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External Assessment 2021

PHYSICS

PHY415115

Part 1 Newtonian Physics

Pages	12
Questions	6
Information Sheet	1

Reading time: 15 minutes – you may begin writing during this time

Suggested working time: 45 minutes

Instructions

- Attempt **all** questions and **all** parts within each question.
- Write your answers in the spaces provided in this exam paper.
  - Spare diagrams have been provided at the end of the exam booklet. Indicate in the box provided if you have used the spare diagrams.
- A TASC approved scientific calculator can be used throughout the exam.
  - Show your workings in answers to numerical questions. No marks can be given for incorrect answers unless they are accompanied by details of the working.
  - The appropriate units must be included.
- All answers must be written in **English**.

- You **must** make sure your answers address:

  - Criterion 5 identify and apply principles of Newtonian mechanics including gravitational fields.

Marker use	
C5	40

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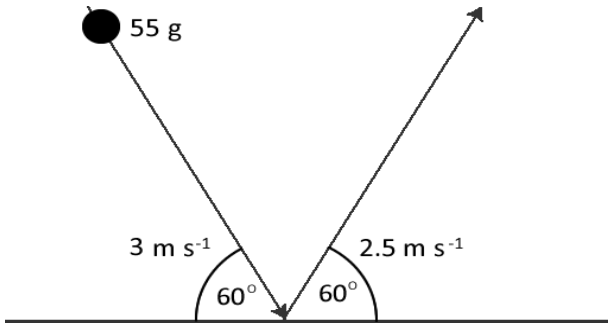
Guide to Exam Structure

	Questions available	How many questions to answer	Suggested working time	Marks available
Part 1	6	6	45 minutes	40 marks
Part 2	5	5	45 minutes	40 marks
Part 3	6	6	45 minutes	40 marks
Part 4	5	5	45 minutes	40 marks
Totals	**22**	**22**	**180 minutes (3 hours)**	**160**

Question 1

Marker use

A ball of mass 55.0 g bounces off the ground as below. It strikes the ground at 3.00 m s^{-1} at an angle of 60° to the surface and leaves at 2.50 m s^{-1} at 60° to the surface. The time of contact with the ground is 1.00 x 10^{-2} s.



a) Draw a suitable vector diagram allowing the change in momentum of the ball to be calculated.

3

b) Calculate the **magnitude** of the change in momentum of the ball.

3

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c) Calculate the **magnitude** of the force on the ball.

1

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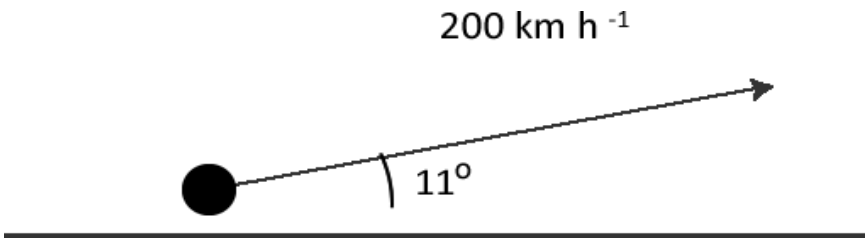
Total Q1

7

Question 2

Marker use

In the future on Mars, where g = 3.72 m s^{-2}, the first settlers are desperate to play golf! At great expense golf clubs and balls are sent from Earth and a golf course is created.



A typical golf ball struck from the tee flies at 200 km h^{-1} at an angle of 11° on level ground.

a) Calculate the vertical and horizontal components of the ball in m s^{-1}.

1

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b) Calculate the time the ball is above the ground.

2

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c) Calculate the distance travelled by the ball.

1

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d) This distance is much greater than on Earth, ignoring the effects of air. Explain why this should be so.

2

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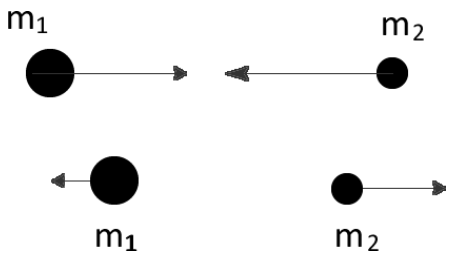
Total Q2

6

Question 3

Marker use

Newton's second and third laws are both associated with change in momentum. From them, Newton derived the principle of conservation of linear momentum.



Consider two masses, m_1, m_2, colliding head on and then rebounding. Their contact time is Δt. m_1 undergoes a velocity change of Δv_1 and m_2 undergoes a velocity change of Δv_2.

Using the notation above:

a) Give the formula of the unbalanced force, F_1, on m_1 while in contact. **1**

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b) Give the formula of the unbalanced force F_2 on m_2 while in contact. **1**

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c) How are a) and b) related? **1**

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d) Show from your answer to c) that momentum is conserved in the collision. **2**

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Total Q3

5

TASC ID:

PHY415115 PHYSICS
QUESTION 4 REPLACEMENT

Marker use

Ingenuity

The helicopter Ingenuity on Mars has a mass of 1.80 kg. Gravity on Mars' surface has a value of 3.72 m s^{-2}. The density of the Martian air is only 2.00 x 10^{-2} kg m^{-3}.

Ingenuity has counterrotating rotors of radius 0.6 m as in the picture.

a) What minimum downward force must the rotors exert on the Martian air for Ingenuity to fly? Justify your answer.

2

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b) If the average speed of the downward air column produced by the rotors is 17.2 m s^{-1} , show that the mass of air forced down by the rotors each second is about 0.4 kg s^{-1}.

2

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Question 4 continues

Question 4 continued

Marker use

c) Show that the work done per second to accelerate this mass of air is about 60 W.

1

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The batteries of Ingenuity enable a 90 second flight while the motor is operating at 350 W.

d) What is the total energy available from the batteries?

1

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e) What percentage of this energy is given to the air?

1

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Question 5

Marker use

In 1665, Newton compared the acceleration of an apple falling to Earth from a tree to the acceleration of the moon towards Earth.

a) The moon orbits Earth in 27.3 days at a radial distance of 3.84×10^8 m. Calculate the centripetal acceleration of the moon in orbit. **3**

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The radius of Earth is 6.37×10^6 m. The acceleration of an object falling close to Earth's surface is 9.81 m s^{-2}.

b) Show that an inverse square law of gravity correctly predicts the acceleration of the moon. **3**

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c) Knowing the value of G = 6.67×10^{-11} N m^2 kg^{-2}, calculate the mass of Earth. **3**

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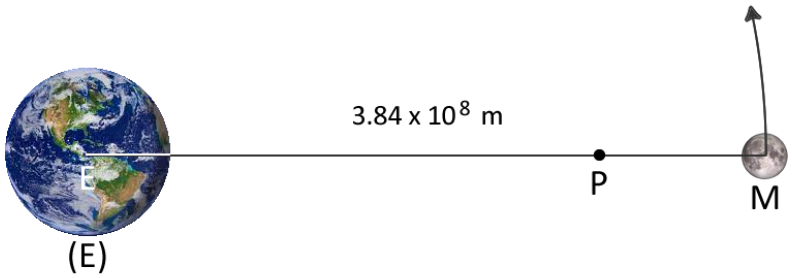
Total Q5

9

Question 6

Marker use



Spare diagram used (✓)

☐

On the diagram above of the Earth–moon system, P is a point 3.46 x10^8 m from the centre of Earth.

a) Calculate the total gravitational field strength of the Earth–moon system at P.

3

M_{Earth} = 5.97 x 10^{24} kg M_{Moon} = 7.34 x 10^{22} kg Orbital radius of moon = 3.84 x 10^8 m

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b) On the diagram above, sketch the total gravitational field around the Earth–moon system.

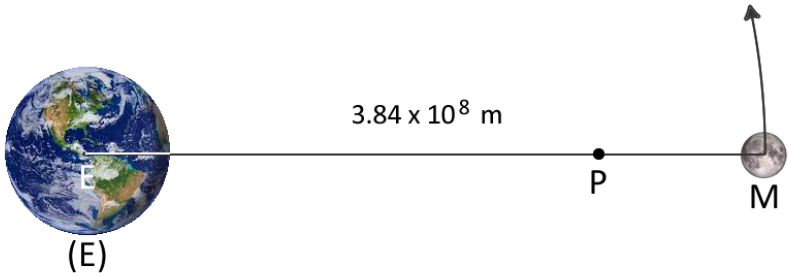
3

Total Q6

6

Spare Diagram

Question 6 b)



End of Part 1

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External Assessment 2021

PHYSICS

PHY415115

Part 2 Electromagnetism

Pages	16
Questions	5
Information Sheet	1

Suggested working time: 45 minutes

Instructions

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  - The appropriate units must be included.
- All answers must be written in **English**.

