Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number | Candidate Number

Time 1 hour 45 minutes

Paper reference **9PH0/02**

Physics

Advanced

PAPER 2: Advanced Physics II

You must have:
Scientific calculator, ruler

Total Marks

Instructions

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

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- The list of data, formulae and relationships is printed at the end of this booklet.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- You are advised to show your working in calculations, including units where appropriate.
- Good luck with your examination.

Turn over ▶

Answer ALL questions.

For questions 1–10, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Ultrasound can be used to investigate the structure of organs of the human body using the pulse-echo technique.
The level of detail obtained depends on the wavelength and the length of the pulses.

Which line of the table shows a change to wavelength and a change to pulse length that would each improve the level of detail?

		Wavelength	Pulse length
☒	**A**	decrease	decrease
☒	**B**	increase	decrease
☒	**C**	decrease	increase
☒	**D**	increase	increase

(Total for Question 1 = 1 mark)

2 An object is placed in front of a lens.

Which row of the table shows a combination that will produce a real image of the object?

		Focal length of lens / cm	Object distance / cm
☒	**A**	−5	10
☒	**B**	−5	2
☒	**C**	5	10
☒	**D**	5	2

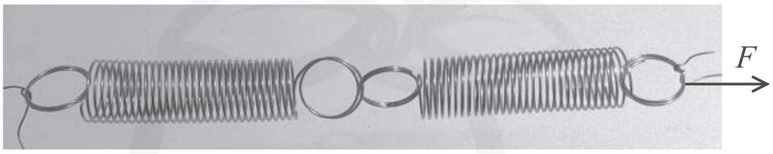
(Total for Question 2 = 1 mark)

Questions 3 and 4 refer to the following information.

A horizontal force F is applied to a horizontal spring, fixed at one end.

The stiffness of the spring is k and the elastic strain energy stored is E.

A second, identical spring is added and the same force is applied to the combination of springs, as shown.



3 What is the stiffness of the combination of springs?

☒ **A** $\frac{k}{2}$

☒ **B** k

☒ **C** $2k$

☒ **D** $4k$

(Total for Question 3 = 1 mark)

4 What is the elastic strain energy stored for the combination of springs?

☒ **A** $\frac{E}{2}$

☒ **B** E

☒ **C** $2E$

☒ **D** $8E$

(Total for Question 4 = 1 mark)

5 A mass of 24 kg is suspended from a steel wire of length 1.5 m. The wire has cross-sectional area $3.1 \times 10^{-6}\,\text{m}^2$.

The Young modulus of steel is 1.8×10^{11} Pa.

Which of the following gives the extension of the wire?

☒ **A** $\dfrac{24 \times 1.5}{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}$

☒ **B** $\dfrac{24 \times 9.81 \times 1.5}{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}$

☒ **C** $\dfrac{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}{24 \times 1.5}$

☒ **D** $\dfrac{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}{24 \times 9.81 \times 1.5}$

(Total for Question 5 = 1 mark)

6 The diagram shows a source of sound waves and an observer.

Which row of the table shows a situation which would result in a decrease in the frequency of sound observed?

		Source	Observer
☒	**A**	moves to the right at $20\,\text{m}\,\text{s}^{-1}$	moves to the left at $20\,\text{m}\,\text{s}^{-1}$
☒	**B**	moves to the right at $20\,\text{m}\,\text{s}^{-1}$	moves to the right at $20\,\text{m}\,\text{s}^{-1}$
☒	**C**	moves to the right at $20\,\text{m}\,\text{s}^{-1}$	stationary
☒	**D**	stationary	moves to the right at $20\,\text{m}\,\text{s}^{-1}$

(Total for Question 6 = 1 mark)

7 The photoelectric effect provides evidence for the particle nature of electromagnetic radiation.

Which of the following observations of the photoelectric effect could also be explained using the wave nature of electromagnetic radiation?

- ☒ **A** The emission of photoelectrons is instantaneous.
- ☒ **B** The maximum kinetic energy of photoelectrons depends on frequency.
- ☒ **C** The rate of emission of photoelectrons depends on intensity.
- ☒ **D** There is a minimum frequency for emission of photoelectrons to occur.

(Total for Question 7 = 1 mark)

---

8 The acceleration of free fall at the surface of the Earth is $9.81\,\text{m}\,\text{s}^{-2}$.
The mass of the Earth is M and the diameter of the Earth is D.

