and is travelling at 12.0 $m\,s^{-1}$.

Car Y has a mass of 840 kg and is travelling at 4.0 $m\,s^{-1}$.



The cars collide and move off separately.

Car Y moves off with a velocity of 8.5 $m\,s^{-1}$.

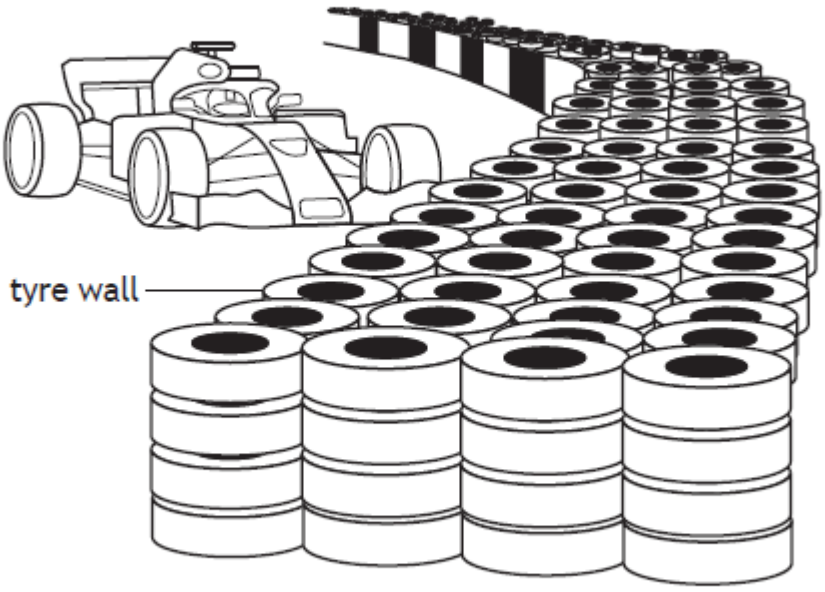
(a) Calculate the velocity of car X immediately after the collision. 3

(b) Show by calculation that the collision is inelastic. 4

(c) During the collision, the cars are in contact for 0.82 s.

Calculate the magnitude of the average force car X exerts on car Y. 3

(d) One safety feature on Formula 1 racetracks is the use of tyre walls on bends. Tyre walls are designed to protect the driver in the event of their car leaving the track.



Explain how tyre walls protect the driver. 2

20.

A person is standing at the side of a road. A police car approaches and then passes the person at a constant speed of 31 $m\,s^{-1}$. A siren on the police car emits sound with a frequency of 440 Hz.

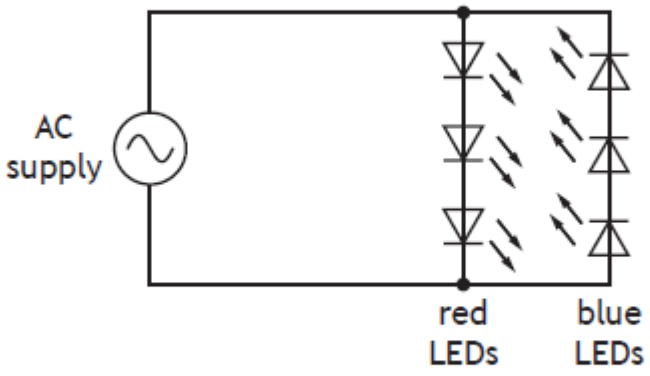
(a) (i) Calculate the frequency of the sound heard by the person as the police car approaches.

The speed of sound in air is 340 $m\,s^{-1}$. 3

(ii) State whether the frequency of the sound heard by the person as the police car moves away is greater than, the same as, or less than the frequency heard by the person as the police car approached.

You must justify your answer. 2

(b) The emergency lights on top of the police car consist of an array of red LEDs and blue LEDs. A simplified diagram of the lighting circuit is shown.