- You **must** make sure your answers address:
  - Criterion 6 identify and apply principles and theories of electricity and magnetism.

Marker use	
C6	40

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Guide to Exam Structure

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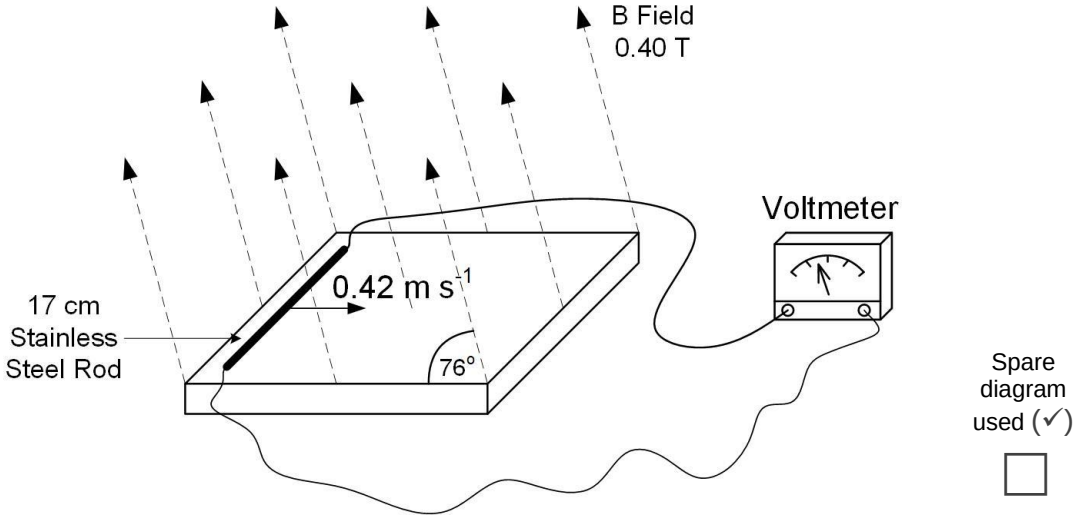
Part 1	6	6	45 minutes	40 marks
Part 2	5	5	45 minutes	40 marks
Part 3	6	6	45 minutes	40 marks
Part 4	5	5	45 minutes	40 marks
Totals	**22**	**22**	**180 minutes (3 hours)**	**160**

Question 7

Marker use

A 17 cm long stainless steel rod moves along a flat surface with a constant velocity of 0.42 m s^{-1}. A magnetic field of 0.40 T exists that is directed 76° from vertical.



Spare diagram used (✓) ☐

When both ends of the conductor are connected to a voltmeter a constant EMF is observed.

a) Calculate the EMF produced. **2**

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b) Clearly mark on the above diagram which end of the rod is positive. **1**

The voltmeter is replaced by an ammeter. A current of 0.045 A is observed when the velocity of the rod is at a constant 0.42 m s^{-1}.

c) What horizontal force is applied to the rod? **2**

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Question 7 continues

Marker use

2

d) The stainless steel rod, which is relatively poor conductor of electricity, was replaced with the highly conductive silver rod. The silver rod is moved through the field at the same velocity of 0.42 m s^{-1}. Will the applied force on the silver rod be the same or different to the applied force on the stainless steel rod? Justify your reasons.

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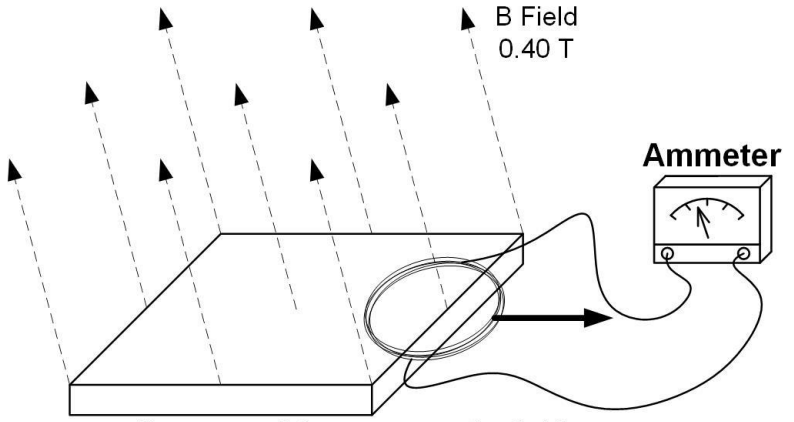
As shown in the diagram below a metal coil was placed in the uniform magnetic field. No current was noted when the coil was stationary or moving <u>within</u> the uniform magnetic field. However, as the coil is removed from the magnetic field a current is briefly noted.



Coil removed from magnetic field

Spare diagram used (✓) ☐

e) Mark on the diagram above the direction of the induced current in the coil when it is removed from the field. Explain using physics principles.

3

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Total Q7

10

Question 8

Marker use

A build up of static charge occurs on helium filled weather balloons as they rise through the atmosphere.

a) How might this charge build up on the balloons?

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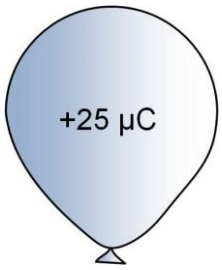
1

One such balloon has a radius of 1.5m and a charge of +25 μC.

b) On the image below, sketch the electric field lines around the balloon.

1



Spare diagram used (✓)

☐

c) Calculate the electric field strength near the surface of the balloon.

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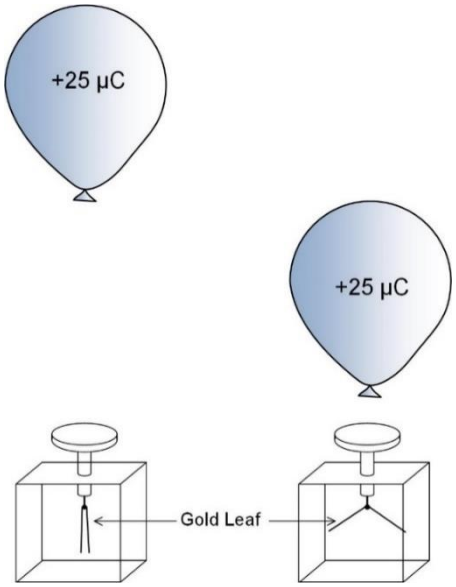
1

Question 8 continues

Marker use

d) When the balloon is brought near (but not touching) a gold leaf electroscope, as in the diagram below, the gold leaves separate. With the aid of a diagram, explain why the gold leaves separate when a charged object approaches the electroscope.



3

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e) The balloon was brought close enough to touch the electroscope and then moved away. What effect would this have on the gold leaves?

1

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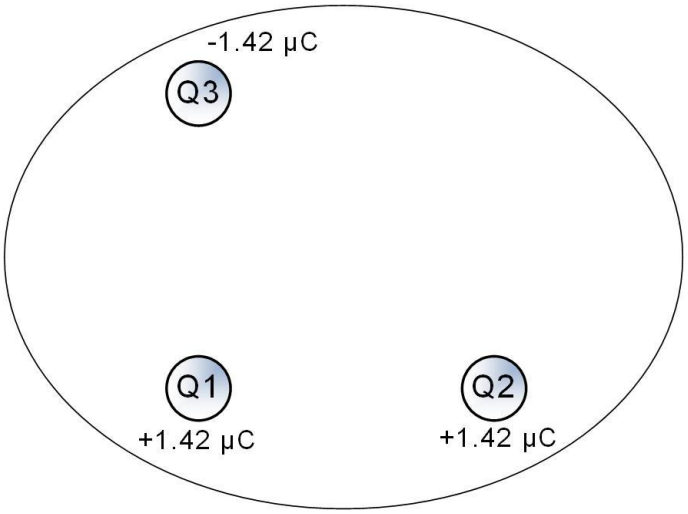
Total Q8

7

Question 9

Marker use

Three point-charges are in an evacuated flask as indicated below. Q1 and Q2 have a charge of +1.42 μC and are 11 cm apart horizontally. Q3 has a charge of -1.42 μC and is 11 cm vertically above Q1.



