Name: JJLD Mark Scheme. Centre Number:........................

Candidate Number:............................ Set (Please circle): 4P1 AF 4P2 MGC 4P3 JJLD 4P4 JWC

manners makyth man

Winchester College Physics Mock
Thursday 21th April 2016 a.m.

Time allowed: 135 min

Write your name, candidate number and centre number at the top of this page, and on all work you hand in.
Write in dark blue or black pen, except the multiple choice answer grid, which should be answered in pencil. You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
You may use a calculator.
Multiple choice questions are worth *two* marks each.
The number of marks for the written answer questions is at the end of each question or part question.
You may lose marks if you do not show your working or if you do not use appropriate units.
You are advised to spend no more than 45 minutes on the multiple choice portion of the exam.

Section A:
This section has **twenty (20)** questions. Answer **all** the questions
For each question there are four possible answers; **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice on the separate answer sheet, following the instructions on that sheet.
Read the instructions on the answer sheet very carefully.
Each correct answer will score **two** marks. Marks will not be deducted for a wrong answer.
Any working should be done in this booklet. You will not be marked on this.

Section B:
This section has **seven (7)** questions. Answer **all** the questions, writing on the question paper.

Section A

(Multiple Choice)

Answer on the separate sheet

Each question is worth 2 marks

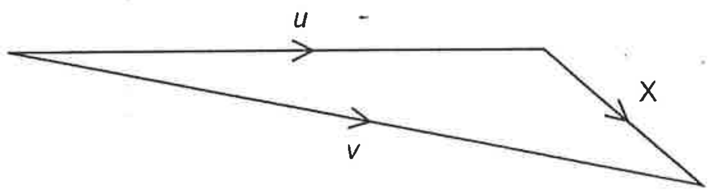
You are advised to spend no more than 45 minutes on this section

1 Which pair includes a vector quantity and a scalar quantity?

A	displacement;	acceleration
B	force;	kinetic energy
C	power;	speed
D	work;	potential energy

2. An object has an initial velocity *u*. It is subjected to a constant force *F* for *t* seconds, causing a constant acceleration *a*. The force is **not** in the same direction as the initial velocity.

A vector diagram is drawn to find the final velocity *v*.



What is the length of side X of the vector diagram?

A F **B** Ft **C** at **D** $u + at$

3. A stone is dropped from the top of a tower of height 40 m. The stone falls from rest and air resistance is negligible.

What time is taken for the stone to fall the last 10 m to the ground?

A 0.38 s **B** 1.4 s **C** 2.5 s **D** 2.9 s

4. A cyclist is riding at a steady speed on a level road.

According to Newton's third law of motion, what is equal and opposite to the backward push of the back wheel on the road?

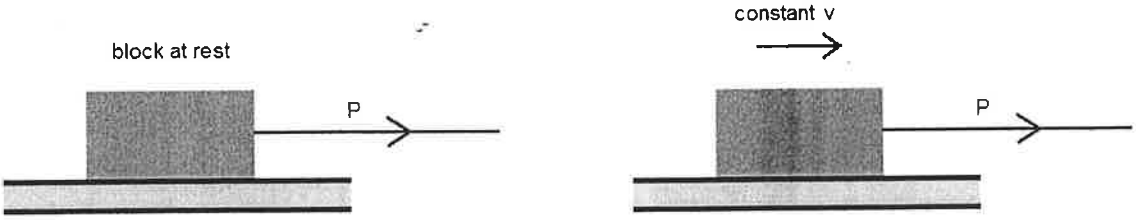
A the force exerted by the cyclist on the pedals

B the forward push of the road on the back wheel

C the tension in the cycle chain

D the total air resistance and friction force

A5. A wooden block sits on a rough horizontal surface as shown. On the left, the block is at rest. The picture on the right shows the block is moving at constant velocity v. The force P is pulling the block to the right.



The coefficient of static friction between the block and the plane is μ_s.

The coefficient of dynamic friction between the block and the plane is μ_d and it is slightly smaller than μ_s.

Which of the statements below are correct?

~~allow B or C~~ B (allow C)

I. The pulling force P is the same in both cases.
II. The resultant force on the block is the same in both cases.
III. The work done on the block is the same in both cases.