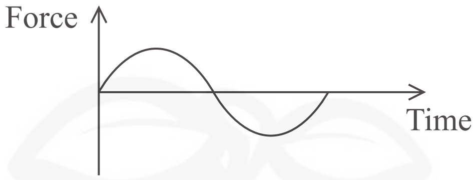
Which of the following gives the acceleration of free fall, in $\text{m}\,\text{s}^{-2}$, at the surface of a planet with diameter $\frac{D}{2}$ and mass $\frac{M}{9}$?

- ☒ **A** $\frac{9.81 \times 2}{9}$
- ☒ **B** $\frac{9.81 \times 4}{9}$
- ☒ **C** $\frac{9.81 \times 2}{3}$
- ☒ **D** $\frac{9.81 \times 9}{4}$

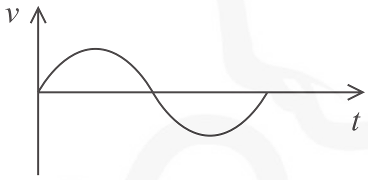
(Total for Question 8 = 1 mark)

---

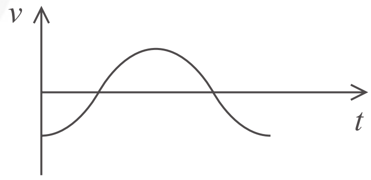
9 A mass is suspended from a spring and allowed to come to equilibrium.
The mass is displaced vertically and moves with simple harmonic motion.
The graph shows how the resultant force on the mass varies with time.



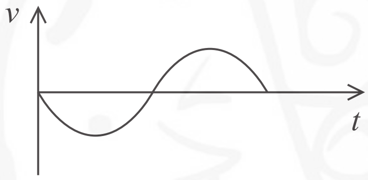
Which of the following graphs shows how the velocity *v* of the mass varies with time *t* over the same time interval?



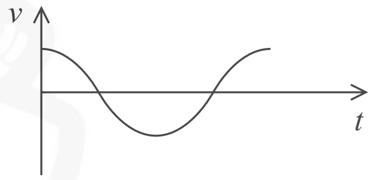
A



B



C



D

☒ **A**

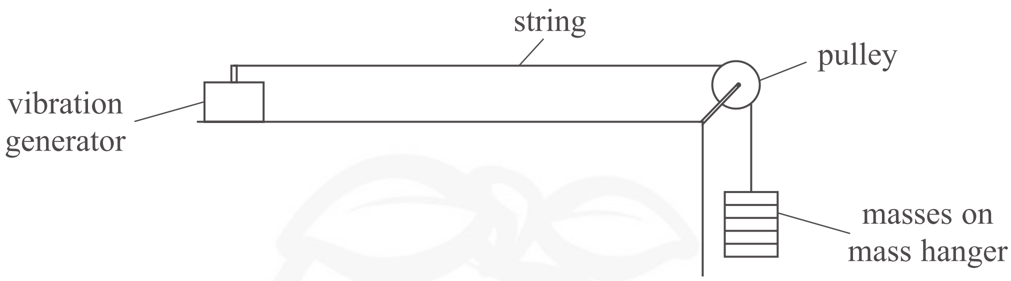
☒ **B**

☒ **C**

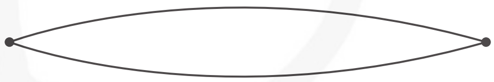
☒ **D**

(Total for Question 9 = 1 mark)

10 The diagram represents an arrangement used to generate standing waves on a string.



A standing wave pattern with two nodes is obtained as shown.



Which of the following single changes could produce a standing wave pattern with three nodes?