Spare diagram used (✓) ☐

a) Show the magnitude of the force on Q3 from Q1 is 1.5 N and on Q3 from Q2 is 0.75 N. /3

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b) On the diagram above, sketch the force vectors acting on Q3 from both Q1 and Q2. /1

c) Determine the **magnitude** of the resultant force on Q3 from Q1 and Q2. /2

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Total Q9 /6

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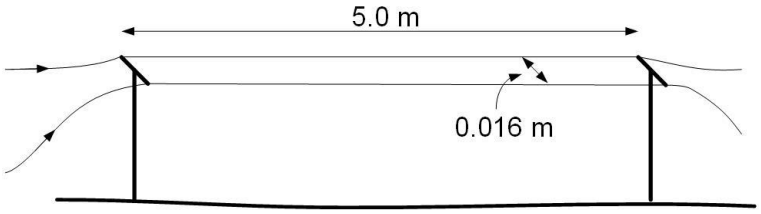
Exam continues over the page

Question 10

Marker use

Two horizontal 5.0 m long wires are held 0.016 m apart and both carry a current of 15 A.

No potential difference exists between the wires.



a) Calculate the magnitude of the force between the wires. /2

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b) Are the wires attracted or repelled? /1

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c) On the figure below, which is a cross section of the two wires, indicate the magnetic field around and between the wires. /2

Spare diagram used (✓)

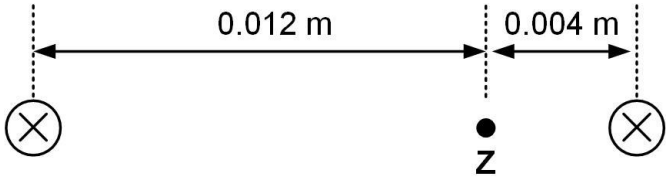
☐

Question 10 continues

Marker use

d) Show the magnetic field strength at a point **z**, 4.0 x 10^{-3} m from one wire is 5.0 x 10^{-4} T.

3



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e) A proton with a velocity of 7.0 x 10^{4} m s^{-1} in the same direction as the current enters at point Z, where the magnetic field strength is 5.0 x 10^{-4} T. Calculate the initial radius of curvature of the proton's motion.

2

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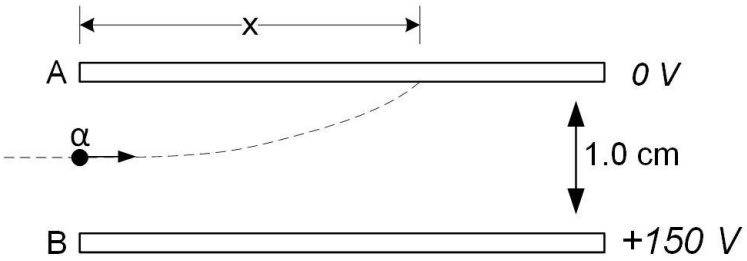
Total Q10

10

Question 11

Marker use

An alpha particle (mass = 6.64 x 10^{-27} kg) is fired midway between oppositely charged plates with a velocity of 5.0 x 10^{6} m s^{-1}. The plates are separated by 1.0 cm and potential difference of 150 V exists between the plates.



a) Calculate the **magnitude** of the E-field between the two plates. **1**

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b) Show that the **magnitude** of the force experienced on the alpha particle by the E-field is 4.8 x 10^{-15} N up. **1**

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c) On the diagram, **X** indicates the horizontal distance travelled by the alpha particle before it strikes the plate. Calculate this distance. **3**

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Question 11 continues

Marker use

/ 2

d) A magnetic field is applied between the plates. What magnitude and direction must the B-field be to cause the alpha particle to travel in a straight line?

Magnitude: .....

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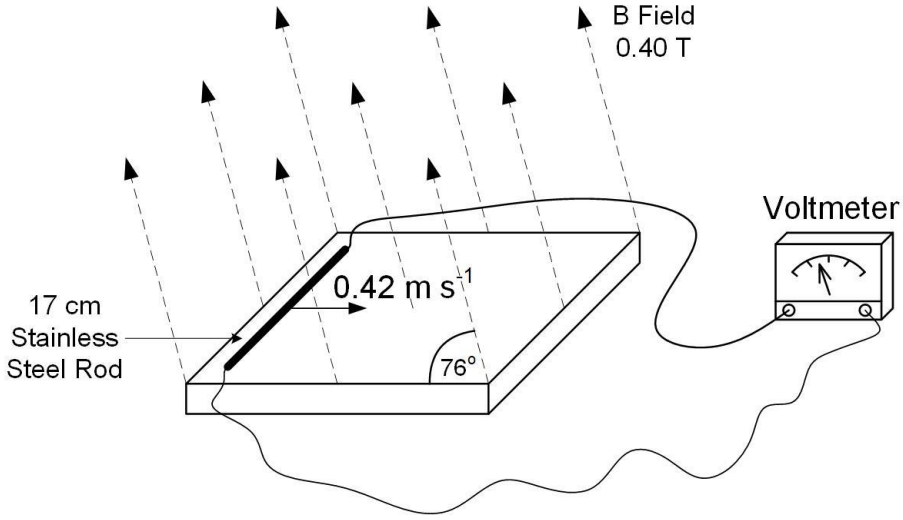
Direction: .....

Total Q11

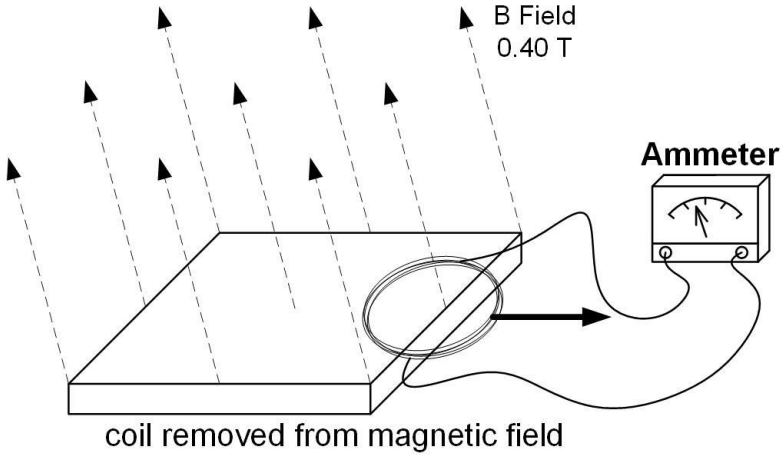
/ 7

Spare Diagrams

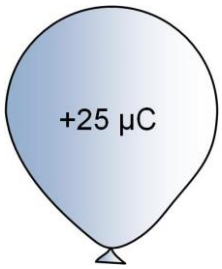
Question 7



Question 7 d)

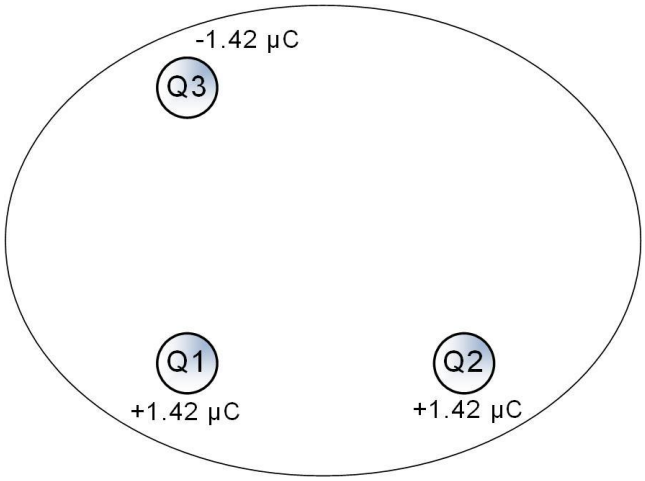


Question 8 b)



Spare Diagrams

Question 9 b)



Question 10 c)

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External Assessment 2021

PHYSICS

PHY415115

Part 3 Wave Motion

Pages	16
Questions	6
Information Sheet	1

Suggested working time: 45 minutes

Instructions

- Attempt **all** questions and **all** parts within each question.
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  - The appropriate units must be included.
- All answers must be written in **English**.
- You **must** make sure your answers address:
  - Criterion 7 identify and apply general principles of wave motion.