A. I only B. II only C. I & II D. I, II and III

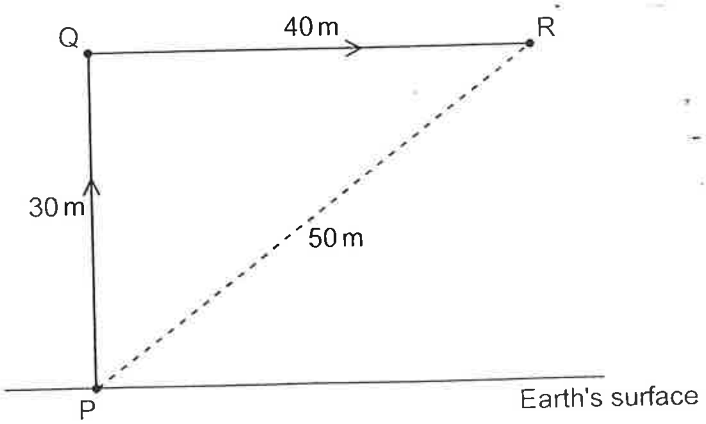
A6. A motorist travelling at 10 m s^{-1} can bring his car to rest in a braking distance of 10 m.

In what distance could he bring the car to rest from a speed of 30 m s^{-1} using the same braking force?

D

A 17 m B 30 m C 52 m D 90 m

A7. A stone of weight 4.0 N in the Earth's gravitational field is moved from P to Q and then to R along the path shown.

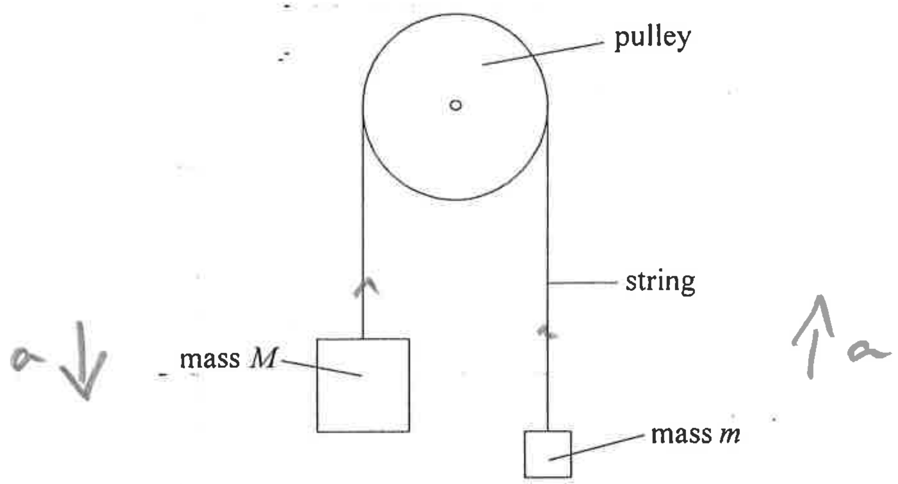


A

How much potential energy does the stone gain?

A 120 J B 200 J C 280 J D 1200 J

A8. A light inextensible string has a mass attached to each end and passes over a frictionless pulley as shown.



The masses are of magnitudes M and m, where $m < M$. The acceleration of free fall is g. The downward acceleration of the mass M is

A $\dfrac{(M-m)g}{(M+m)}$.

B. $\dfrac{(M-m)g}{M}$.

C. $\dfrac{(M+m)g}{(M-m)}$.

D. $\dfrac{Mg}{(M+m)}$.

A9. A particle has kinetic energy E and its associated de Broglie wavelength is λ. The energy E is proportional to

A. λ^2.

B. λ.

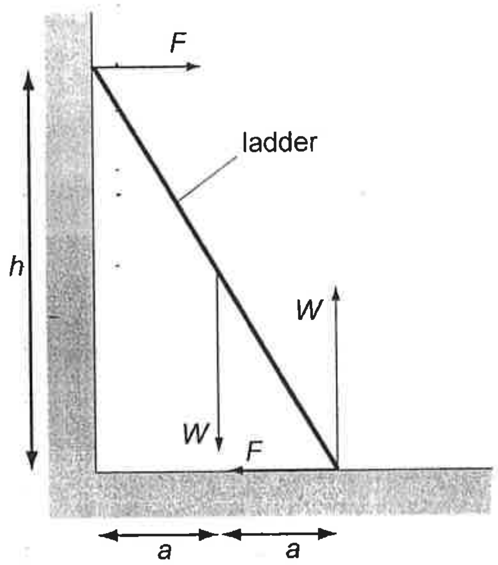
C. λ^{-1}.