☒ **A** decreasing the distance between the vibration generator and pulley

☒ **B** decreasing the frequency of the vibration generator

☒ **C** decreasing the mass on the mass hanger

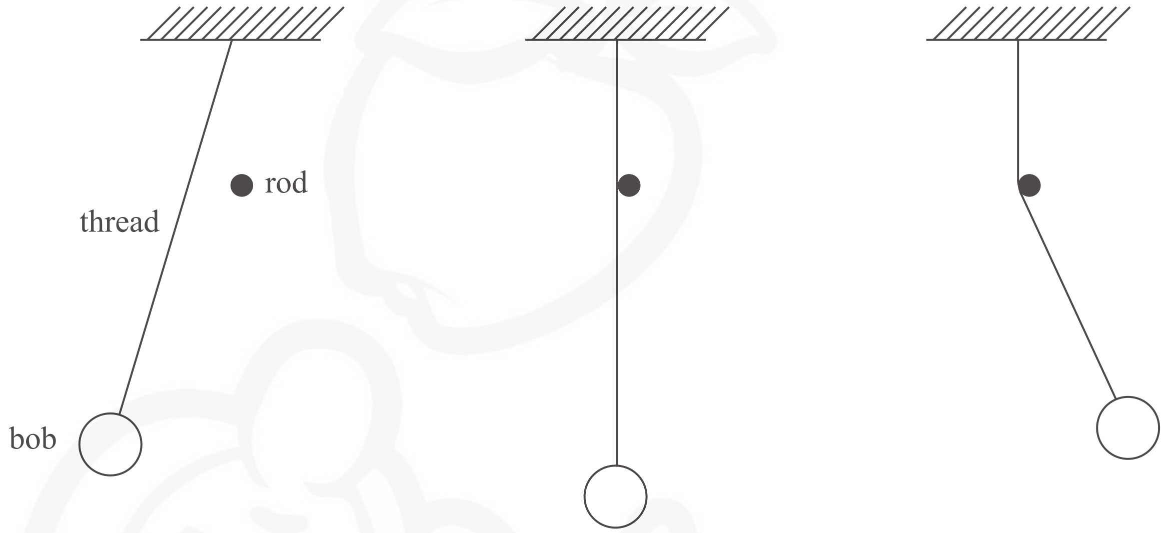
☒ **D** decreasing the mass per unit length of the string

(Total for Question 10 = 1 mark)

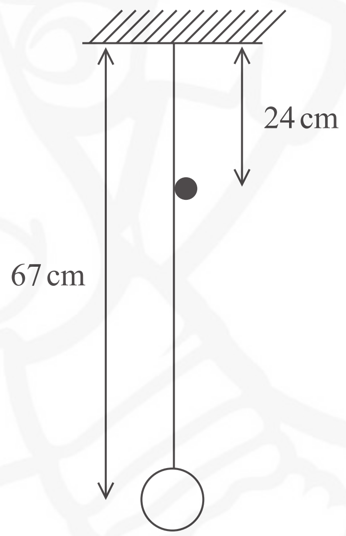
11 A simple pendulum consisting of a thread and a bob is set up next to a horizontal rod.

The bob is displaced to the left and released. When the bob reaches the equilibrium position the thread strikes the horizontal rod. For half of the cycle, only the lower part of the pendulum moves.

The diagram shows the swing of the pendulum.



The diagram below shows the dimensions of the pendulum.



Determine the frequency of the oscillations of the pendulum.

....

....

....

....

....

....

....

Frequency = ...

(Total for Question 11 = 4 marks)

12 Latte is a type of coffee made with hot frothy milk. The milk is heated by pumping steam into it.

Calculate the maximum mass of milk that could be warmed to a temperature of 65 °C by absorbing 15 g of steam at 100 °C.

initial temperature of milk = 4.0 °C
specific heat capacity of milk = $3900\ J\,kg^{-1}\,K^{-1}$
specific heat capacity of water = $4200\ J\,kg^{-1}\,K^{-1}$
specific latent heat of vaporisation of water = $2.3 \times 10^{6}\ J\,kg^{-1}$

....

....

....

....

....

....

....

....

....

....

Maximum mass = ...

(Total for Question 12 = 4 marks)

***13** The energy radiated by stars is released by nuclear fusion.

Explain the conditions required to bring about and maintain nuclear fusion in stars.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

(Total for Question 13 = 6 marks)

14 A student investigated the terminal velocity of steel spheres falling through oil.

The student obtained the following results.

radius of steel sphere = 1.50 mm
volume of steel sphere = $1.41 \times 10^{-8}\,m^3$
mass of steel sphere = $1.10 \times 10^{-4}\,kg$
maximum speed of sphere = $0.849\,m\,s^{-1}$

The student had the following table.

Type of oil	Density at 26 °C / $kg\,m^{-3}$	Viscosity at 26 °C / Pa s
Corn	918	0.0447
Hazelnut	918	0.0504
Sunflower	918	0.0414

(a) Identify which type of oil the student used.

(4)

....

....

....

....

....

....

....

....

....

....

P 6 7 0 9 7 A 0 1 2 3 2

(b) The values in the table are for oil at 26 °C.