Marker use	
C7	40

Guide to Exam Structure

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Part 1	6	6	45 minutes	40 marks
Part 2	5	5	45 minutes	40 marks
Part 3	6	6	45 minutes	40 marks
Part 4	5	5	45 minutes	40 marks
Totals	**22**	**22**	**180 minutes (3 hours)**	**160**

Question 12

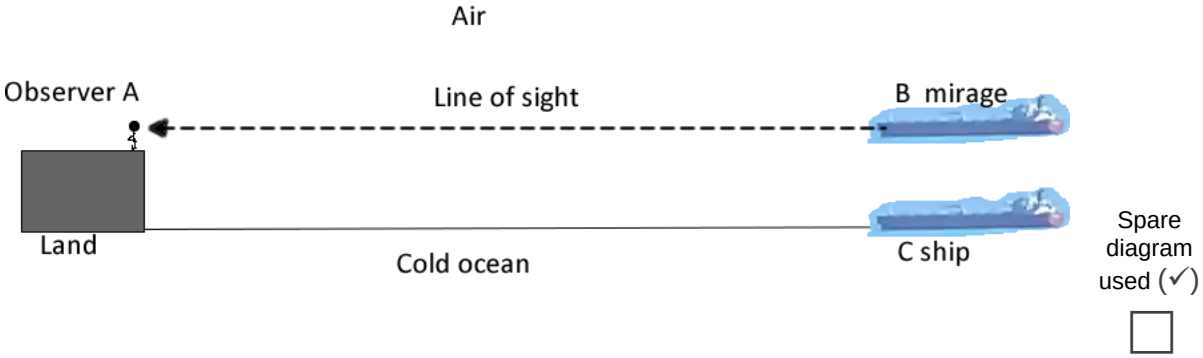
Marker use

Photographer; David Morris

A spectacular “superior mirage” can occur in colder climates. The picture above is a mirage of a ship. It seems to be floating above the sea!

Mirages are caused by air at different temperatures having different refractive indices.

On the diagram below, the line of sight to the image is shown by the line AB but the ship is on the water at C. (The line of sight is the straight line from the mirage to the eye.)



Spare diagram used (✓)

☐

a) On the diagram above sketch a line AC, that light will take through the air to the observer A that will give this mirage.

2

Marker use

Question 12 continued

b) Is the air's refractive index rising or falling as light leaves the ship along your path AC? Justify your answer using Snell's Law.

2

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The seawater temperature is very cold for this mirage to occur. It cools the air immediately above it.

1

c) Has cold air a higher or lower refractive index than warmer air?

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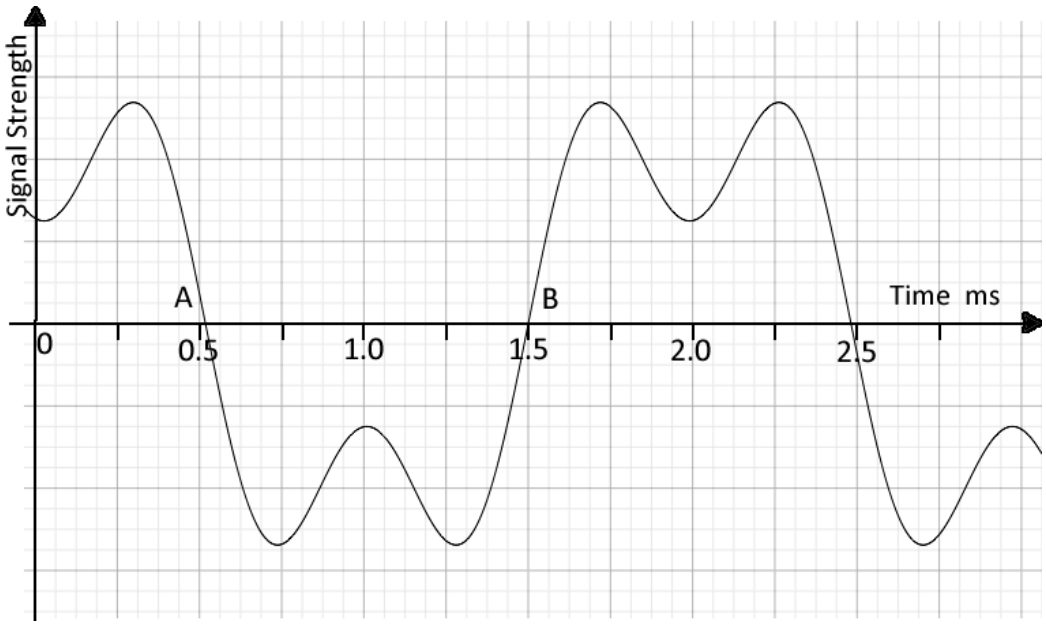
Total Q12

5

Question 13

Marker use

"Active" headphones reduce unwanted sound (noise) by using a microphone in the headphones to sample the surrounding noise and sending this to a circuit. The circuit looks at the frequency and amplitude of the noise then generates a sound wave that is sent to the headphones cancelling the noise.



Spare diagram used (✓) ☐

a) On the graph above, the line represents an unwanted sound wave (noise). Sketch on the same graph between A and B an approximate wave that "cancels" the unwanted noise. **2**

b) Which physics principle have you used to sketch this wave? **1**

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c) From the graph, calculate the approximate frequency of the unwanted wave. **2**

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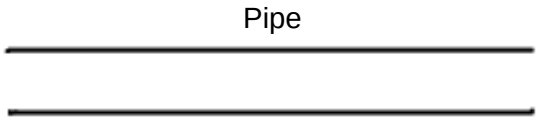
Total Q13 **5**

Question 14

Marker use



A long wooden pipe open at both ends is found to resonate at a fundamental frequency of 160 Hz.

a) Calculate its length.

2

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The pipe is then used as a didgeridoo with one end closed by a player's mouth.

b) Calculate its new fundamental resonant frequency.

2

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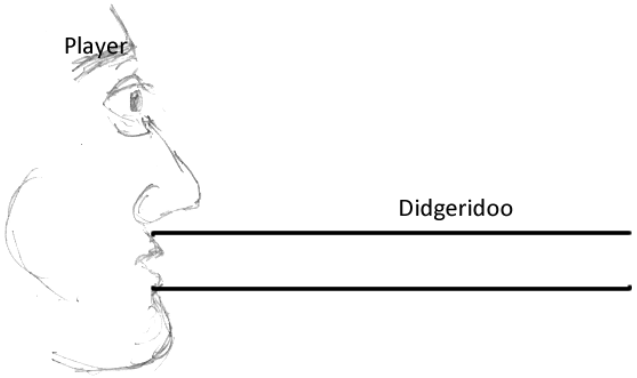
Question 14 continues

Marker use

c) Sketch on the diagram below the second overtone as a didgeridoo.



Spare diagram used (✓) ☐

/2

d) Is it possible for the didgeridoo to have a fourth harmonic? Justify your answer.