D. λ^{-2}.

A 10

A uniform ladder rests against a vertical wall where there is negligible friction. The bottom of the ladder rests on rough ground where there is friction. The top of the ladder is at a height h above the ground and the foot of the ladder is at a distance $2a$ from the wall.

The diagram shows the forces which act on the ladder.



Which equation is formed by taking moments?

A $Wa + Fh = 2Wa$

B $Fa + Wa = Fh$

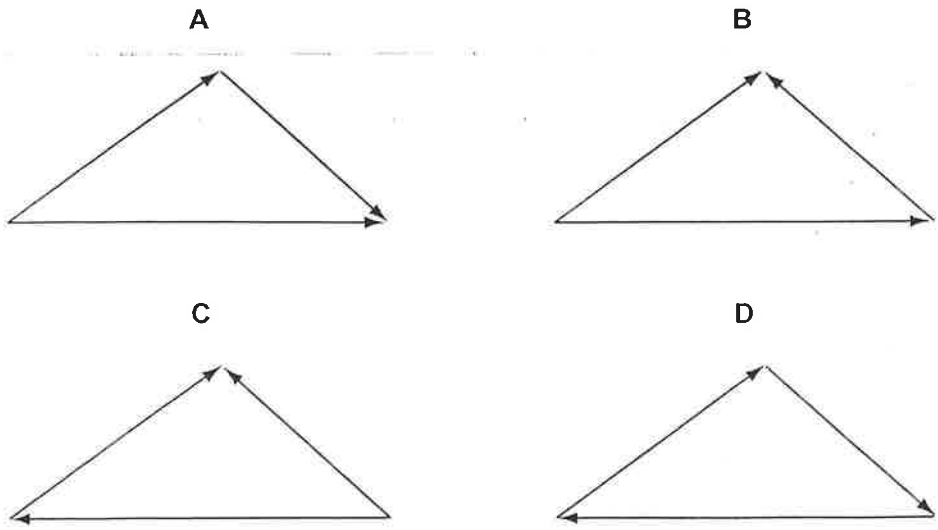
C $Wa + 2Wa = Fh$

D $Wa - 2Wa = 2Fh$

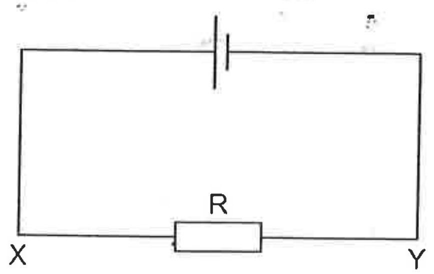
A (take moments around top of ladder).

A11. The diagrams show three forces acting on a body. D

In which diagram is the body in equilibrium?



A 12. The current in the circuit is 4.8 A.



What is the rate of flow and the direction of flow of electrons through the resistor R?

A $3.0 \times 10^{19}\,s^{-1}$ in direction X to Y

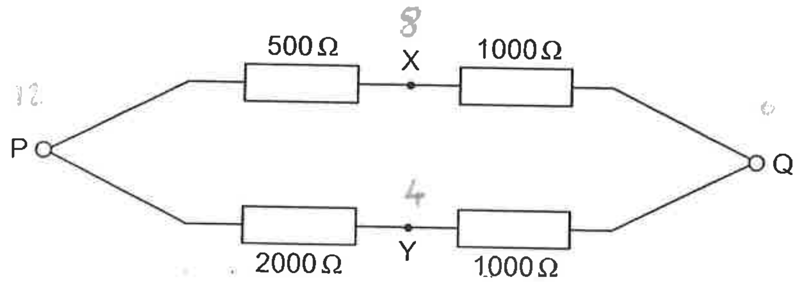
B $6.0 \times 10^{18}\,s^{-1}$ in direction X to Y

C $3.0 \times 10^{19}\,s^{-1}$ in direction Y to X

D $6.0 \times 10^{18}\,s^{-1}$ in direction Y to X

C

A 13. A p.d. of 12 V is connected between P and Q.