Explain the effect of carrying out the investigation with oil at a lower temperature.

(2)

....

....

....

....

(Total for Question 14 = 6 marks)

15 One of the largest stars in our galaxy is VY Canis Majoris. This star's radius is 1420 times the radius of the Sun. The luminosity of this star is 270 000 times the luminosity of the Sun.

A student states that the surface temperature of VY Canis Majoris must be much greater than the surface temperature of the Sun.

(a) Determine whether the student's statement is correct.

surface temperature of Sun = 5780 K
luminosity of Sun = 3.85×10^{26} W
radius of Sun = 6.96×10^{8} m

(3)

....

....

....

....

....

....

....

....

(b) Calculate the wavelength with maximum intensity in the black body radiation spectrum of VY Canis Majoris.

(2)

....

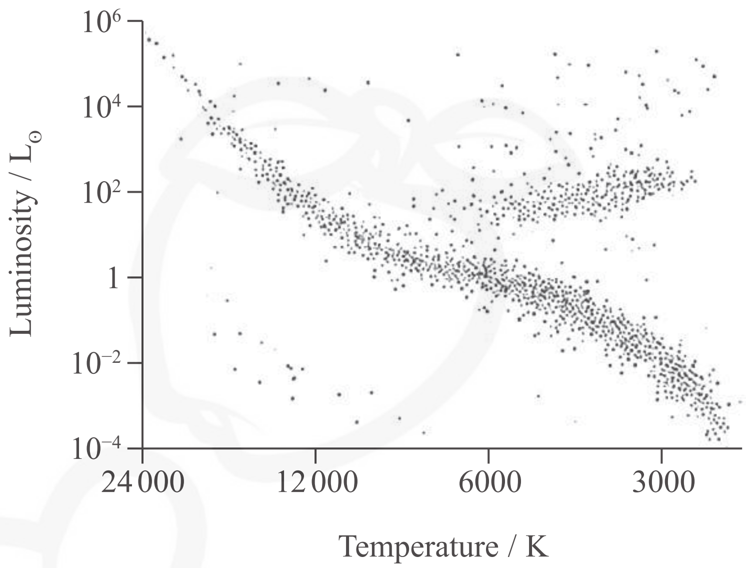
....

....

Wavelength = ...

(c) Add the position of VY Canis Majoris to the Hertzsprung Russell diagram to determine which type of star it is.

(2)



Type of star ....

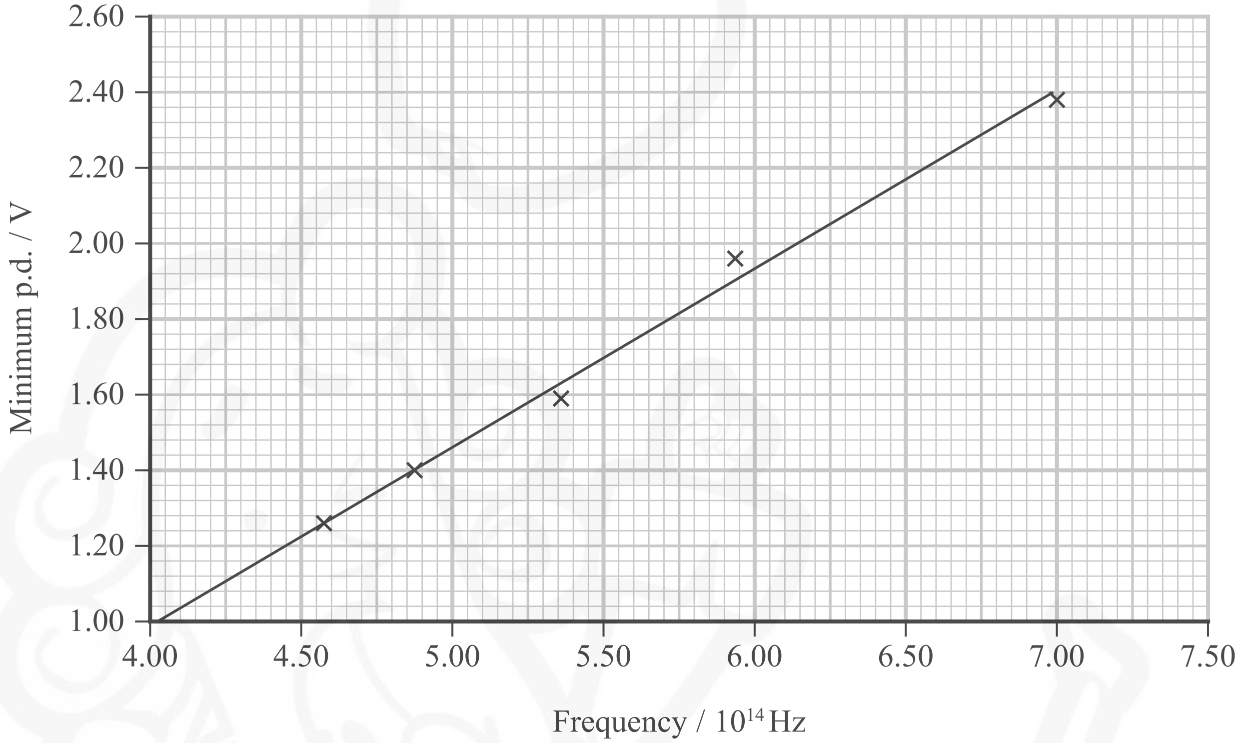
(Total for Question 15 = 7 marks)