/2

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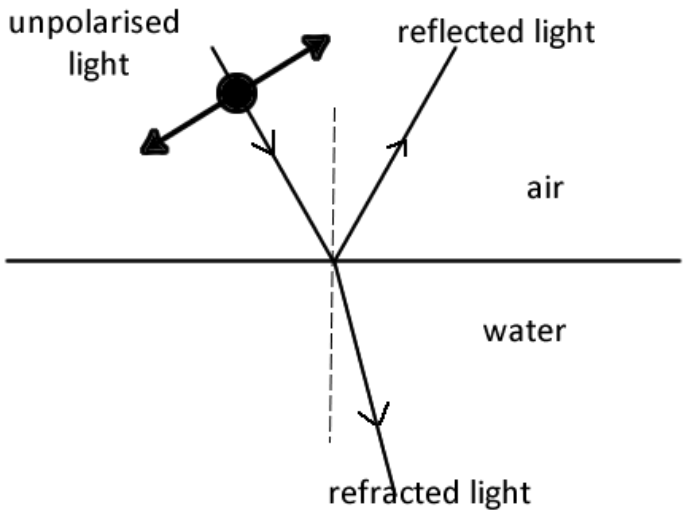
Total Q14

/8

Question 15

Marker use



Spare diagram used (✓) ☐

Unpolarised light from the sun shining on the surface of water is partly polarised on both reflection from the water surface and refraction into the water.

a) Draw dots and arrows on the reflected and refracted rays indicating the relative intensities of the planes of polarisation on the diagram above. **2**

b) "Polaroid" sunglasses strongly reduce some light reflections and scatterings. How do polaroid sunglasses enable fishermen to see fish underwater more clearly? **2**

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Question 15 continues

Marker use

c) Would normally worn polaroid sunglasses reduce reflections from shop windows? Justify your answer possibly using a sketch diagram to assist.

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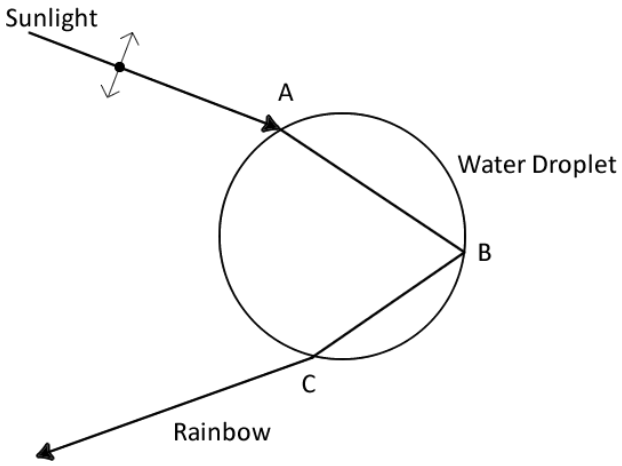
d)



A rainbow is caused by light refracting and reflecting in droplets of water. Would you expect rainbow light to be detectable by polaroid sunglasses? Explain your answer with reference to the diagram above.

2

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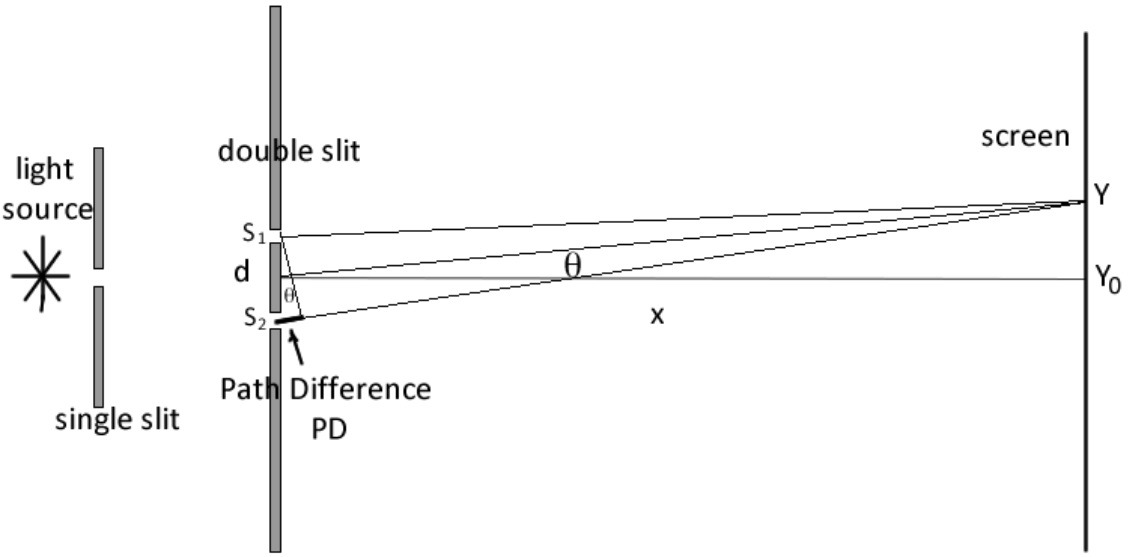
Total Q15

8

Question 16

Marker use



The diagram above represents light shining onto a screen through slits.

a) What is the purpose of the single slit? 2

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b) If the slits are a distance, d, apart and the screen is a distance, x, from the slits, **show that** for a small angle, θ, the path difference PD, from the slits to the point A on the screen is given by: $PD = \frac{YY_0}{x} d$ 2

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Question 16 continues

Marker use

Two wavelengths of values 586 nm and 390 nm are shone through the single slit onto the two slits 50 μm apart. Interference patterns for both wavelengths appear on the screen set at a distance of 2.00 m.

c) Calculate the bandwidth of the 586 nm pattern on the screen.

2

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d) Which wavelength pattern will have the largest number of antinode-node patterns on the screen? Justify your reason.

1

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e)

Using one wavelength, the patterns drop in intensity until they disappear then faintly reappear again on either side. What additional effect is superimposed on the classic double slit pattern?

1

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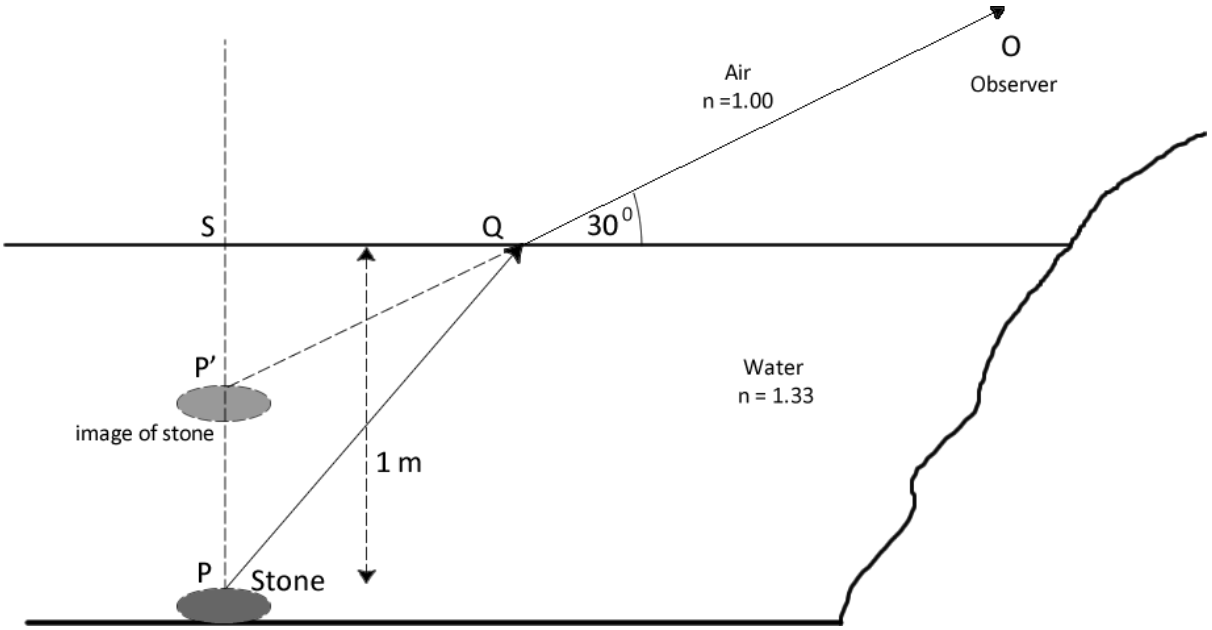
Total Q16

8

Question 17

Marker use



A stone is at the bottom of a pond as in the diagram above. Water has a refractive index of 1.33. The stone is 1.00 m down. An observer, O, on the shore is looking into the pond.

The observer sees the stone with the light emerging at an angle of 30^{o} to the surface. It appears to be P', ABOVE its real position.

a) Calculate the angle SPQ.

2

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b) Show that the distance SQ is about 0.87 m.

1

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Question 17 continues

Marker use

c) Calculate the distance SP'.

2

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d) Why is it easy to misjudge the depth of water when stepping in ponds?