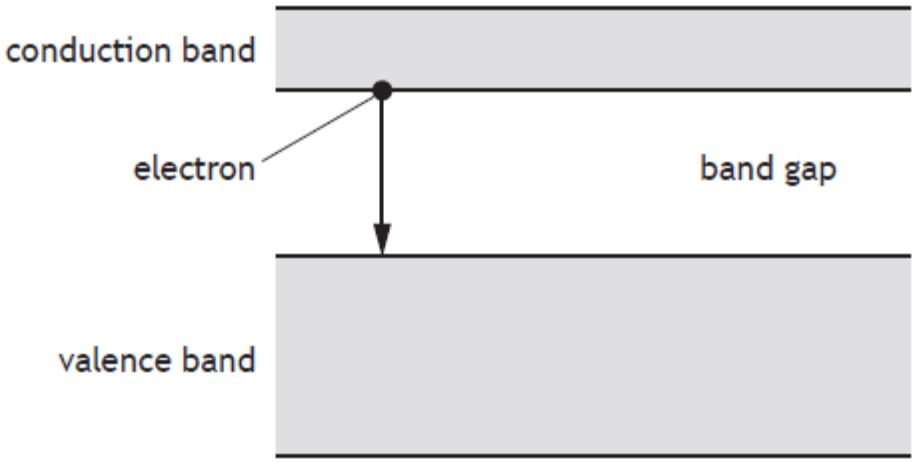
The red LEDs and blue LEDs each flash twice per second.

(i) Determine the period of the AC supply used. 1

(ii) Explain why the red LEDs and the blue LEDs do not light at the same time. 2

(b) (continued)

(iii) An energy band diagram for a red LED is shown.



A photon of wavelength 625 nm is emitted when an electron falls from the conduction band to the valence band, across the energy band gap.

(A) Determine the energy of the emitted photon. 4

(B) Explain, in terms of the energy band gaps, the difference between photons emitted by the red LEDs and photons emitted by the blue LEDs. 2

H 2023 S2 Q5

21.

A student carries out an experiment to verify the inverse square law for a point source of light.

(a) Describe an experiment to verify the inverse square law for a point source of light. 2

(b) The student records the following data from their experiment.

Distance d (m)	0.200	0.300	0.400	0.500	0.600
Irradiance I ($W\,m^{-2}$)	142.0	63.1	35.5	22.7	15.8

(i) State what is meant by the term *irradiance*. 1

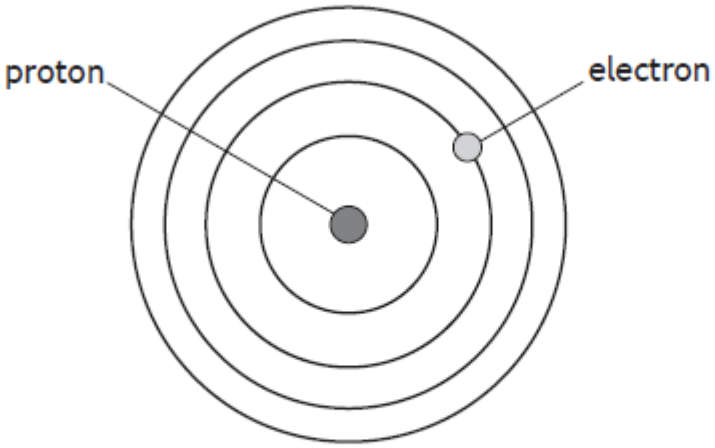
(ii) Use all the data to establish the relationship between irradiance I and distance d. 3

(c) Explain why the irradiance decreases when the distance from a point source of light increases. 2

H 2023 S2 Q8

22.

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



(a) One of the features of the Bohr model of the hydrogen atom is that the electron can only occupy discrete energy levels.