16 The Planck constant can be determined in a school laboratory using light emitting diodes (LEDs).

An LED emits light when the potential difference (p.d.) across it is large enough to transfer sufficient energy to an electron to result in the emission of a photon. The electron must have energy greater than or equal to the photon energy.

The minimum p.d. required to produce light from LEDs emitting different frequencies was measured by increasing the p.d. from zero until light was first seen.

The graph shows the results.



(a) Determine the value of the Planck constant given by this graph.

(4)

Value of Planck constant given by graph = ...

(b) There are two problems with using LEDs to determine the Planck constant:

- when the p.d. is increased and the LED first emits light it is difficult to see
- the LEDs do not emit a single frequency but also light of frequencies slightly above and below the recorded frequency.

Discuss the extent to which these problems are consistent with obtaining a result from this graph for the Planck constant which is higher than the accepted value.

(3)

(Total for Question 16 = 7 marks)

17 Astronomers observing stars at the centre of our galaxy have suggested that many of them are orbiting a supermassive black hole. The mass of this black hole is 9.2×10^{36} kg.

(a) Calculate the orbital period for a star in a circular orbit at a distance of 1.9×10^{14} m from a black hole of this mass.

(3)

Orbital period = ...

(b) The star S0-2 is in a highly elliptical orbit around the position of the black hole.

At its point of closest approach, S0-2 is at a distance of 1.8×10^{13} m from the centre of the black hole.

At the most distant point of its orbit, S0-2 is 2.7×10^{14} m from the black hole.

(i) Show that the change in gravitational potential between the closest and most distant points in this orbit is about $3 \times 10^{13}\,\mathrm{J\,kg^{-1}}$.

(2)

(ii) At its point of closest approach, the star is travelling at a speed of $8.1 \times 10^{6}\,\mathrm{m\,s^{-1}}$.

Calculate the speed of S0-2 at the furthest point in its orbit using the change in gravitational potential.

mass of S0-2 = 2.4×10^{31} kg

(3)

Speed = ...

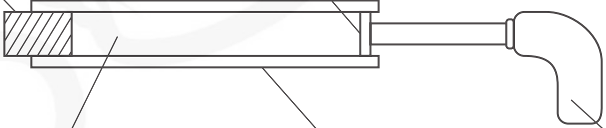
(c) Trigonometric parallax and Hubble's law are two methods used to determine astronomical distances.
Explain whether either of these methods is suitable to determine the distance to S0-2.

(3)

(Total for Question 17 = 11 marks)

18 The photographs show a wooden pop gun before and after the cork is popped.

The diagram shows a cross-section through the pop gun.



Initially the piston is at the right-hand end of the cylinder, as shown. Then the cork is pushed into the other end of the cylinder.

When the handle is pushed in, the pressure of the air in the cylinder increases. This exerts an additional force on the cork.

Once the additional force is sufficient to overcome the frictional force between the cork and the cylinder, the cork is pushed out.

(a) Show that the pressure of the air in the cylinder must be about 2×10^5 Pa in order to push the cork out.

maximum frictional force = 8.8 N
cross-sectional area of cork = 9.2×10^{-5} m^2
atmospheric pressure = 1.0×10^5 Pa

(3)

....

....

....

....

....