What is the p.d. between X and Y?

A 0 V B 4 V C 6 V D 8 V

B

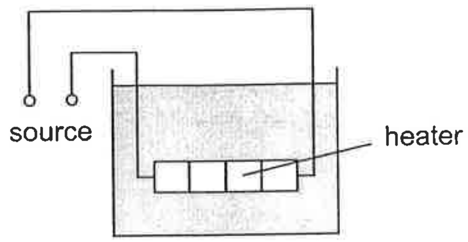
A 14. An electric kettle running at 230 V and 8.0 A is used to boil water. The switch is kept pressed down so that the water keeps boiling. The specific latent heat of vaporization of water is 22.6×10^6 J/kg. How much water will evaporate in 5 minutes?

A 2.4 g B 3.0 g C: 24 g D: 30 g

$IVt = mL$ $m = \frac{IVt}{L}$

C.

A 15 The diagram shows a low-voltage circuit for heating the water in a fish tank.



$I = \frac{12V}{4\Omega} = 3A$. $V = 9V$ $P = 27W$

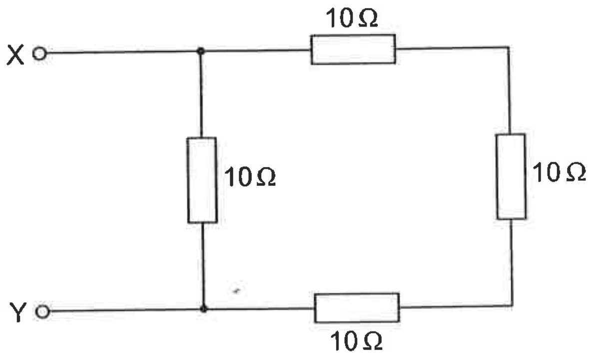
The heater has a resistance of 3.0 Ω. The voltage source has an e.m.f. of 12 V and an internal resistance of 1.0 Ω.

At what rate does the voltage source supply energy to the heater?

A 27 W   B 36 W   C 48 W   D 64 W

A.

A 16 The diagram shows an arrangement of resistors.



What is the total electrical resistance between X and Y?

A less than 1 Ω

B between 1 Ω and 10 Ω

C between 10 Ω and 30 Ω

D 40 Ω

B

A17

Which phenomenon is associated with transverse waves but **not** longitudinal waves?

A polarisation

B reflection

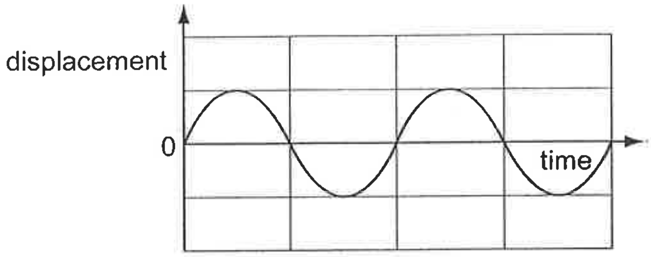
C refraction

D superposition

A

A18

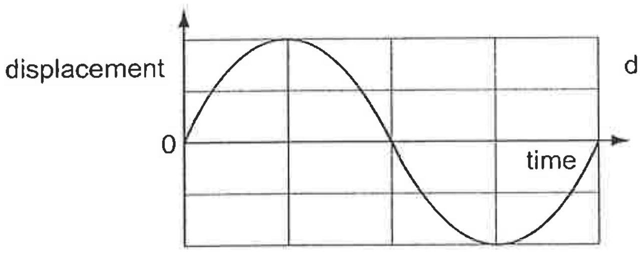
A displacement-time graph is shown for a particular wave.



A second wave of similar type has twice the intensity and half the frequency.

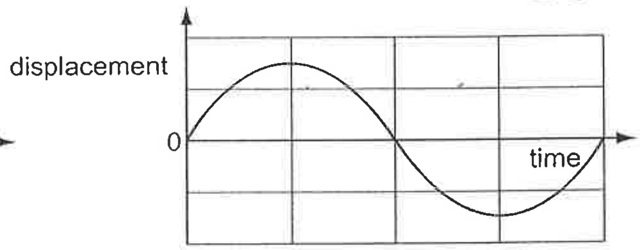
When drawn on the same axes, what would the second wave look like?