1

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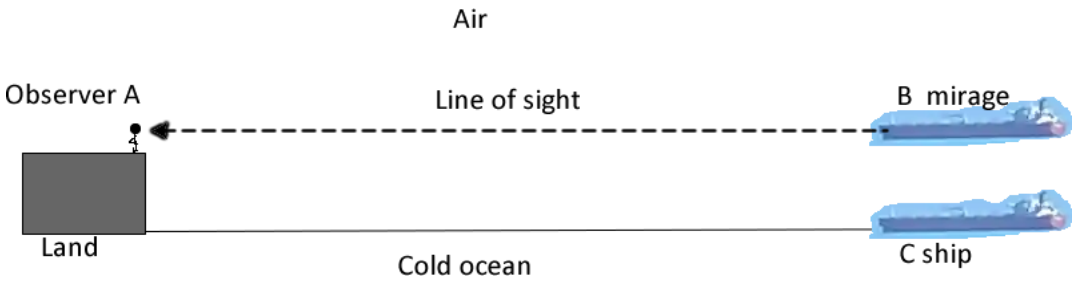
Total Q17

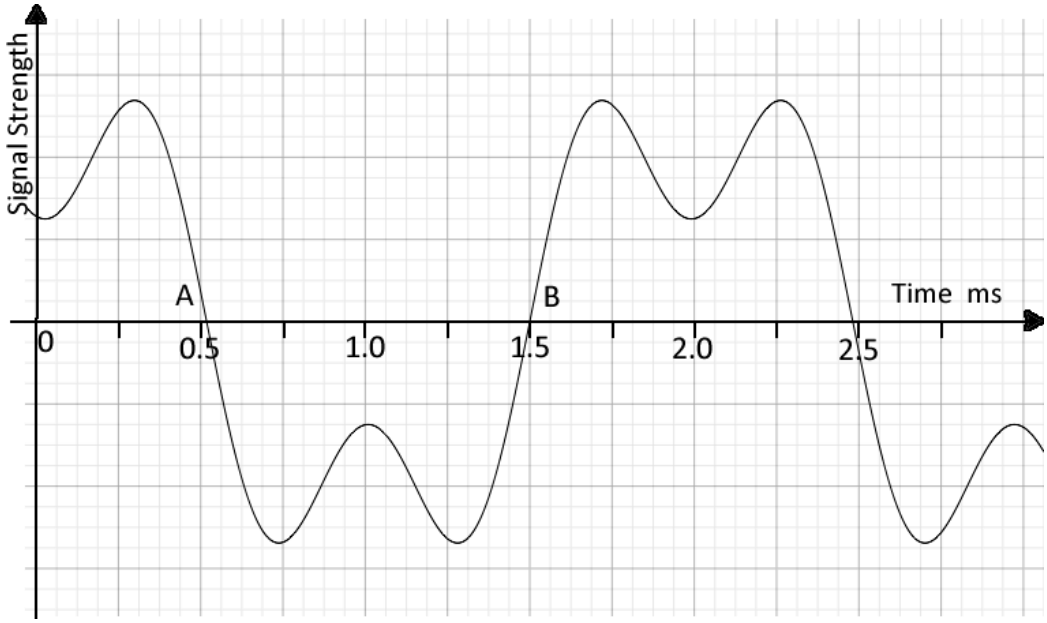
6

Spare Diagrams

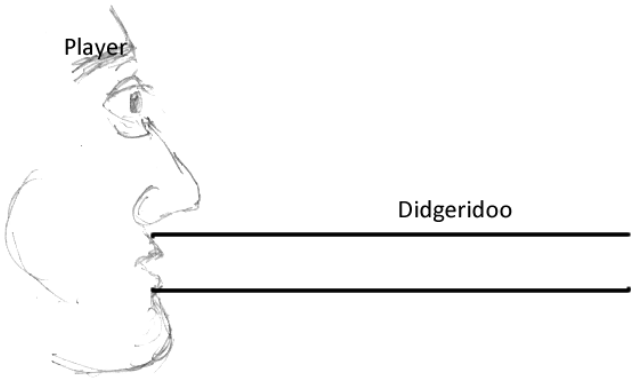
Question 12 a)



Question 13 a)

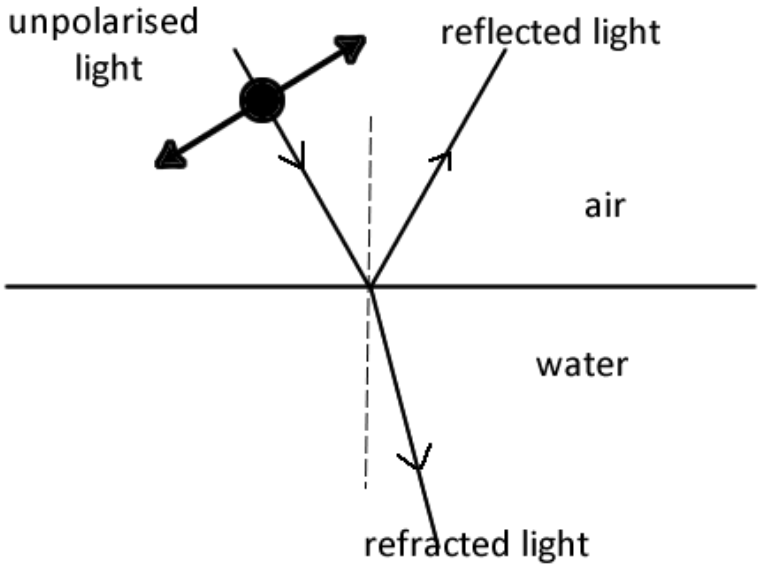


Question 14 c)



Spare Diagrams

Question 15 a)



End of Part 3

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External Assessment 2021

PHYSICS

PHY415115

Part 4 Twentieth Century

Pages	16
Questions	5
Information Sheet	1

Suggested working time: 45 minutes

Instructions

- Attempt **all** questions and **all** parts within each question.
- Write your answers in the spaces provided in this exam paper.
  - Spare diagrams have been provided at the end of the exam booklet. Indicate in the box provided if you have used the spare diagrams.
- A TASC approved scientific calculator can be used throughout the exam.
  - Show your workings in answers to numerical questions. No marks can be given for incorrect answers unless they are accompanied by details of the working.
  - The appropriate units must be included.
- All answers must be written in **English**.

- You **must** make sure your answers address:

  - Criterion 8 identify and apply principles of the wave-particle nature of light, atomic and nuclear physics and models of the nucleus and nuclear processes.

Marker Use	
C8	40

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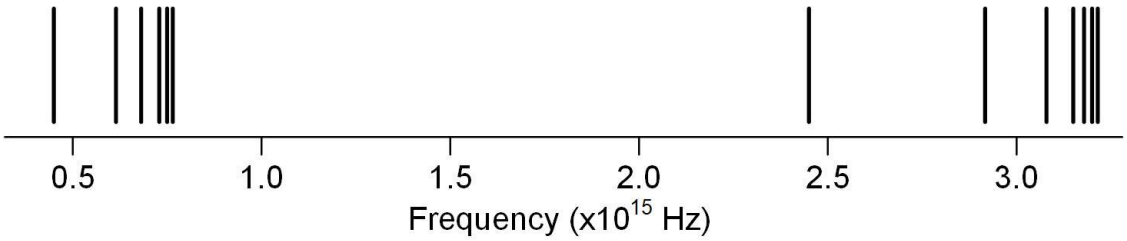
Guide to Exam Structure

	Questions available	How many questions to answer	Suggested working time	Marks available
Part 1	6	6	45 minutes	40 marks
Part 2	5	5	45 minutes	40 marks
Part 3	6	6	45 minutes	40 marks
Part 4	5	5	45 minutes	40 marks
Totals	**22**	**22**	**180 minutes (3 hours)**	**160**

Question 18

Marker use



The emission spectrum of hydrogen displayed above can be provided by passing a current through the gaseous element.

a) How does a current applied to hydrogen gas produce a spectrum?

1

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b) One spectral line occurs at 6.16 x 10^{14} Hz. Calculate the energy of this line in **electron volts**.