State one other feature of the Bohr model of the hydrogen atom. 1

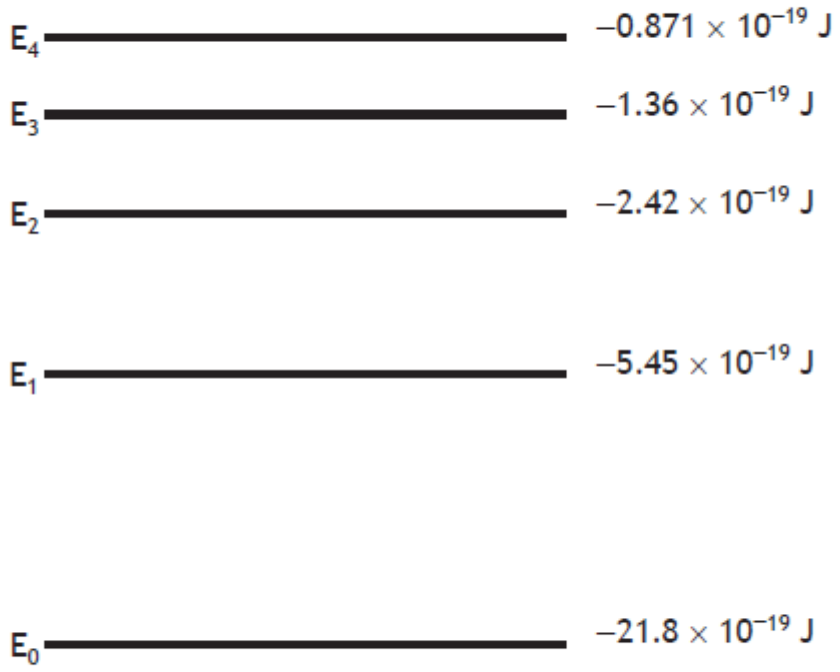
(b) The line emission spectrum from a hydrogen discharge lamp has four lines in the visible region of the electromagnetic spectrum, as shown.

(i) Explain how a line emission spectrum is produced. 2

(ii) Explain why some of these lines appear brighter than others. 2

(continued)

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



(i) State the number of possible emission lines caused by the transition of electrons between the energy levels shown. 1

(ii) (A) One of the emission lines produced is due to electron transitions from E_4 to E_1.

Calculate the frequency of the photon emitted when an electron makes this transition. 3

(B) The photons produced by a different electron transition correspond to the blue-green spectral line in the hydrogen emission spectrum.

State the wavelength of these photons. 1

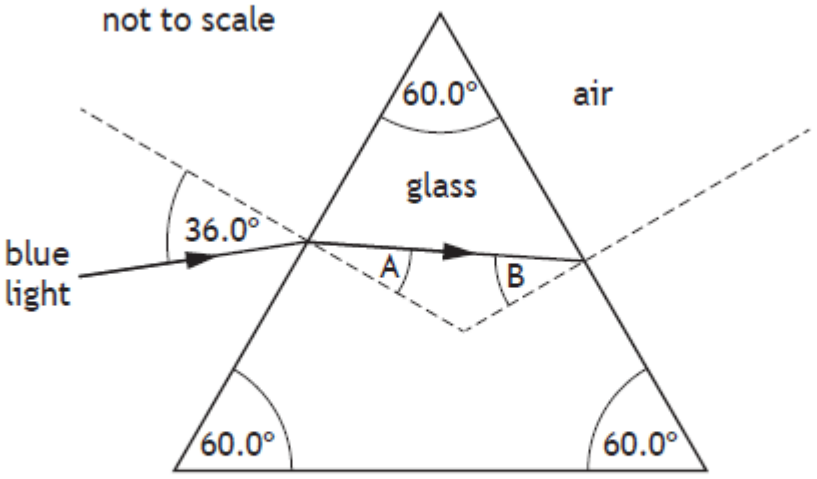
(C) A distant galaxy has a recessional velocity of 4.52×10^6 m s^{-1}.

The hydrogen emission spectrum from the distant galaxy is viewed on Earth.