A

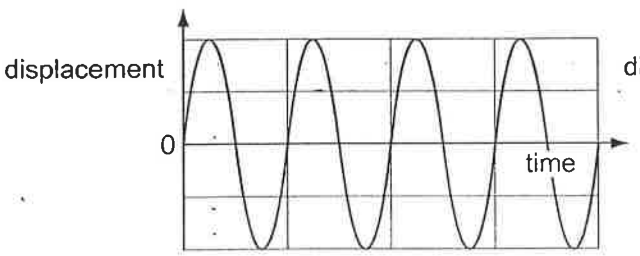


B

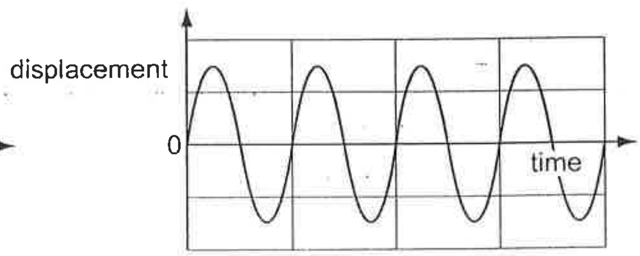
B



C



D



A19

The frequency of a certain wave is 500 Hz and its speed is 340 m s^{-1}.

$\lambda = 0.68$ m

What is the phase difference between the motions of two points on the wave 0.17 m apart?

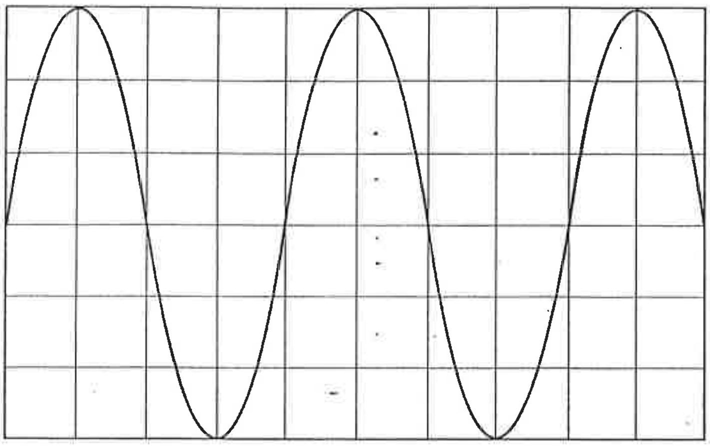
$\frac{1}{4}\lambda$

A $\frac{\pi}{4}$ rad **B** $\frac{\pi}{2}$ rad **C** $\frac{3\pi}{4}$ rad **D** π rad

B

A 20.

The cathode-ray oscilloscope (c.r.o.) display shows the waveform produced by an electronic circuit. The c.r.o. time-base is set at 10 ms per division.



What is the period of the signal shown?

A 20 ms **B** 30 ms **C** 40 ms **D** 80 ms

C

Section B

(Structured Questions)

Answer all the questions

Answer in this booklet

B1. Two astronauts, Tim and Igor, are doing some maintenance outside of the International Space Station (ISS). Tim's mass is 80 kg and he is holding a tool box of mass 10 kg. Igor's mass is 90 kg. Tim and Igor are separated by 10 m and both are stationary relative to the ISS and not in direct contact with it. Tim pushes the tool box towards Igor, giving it a speed of 3 ms^{-1}. When it reaches him, Igor grabs hold of the toolbox.

a. Calculate the velocity of Tim after he releases the tool box. [3]

Momentum of toolbox = mv = 10kg × 3m/s = 30kgm/s ✓①

Momentum is conserved ✓①

thus Tim's ~~mom~~ velocity = (−) $\frac{30 \text{ m/s}}{80 \text{ kg}}$ = (−) 0.375 m/s

0.4 m/s to 1sf. ✓①

(ignore presence/absence of minus sign)

b. Calculate Tim's kinetic energy after he releases the tool box. [2]

$E_k = \frac{1}{2}mv^2$ ✓①

$E_k = \frac{1}{2} \times 80\text{kg} \times (0.375\text{m/s})^2 = 5.625\text{J}$ ✓①