(b) Calculate the temperature of the gas in the cylinder at the instant the cork is expelled.

volume of air in the cylinder with the handle pulled out = $1.1 \times 10^{-5}\,m^3$
volume of air in the cylinder at the moment the cork is pushed out = $6.7 \times 10^{-6}\,m^3$
atmospheric pressure = $1.0 \times 10^5\,Pa$
initial temperature of air = 19 °C

(2)

....

....

....

Temperature = ...

(c) The formulae sheet for this paper includes the equation

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

Derive the equation $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

(2)

....

....

....

....

(d) Calculate the root mean square speed of the molecules of air in the cylinder before the handle is pushed in.

average mass of molecule of air = $4.8 \times 10^{-26}\,kg$
temperature of air = 19 °C

(2)

....

....

....

Root mean square speed = ...

(Total for Question 18 = 9 marks)

19 The lens in the eye of an octopus focuses light onto the retina at the back of the eye.

The octopus focuses on objects at different distances from the eye by changing the shape of the eye to move the lens closer or further from the retina.

(a) (i) The power of an octopus lens is 118 D.

Show that the focal length of the lens is about 8.5 mm.

(2)

(ii) Calculate the shortest distance from the eye at which an object may be focused clearly on the retina.

maximum distance from lens to retina = 2.0 cm

(2)

Shortest distance from the eye = ...

(iii) The lens in the eye of an octopus is in contact with seawater. The refractive index of freshwater is less than the refractive index of seawater.

Deduce what would happen to the shortest distance from the eye at which an object may be focused clearly if the octopus was in freshwater.

(3)

....

....

....

....

....

....

(iv) Calculate the speed of light in seawater.

refractive index of seawater = 1.37

(2)

....

....

....

Speed of light in seawater = ...

(b) An octopus can detect the orientation of polarised light.

State what is meant by polarised light.

(2)

....

....

....

....

(Total for Question 19 = 11 marks)

20 The photograph shows a vase made of uranium glass. Uranium glass is radioactive.

Uranium glass usually contains a maximum of 2% uranium. Uranium glass made in the early part of the 20th century can contain up to 25% uranium.

A student carried out an investigation to determine the percentage of uranium in the glass.

The student measured the count rate by placing a Geiger Muller (GM) tube against the vase at a single position. This value was used to calculate the decay rate for the whole vase.

(a) (i) Show that the decay constant for uranium is about $5 \times 10^{-18}\,\text{s}^{-1}$

half-life of uranium = $1.41 \times 10^{17}\,\text{s}$

(2)

(ii) Calculate the percentage of uranium, by mass, in the glass.

area of GM tube window = $6.36 \times 10^{-5}\,\mathrm{m}^2$
surface area of vase = $0.0177\,\mathrm{m}^2$
background count rate = 525 counts in 10 minutes
count rate when GM tube next to vase = 3623 counts in 5 minutes
mass of vase = 149 g
mass of uranium atom = 238 u

(6)

Percentage of uranium = ...

(iii) The uranium decays by emitting alpha particles.

Criticise the method used to determine the percentage of uranium in the vase.

(2)

Turn over ▶

(b) A uranium nucleus decays to thorium by emission of an alpha particle.

It can be assumed that all the energy of the decay is transferred to kinetic energy of the alpha particle.

Calculate the speed of the emitted alpha particle.

mass of uranium nucleus = 238.0003 u
mass of thorium nucleus = 233.9942 u
mass of alpha particle = 4.0015 u

(5)

Speed of alpha particle = ...

(Total for Question 20 = 15 marks)

TOTAL FOR PAPER = 90 MARKS

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	
Coulomb law constant	$k = \dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19} \text{ C}$	
Electron mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$	
Electronvolt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	
Gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	
Gravitational field strength	$g = 9.81 \text{ N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27} \text{ kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8} \text{ m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27} \text{ kg}$	