Determine the observed wavelength of the same spectral line as in (c) (ii) (B), when viewed on Earth. 5

23.

A ray of blue light is incident on a triangular glass prism as shown.



The refractive index of the glass for this blue light is 1.53.

(a) (i) Calculate angle A. 3

(ii) Determine angle B. 2

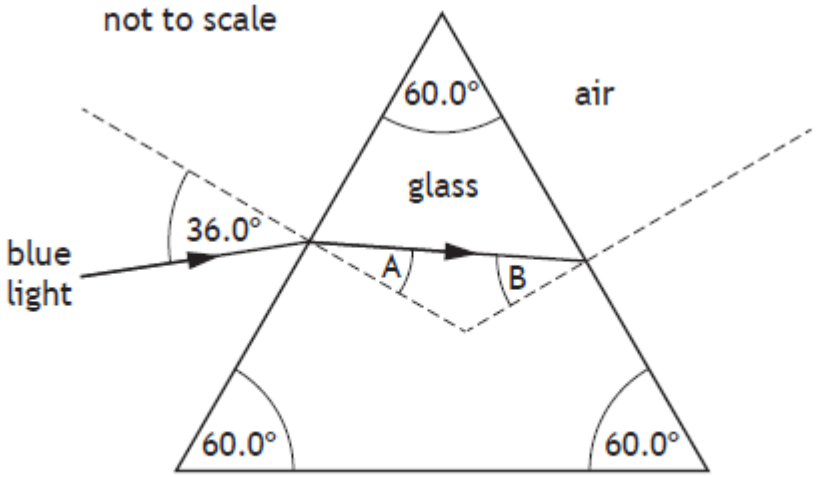
(b) (i) State what is meant by the term *critical angle*. 1

(ii) Calculate the critical angle for this blue light in the glass prism. 3

(c) Complete the diagram below to show the path of the ray after it is incident on the glass-air boundary at the right-hand side of the prism.

Mark on the diagram the value of the angle between this ray and the normal after it is incident on this glass-air boundary. 3

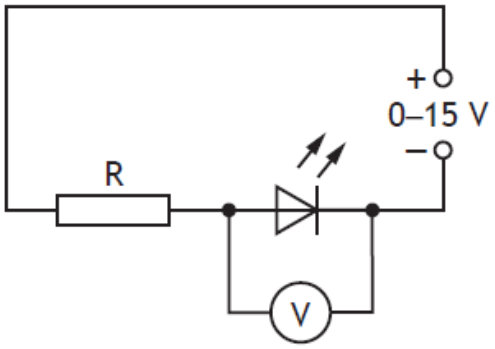
(An additional diagram, if required, can be found on *page 43*.)



24.

A student carries out an experiment to determine the value of Planck's constant h, using various LEDs.

An LED that produces light of known frequency f is connected into the circuit as shown.



The student adjusts the voltage output of the variable power supply until they see the LED start to emit light.

The student records the potential difference across the LED at this point. This is the switch-on voltage V of the LED.

The student repeats this procedure using a number of LEDs, each producing light of a different known frequency.

To determine a value for Planck's constant, the student uses the relationship

$$eV = hf$$

where e is the charge on an electron.

The results obtained by the student are shown in the table.

f ($\times 10^{14}$ Hz)	V (V)
4.5	1.38
5.0	1.62
5.1	1.65
5.3	1.74
6.4	2.32

(a) Using the square-ruled paper on *page 40*, draw a graph of V against f. 3

(continued)