6 J to 1sf.

(No sig. figs. penalty)

c. Calculate the speed of Igor (and the toolbox) after he grabs the tool box. [3]

Combined mass = 100 kg ✓①

Momentum is still 30 kg m/s ✓①

Velocity is $\frac{30\text{kg m/s}}{100\text{kg}} = 0.3\text{ms}^{-1}$ ✓①

Having grabbed the tool box, Igor is now travelling away from the ISS. He uses his rocket pack to bring himself to rest, whilst maintaining his grip on the tool box. The rocket pack brings him to rest after a 5 s burn.

d. Calculate the average force exerted by the rocket pack. [3]

Impulse = change in momentum ✓①

Impulse = Force × Time ✓①

$F = \frac{30\text{kg m/s}}{5\text{s}} = 6\text{N}$ ✓①

[Total: 10]

B2.

A sample of copper wire has an electrical resistance of 5 Ω. A sample of iron wire has a resistance of 10 Ω. Both wires are of cylindrical construction and have the same radius. The resistivity of copper is 1.7×10^{-8} Ωm and that of iron is 1.0×10^{-7} Ωm. The copper wire has length L.

a. What is the length of the iron sample, in terms of L? [3]

$R = \frac{\rho l}{A}$ in any form ✓(1) thus $L = \frac{AR}{\rho}$

A is constant thus $L \propto \frac{R}{\rho}$ OWTTE ✓(1).

R doubles, ρ increases by factor $\frac{100}{17}$ thus length is $\frac{2 \times 17}{100} L = 0.34L$ ✓(1)

b. Given that the radius of the (cylindrical) wire is 3×10^{-4} m, calculate L. [2]

$L = \frac{AR}{\rho} = \frac{\pi r^2 R}{\rho}$ ✓(1)

$L = \frac{\pi \times (3 \times 10^{-4} m)^2 \times 5 \Omega}{1.7 \times 10^{-8} \Omega m}$

$L = 83$ m ✓(1)

A 1 Ω resistor and a 4 Ω resistor are connected in parallel and a 15 V cell with an internal resistance of 0.2 Ω is connected across the pair of resistors.

c. Under these circumstances, what is the total power dissipated by the *load* in the circuit? [3]

Effective load $R = \frac{1}{\frac{1}{1} + \frac{1}{4}} \Omega = \frac{4}{5} \Omega$. ✓(1)

Total R of circuit = 1 Ω.

Current = 15 A ✓(1)

✓ credit for alternative methods.

Power = $I^2 R = (15A)^2 \times 0.8 \Omega = 180 W$ ✓(1)

d. The 4 Ω resistor is replaced with a 0.25 Ω resistor. Without actually performing a complete calculation state whether the power dissipated in the load will now be higher or lower. Justify your answer. [2]

Higher ✓(1) since load resistance is now close to internal resistance. ✓(1)

[Total: 10]

B3 (a) One end of a long string is attached to an oscillator. The string passes over a frictionless pulley and is kept taut by means of a weight, as shown in Fig. 5.1.

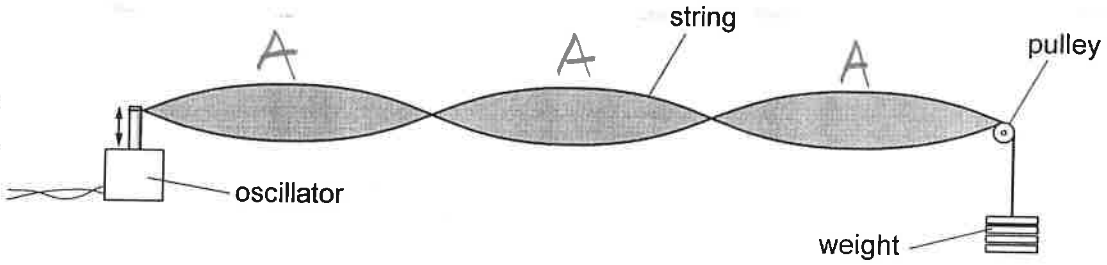


Fig. 5.1

The frequency of oscillation is varied and, at one value of frequency, the wave formed on the string is as shown in Fig. 5.1.

(i) Explain why the wave is said to be a *stationary wave*.