1

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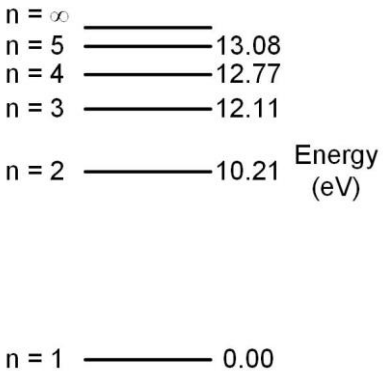
c) Emission spectra can be used to calculate the electron energy levels in hydrogen, as outlined in the diagram opposite.



Which electron transition does the 6.16 x 10^{14} Hz spectral line represent?

1

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Question 18 continues

Marker use

d) If an electron in a hydrogen atom is in the ground state $(n=1)$, describe what would happen to the electron if struck by:

i. A photon of energy 12.5 eV.

.....

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1

ii. An electron of energy 12.5 eV.

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1

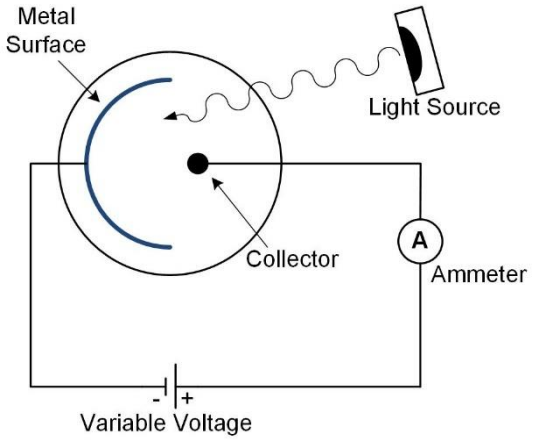
Total Q18

5

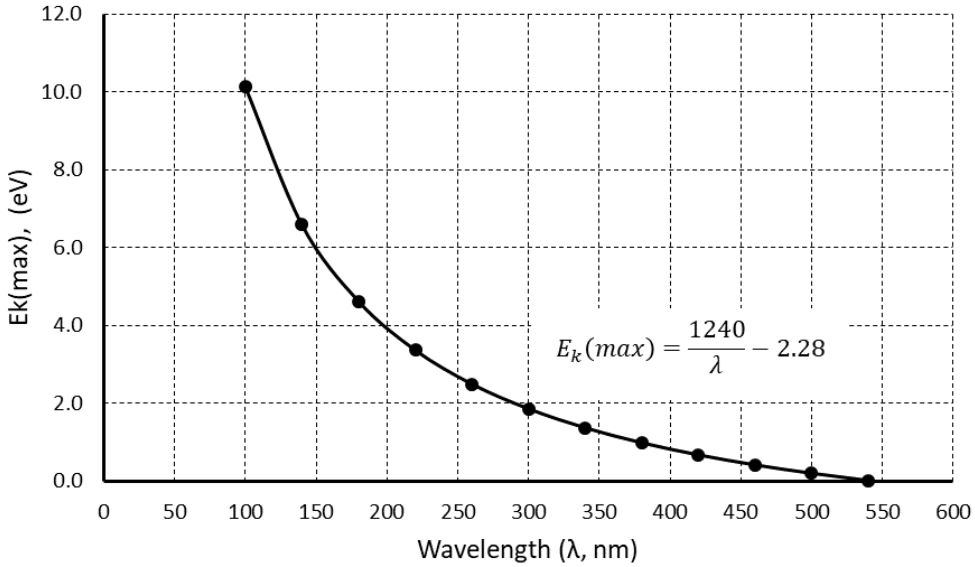
Question 19

Marker use

An experiment was conducted where light of varying wavelengths was shone onto a sample of sodium. The diagram opposite illustrates the setup of the experiment.



The maximum energy of the ejected photoelectrons was recorded, and the following graphical data obtained as the light source wavelength was varied.



Spare diagram used (✓) ☐

a) What is the work function of sodium in **eV**.

1

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b) What minimum variable voltage setting would be needed to produce no current when light of wavelength 200 nm is shone onto the sodium metal?

1

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Question 19 continues

Marker use

c) Explain why no photoelectrons are observed when the light source has a wavelength > 550 nm?

/2

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d) The intensity of the light is doubled. What change, if any, would be observed in the graph on page 6?

/1

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e) The sodium metal was changed to gold, which has a work function of 5.10 eV. On the graph on page 6, sketch a curve that might represent the Ek(max) of photoelectrons produced from gold. Indicate the value of the x-intercept.

/2

Total Q19

/7

Question 20

Marker use

90–103 Actinide Series	90 **Th** Thorium 232.0	91 **Pa** Protactinium	92 **U** Uranium 238.0	93 **Np** Neptunium	94 **Pu** Plutonium	95 **Am** Americium

Plutonium-238 is a radioactive isotope of plutonium that has a half-life of 87.7 years. Plutonium-238 is a very powerful alpha emitter and, due to the heat it generates, is suitable for usage in radioisotope thermoelectric generators such as that used to power the Mars Rover.

The Mars Rover contains the equivalent of 4.23 kg of Pu-238

a) What is the activity of 4.23 kg of newly prepared Pu-238? **3**

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b) Some older stockpiles of Pu-238 (in the US) have activity 73.4% less than newly produced Pu-238. How old are these stockpiles? **2**

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Pu-238 can be produced by bombarding Uranium-238 with deuterium (H-2) in the reaction

$^{238}_{92}U + {}^{2}_{1}H \rightarrow {}^{238}_{93}Np + 2{}^{1}_{0}n + e^{+} + \nu$ followed by beta-minus decay of the Np-238

c) Write the beta-minus decay equation of Np-238. **1**

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Question 20 continues

Marker use

d) Show that the energy released in the beta-minus decay is 0.786 MeV.
Relative isotopic masses Pu-238 = 238.049553 u Np-238 = 238.050946 u

2

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e) The bombardment reaction indicated on page 8 includes, as one of its products, a neutrino. Describe the neutrino particle in terms of its mass, charge and speed.

1

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f) Calculate the binding energy of Pu-238 per **nucleon**.

3

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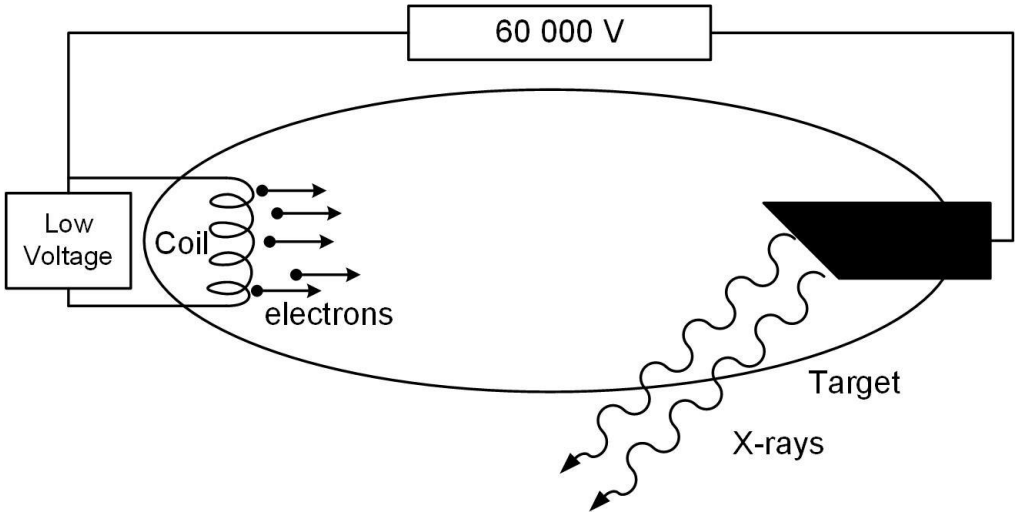
Total Q20

12

Question 21

Marker use

When electrons are accelerated towards a target metal as illustrated below, X-rays are produced.



The accelerating high voltage is set to 60 000 V.

a) Calculate the kinetic energy of the electrons in Joules as they reach the target. (Ignore special relativistic effects.)

1

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b) Calculate the De Broglie wavelength of these electrons as they enter the target.

3

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c) What is the wavelength of the highest energy X-rays produced?