(b) Calculate the gradient of your graph. 2

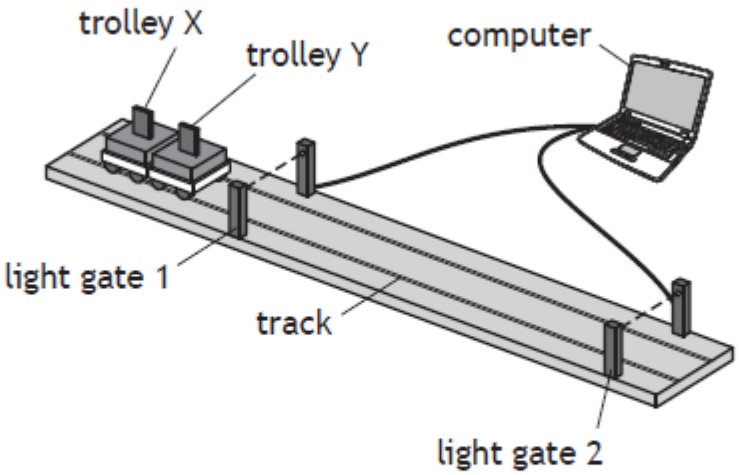
(c) Using the gradient of your graph, determine a value for Planck's constant h. 2

(d) Suggest one improvement to the experiment the student could make that would improve the accuracy of their final result. 1

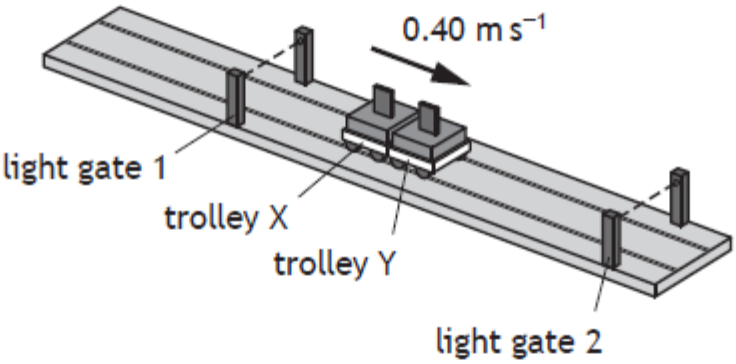
H 2023 S2 Q14

25. A student sets up an experiment to investigate the interaction between two trolleys on a smooth, horizontal track.

The mass of trolley X is 0.50 kg and the mass of trolley Y is 0.25 kg.



The trolleys X and Y are moving together to the right at 0.40 m s^{-1}.

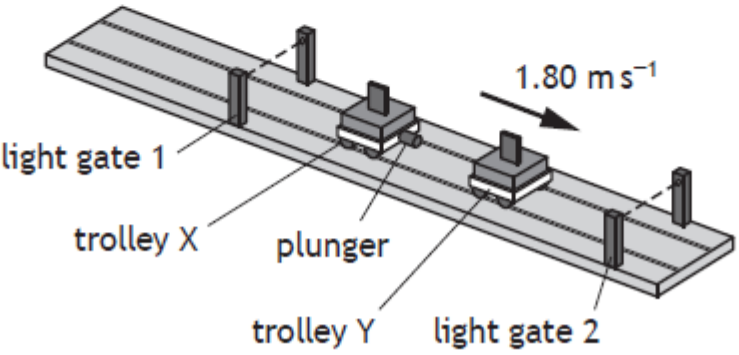


When the trolleys are between the light gates, a plunger in trolley X is activated.

The plunger extends and pushes trolley Y with an average force of 6.25 N for a short time, so that the trolleys separate.

Trolley Y now moves to the right at 1.80 m s^{-1}.

The effects of friction are negligible.



(continued)

(a) (i) Calculate the magnitude of the change in momentum of trolley Y when the plunger is activated. 3

(ii) Calculate the time during which the plunger exerts a force on trolley Y. 3

(b) Calculate the velocity of trolley X immediately after the trolleys separate. 3

(c) Explain how the student would determine whether this interaction was elastic. 2

(d) The light gates used during the experiment each contain a lamp and a photodiode.

A photodiode is a p-n junction.

(i) A photodiode produces a potential difference when photons of light are incident on it.