✓(1) Steady pattern (of nodes and antinodes) .... [1]

(ii) State what is meant by an *antinode*.

✓(1) A point of maximum variation (of displacement) .... [1]

(iii) On Fig. 5.1, label the antinodes with the letter A. ✓(1) at least 2 with none incorrect [1]

(b) A weight of 4.00 N is hung from the string in **(b)** and the frequency of oscillation is adjusted until a stationary wave is formed on the string. The separation of the antinodes on the string is 17.8 cm for a frequency of 125 Hz.
The speed v of waves on a string is given by the expression

$$v = \sqrt{\frac{T}{m}},$$

where T is the tension in the string and m is its mass per unit length.
Determine the mass per unit length of the string.

$v = f\lambda$ in any form or implied ✓(1)

$\lambda = 35.6\text{ cm}$ ✓(1) $\lambda = 0.356\text{ m}$

$v = \sqrt{\frac{T}{m}} \therefore v^2 = \frac{T}{m} \therefore m = \frac{T}{v^2}$ ✓(1) $m = \frac{4.00\text{N}}{(125\text{Hz} \times 0.356\text{m})^2} =$

mass per unit length = 2.02×10^{-3} ✓(1) kg m^{-1} [4]

(allow 2.0)

(TOTAL 7)

B4. A laser pointer emits light of wavelength 532 nm and has a power output of 100 mW. In a science lecture, the laser is directed at a balloon and after about 0.05 s the balloon bursts.

a. Calculate the frequency of the light emitted by the laser. [2]

$f = \frac{c}{\lambda}$ ✓① $f = \frac{3.00 \times 10^{8} m/s}{5.32 \times 10^{-7} m} = 5.64 \times 10^{14} Hz$ ✓①

b. Calculate the energy required to burst the balloon. [2]

$E = Pt$ ✓①

$E = 0.1 W \times 0.05 s = 0.005 J$ ✓①

A lower power version of the laser is directed at a diffraction grating with a slit density of 400 lines per mm.

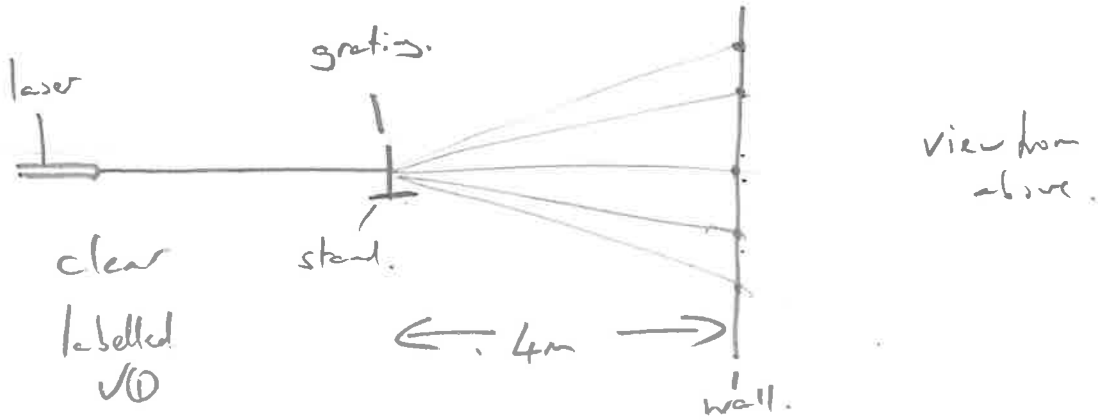
c. Calculate the distance between adjacent slits on the diffraction grating, giving your answer in metres. [3] $1 mm = 0.001 m$ ✓①

$d = \frac{1 \times 10^{-3} m}{400}$ ✓①

$d = 2.5 \times 10^{-6} m$ ✓①

A very large white wall is located 4 m behind the grating and the diffraction pattern can be seen on the wall.

d. In the space below, draw a diagram of the experimental set up. [2]



correct clear ✓①

clear labelled ✓①

diagram.

e. Calculate the distance on the screen between the bright central maximum and the first order maximum for this diffraction pattern. [3]

$$\frac{x}{D} \approx \frac{\lambda}{d} \quad ✓①$$

$$x = \frac{D\lambda}{d} = \frac{4\,m \times 5.32 \times 10^{-7}\,m}{2.5 \times 10^{-6}\,m} = 0.8512\,m$$

✓① (e.c.f.) ✓①

or 0.85m to 2sf or 0.9m to 1sf.