Mechanics

Kinematic equations of motion

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

$$v = u + at$$

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

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

Forces

$$\Sigma F = ma$$

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

$$W = mg$$

$$\text{moment of force} = Fx$$

Momentum

$$p = mv$$

Work, energy and power

$$\Delta W = F\Delta s$$

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

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

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

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

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

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

P 6 7 0 9 7 A 0 2 7 3 2

Electric circuits

Potential difference

$$V = \frac{W}{Q}$$

Resistance

$$R = \frac{V}{I}$$

Electrical power and energy

$$P = VI$$

$$P = I^2R$$

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

$$W = VIt$$

Resistivity

$$R = \frac{\rho l}{A}$$

Current

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

$$I = nqvA$$

Materials

Density

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

Stokes' law

$$F = 6\pi\eta rv$$

Hooke's law

$$\Delta F = k\Delta x$$

Young modulus

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

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

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

Elastic strain energy

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

Waves and particle nature of light

Wave speed

$$v = f\lambda$$

Speed of a transverse wave on a string

$$v = \sqrt{\frac{T}{\mu}}$$

Intensity of radiation

$$I = \frac{P}{A}$$

Power of a lens

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

$$P = P_1 + P_2 + P_3 + \ldots$$

Thin lens equation

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Magnification for a lens

$$m = \frac{\text{image height}}{\text{object height}} = \frac{v}{u}$$

Diffraction grating

$$n\lambda = d \sin \theta$$

Refractive index

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$n = \frac{c}{v}$$

Critical angle

$$\sin C = \frac{1}{n}$$

Photon model

$$E = hf$$

Einstein's photoelectric equation

$$hf = \phi + \tfrac{1}{2}mv^2_{max}$$

de Broglie wavelength

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

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

P 6 7 0 9 7 A 0 2 8 3 2

Further mechanics

Impulse

$$F\Delta t = \Delta p$$

Kinetic energy of a non-relativistic particle

$$E_k = \frac{p^2}{2m}$$

Motion in a circle

$$v = \omega r$$

$$T = \frac{2\pi}{\omega}$$

$$F = ma = \frac{mv^2}{r}$$

$$a = \frac{v^2}{r}$$

$$a = r\omega^2$$

$$F = mr\omega^2$$

Fields

Coulomb's law

$$F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$$

Electric field strength

$$E = \frac{F}{Q}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{V}{d}$$

Electric potential

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

Capacitance

$$C = \frac{Q}{V}$$

Energy stored in a capacitor

$$W = \tfrac{1}{2}QV$$

$$W = \tfrac{1}{2}CV^2$$

$$W = \tfrac{1}{2}\frac{Q^2}{C}$$

Capacitor discharge

$$Q = Q_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

$$V = V_0 e^{-t/RC}$$

$$\ln Q = \ln Q_0 - \frac{t}{RC}$$

$$\ln I = \ln I_0 - \frac{t}{RC}$$

$$\ln V = \ln V_0 - \frac{t}{RC}$$

In a magnetic field

$$F = BIl \sin\theta$$

$$F = Bqv \sin\theta$$

Faraday's and Lenz's laws

$$\mathscr{E} = \frac{-d(N\phi)}{dt}$$

Root-mean-square values

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

Nuclear and particle physics

In a magnetic field

$$r = \frac{p}{BQ}$$

Thermodynamics

Heating

$$\Delta E = mc\Delta\theta$$

$$\Delta E = L\Delta m$$

Molecular kinetic theory

$$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$$

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

Ideal gas equation

$$pV = NkT$$

Stefan-Boltzmann law

$$L = \sigma AT^4$$

$$L = 4\pi r^2\sigma T^4$$

Wien's law

$$\lambda_{max}T = 2.898 \times 10^{-3}\ \text{m K}$$

Space

Intensity

$$I = \frac{L}{4\pi d^2}$$

Redshift of electromagnetic radiation

$$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$

Cosmological expansion

$$v = H_0 d$$

Nuclear radiation

Mass-energy

$$\Delta E = c^2\Delta m$$

Radioactive decay

$$A = \lambda N$$

$$\frac{dN}{dt} = -\lambda N$$

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

$$N = N_0\ e^{-\lambda t}$$

$$A = A_0\ e^{-\lambda t}$$

Gravitational fields

Gravitational force

$$F = \frac{Gm_1m_2}{r^2}$$

Gravitational field strength

$$g = \frac{Gm}{r^2}$$

Gravitational potential

$$V_{grav} = \frac{-Gm}{r}$$

Oscillations

Simple harmonic motion

$$F = -kx$$

$$a = -\omega^2 x$$

$$x = A\cos\omega t$$

$$v = -A\omega\sin\omega t$$

$$a = -A\omega^2\cos\omega t$$

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$

$$\omega = 2\pi f$$

Simple harmonic oscillator

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

BLANK PAGE

BLANK PAGE

P67097A03232