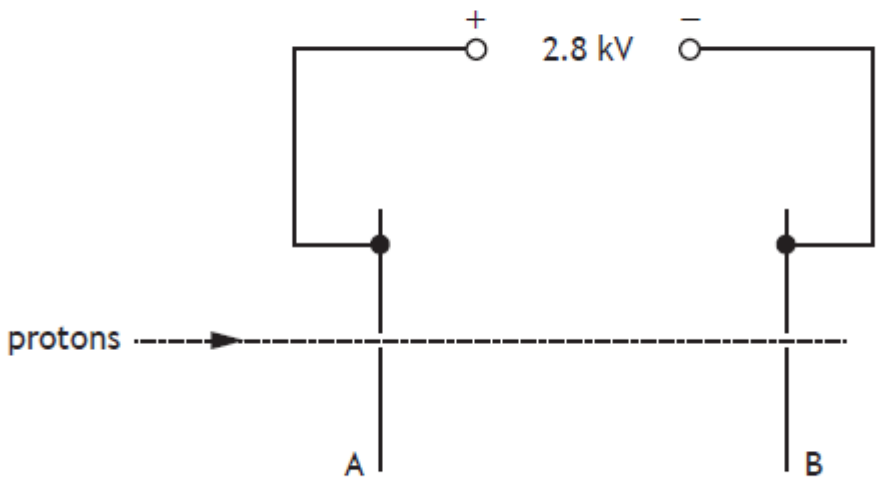
State the name of this effect. 1

(ii) Light from the lamp is incident on the photodiode.

Using **band theory**, explain how a potential difference is produced when photons of light are incident on the photodiode. 3

26 Protons are accelerated by an electric field between metal plates A and B, in a vacuum.

Part of the apparatus used is shown.



(a) Explain why the protons are accelerated by the electric field. 2

(b) (i) A proton is travelling at a speed of 3.8×10^5 m s^{-1} at plate A.

Show that the kinetic energy of the proton at plate A is 1.2×10^{-16} J. 2

(ii) The potential difference between plates A and B is 2.8 kV.

Calculate the work done on the proton as it accelerates from plate A to plate B. 3

(iii) Determine the speed of the proton at plate B. 4

(c) The distance between plates A and B is now doubled.

The potential difference between plates A and B is unchanged.

Another proton, with the same initial speed at plate A, is accelerated between the plates.

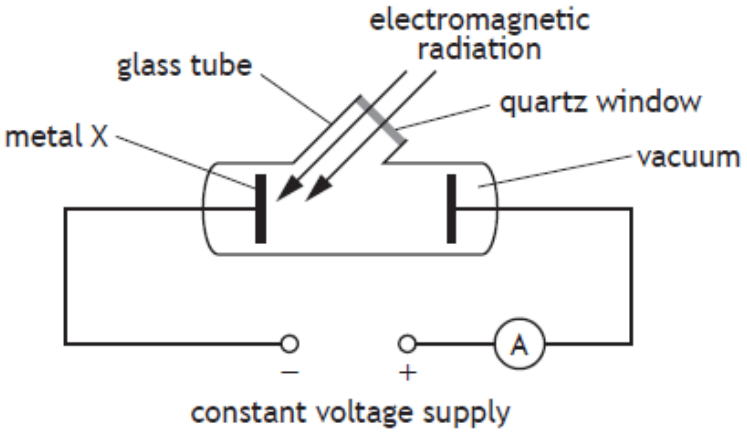
State what effect, if any, this has on the speed of the proton at plate B.