2

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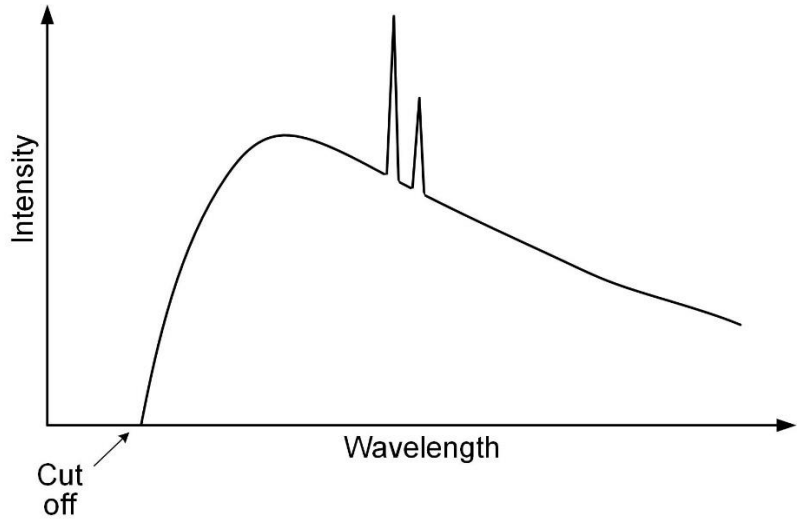
Question 21 continues

Marker use

A wavelength vs intensity spectrum of the X-rays produced is illustrated below showing the continuous X-ray spectrum and the characteristic X-ray peaks.



Spare diagram used (✓) ☐

d) How are continuous X-rays produced?

1

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.....

e) On the image above, sketch the profile if the electron current is increased.

2

f) How are the characteristic X-ray peaks produced?

2

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Total Q21

11

Question 22

Marker use

Hot objects emit a continuous spectrum. This spectrum was not predicted using classic wave theory. Planck resolved this explanation with studies of black bodies.

a) What is a black body?

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1

b) What modern Physics theory did this discovery lead to?

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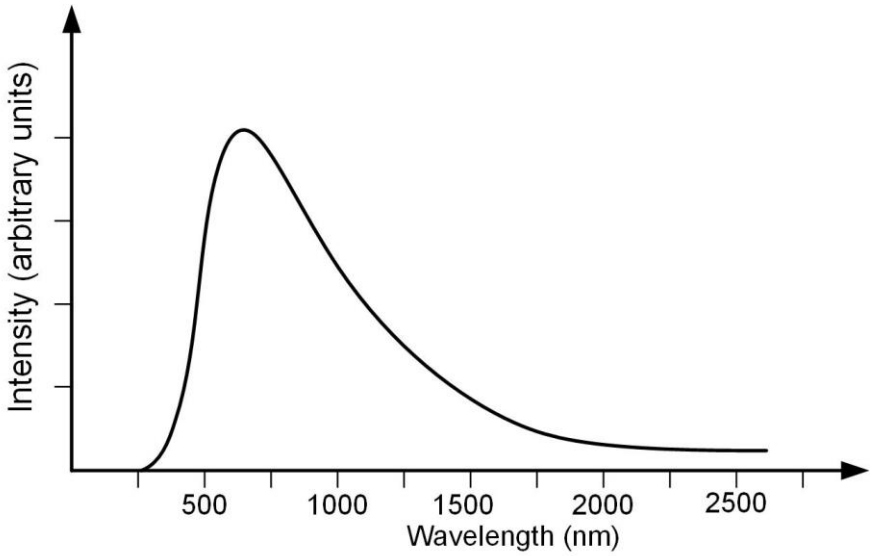
1



Spare diagram used (✓) ☐

c) The spectrum above has a peak wavelength of **625 nm**. Calculate the object's temperature.

.....

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1

d) The object cools down. On the spectrum above, sketch a curve that represents the emission at a lower temperature.

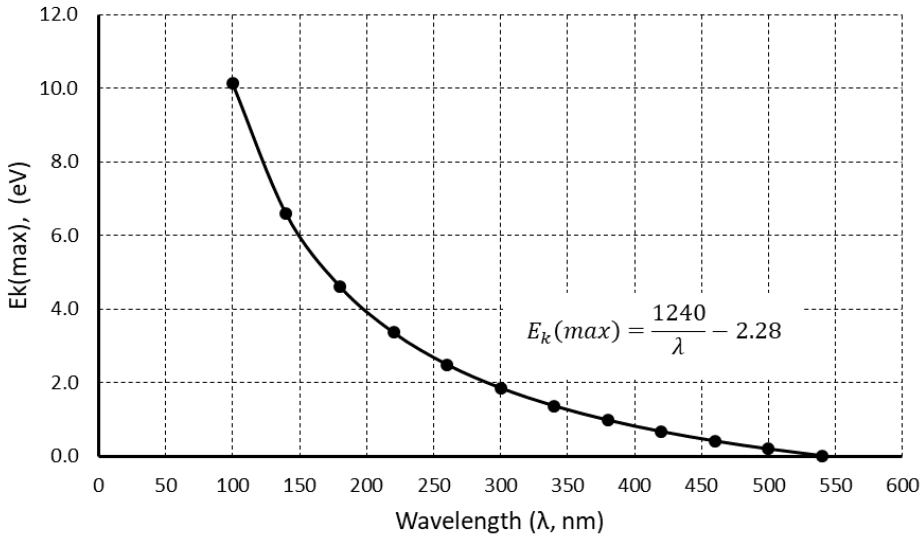
2

Total Q22

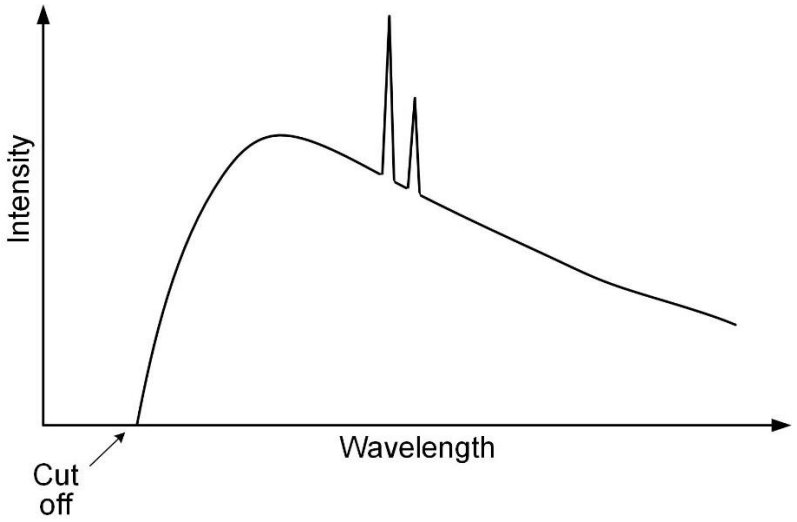
5

Spare Diagrams

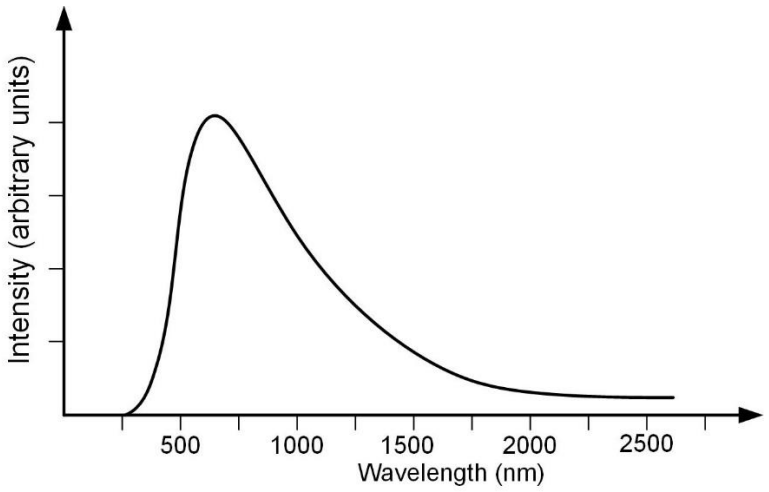
Question 19 e)



Question 21 e)



Question 22 d)



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End of Part 4

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