You must justify your answer. 2

H 2022 S2 Q7

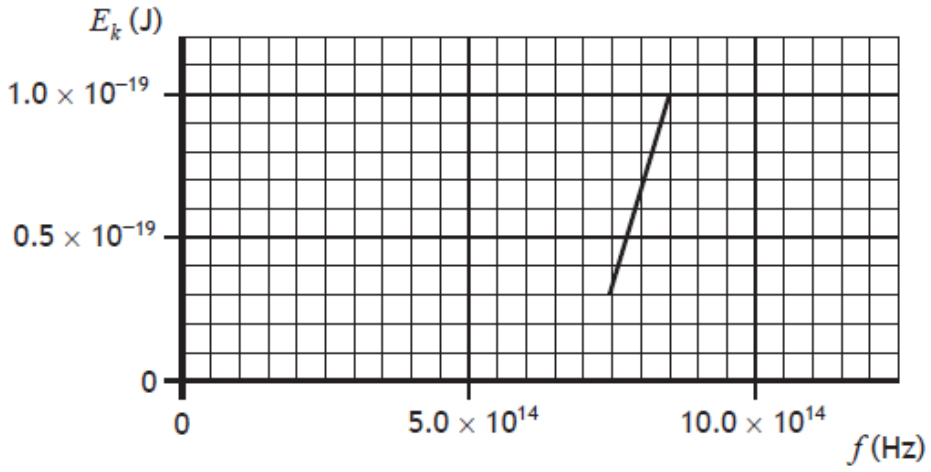
27. The apparatus shown is used to investigate photoemission.

Electromagnetic radiation is incident on metal X.



(a) The frequency of the electromagnetic radiation is varied. The maximum kinetic energy of the photoelectrons emitted from metal X is determined for a range of frequencies.

The graph shows how the maximum kinetic energy E_k of the photoelectrons varies with frequency f.



Using the graph, determine the threshold frequency f_0 of metal X. 1

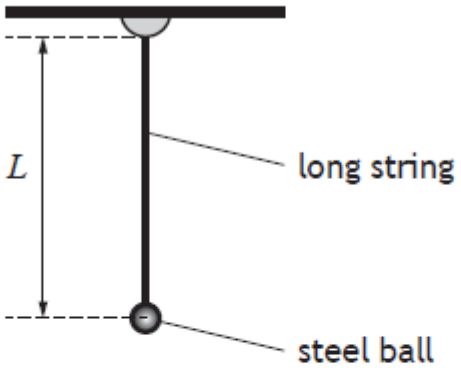
(b) The work function of different metals is shown in the table.

Metal	Work function (J)
Potassium	3.7×10^{-19}
Calcium	4.6×10^{-19}
Zinc	5.8×10^{-19}
Gold	8.5×10^{-19}

Identify which of these metals is metal X.

Justify your answer by calculation. 4

28. A student carries out an investigation to determine the gravitational field strength on Earth, using a simple pendulum.



A long string has a steel ball attached to the end of it. The length L of the pendulum can be adjusted.

The ball is raised through a small angle and then released.

The student records the time for ten complete swings and uses this to determine a value for the period T of the pendulum. The student then determines the value of T^2.

The student repeats the experiment for different lengths.

The results are shown in the table.

L (m)	T^2 (s^2)
0.20	0.85
0.40	1.60
0.60	2.50
0.80	3.40
1.10	4.55

The gravitational field strength g can be determined using

$$\frac{T^2}{L} = \frac{4\pi^2}{g}$$

(a) Using the square-ruled paper on *page 46*, draw a graph of T^2 against L. 3

(The table of results is also shown on *page 47*, opposite the square-ruled paper.)

(continued)

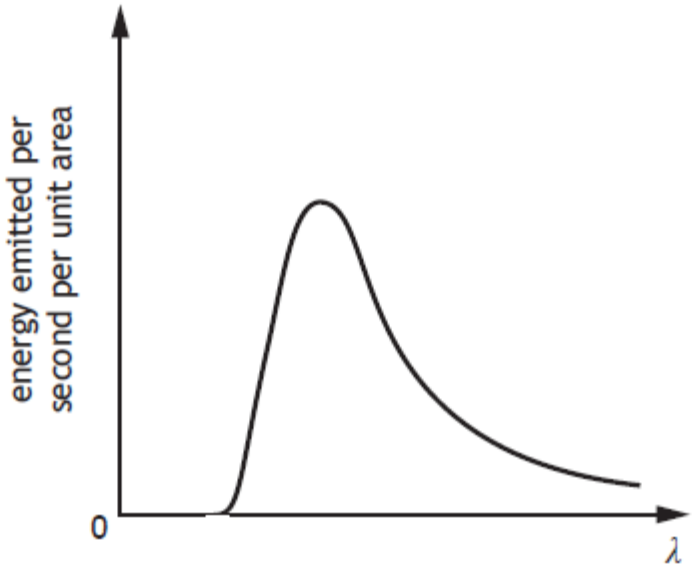
(b) Calculate the gradient of your graph. 2

(c) Using the gradient of your graph, determine the gravitational field strength g. 2

H 2022 S2 Q14

29. Stars emit radiation with a range of wavelengths. The peak wavelength of the radiation depends on the surface temperature of the star.

(a) The graph shows how the energy emitted per second per unit area varies with the wavelength λ of the radiation for a star with a surface temperature of 5000 K.



A second star has a surface temperature of 6000 K.

On the graph above, add a line to show how the energy emitted per second per unit area varies with the wavelength λ of the radiation for the second star. 2

(b) The table gives the surface temperature T, in kelvin, of four different stars and the peak wavelength λ_{peak} of radiation emitted from each star.

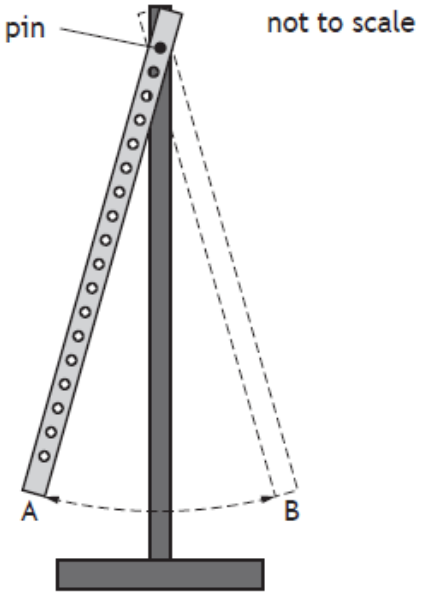
T (K)	λ_{peak} (m)
7700	$3{\cdot}76 \times 10^{-7}$
8500	$3{\cdot}42 \times 10^{-7}$
9600	$3{\cdot}01 \times 10^{-7}$
12 000	$2{\cdot}42 \times 10^{-7}$

Use all the data in the table to show that the relationship between the surface temperature T of a star and the peak wavelength λ_{peak} radiated from the star is 3

$$T = \frac{2{\cdot}9 \times 10^{-3}}{\lambda_{peak}}$$

H 2019 S2 Q6

30. A 1·00 m long wooden rod has a series of small holes drilled at 10 mm intervals along its length. The rod is hung on a horizontal pin passing through a hole 50 mm from one end.



The rod is then raised through a small angle and released.

The period T is the time for the rod to travel from A to B and back to A.

(a) Describe a method to obtain an accurate value for the period T using only a stopwatch. 2

(b) The rod is hung from different holes in turn, and the distance h from the pin to the midpoint of the rod is recorded.

T is determined for each value of h. The results are shown in the table.

h (m)	T (s)
0·45	1·60
0·40	1·56
0·35	1·54
0·30	1·53
0·25	1·53
0·22	1·55
0·20	1·58

(i) Using the square-ruled paper on *page 41*, draw a graph of T against h. 3

(ii) Using your graph, state the two values of h that produce a period of 1·57 s. 1

(iii) (A) Using your graph, estimate the minimum period T. 1

(B) Suggest an improvement to the experimental procedure that would allow a more precise value for the minimum period T to be determined. 1

(c) The quantities T and h are related by the relationship

$$T^2h = \frac{4\pi^2h^2}{g} + C$$

where g is the gravitational field strength and C is a constant.

Use data from the table on *page 40* to calculate a value for C when h is 0·30 m.

A unit is not required. 2

H 2019 S2 Q15