The width of each individual slit in the grating is 0.625 μm.

f. Calculate the number of maxima that you would expect to be visible either side of the bright central maximum. [4]

Path difference can never exceed d ✓①

so $n_{max} = \frac{d}{\lambda} = 4.7$ (max n is thus 4) ✓①.

BUT the 4th order maximum angle coincides with a $b \sin\theta = \lambda$ minimum

so it's absent ✓✓②

[Total: 16].

B5 (a) Tensile forces are applied to opposite ends of a copper rod so that the rod is stretched. The variation with stress of the strain of the rod is shown in Fig. 5.1.

For Examiner's Use

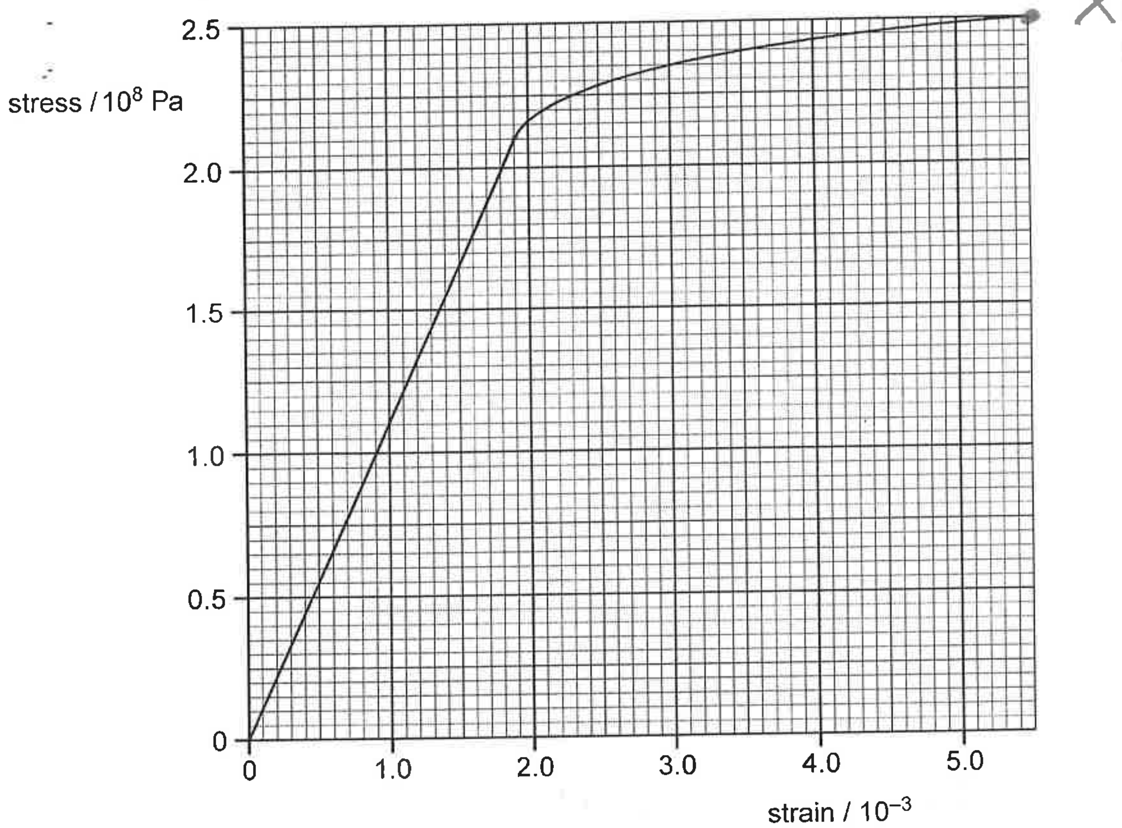


Fig. 5.1

(i) Use Fig. 5.1 to determine the Young modulus of copper.

stress / strain ✓①

gradient of straight line ✓①

$\frac{2.2\times10^{8}\,Pa}{1.9\times10^{-3}}$ =

Young modulus = 1.16×10^{11} Pa [3] ✓①

(ii) On Fig. 5.1, sketch a line to show the variation with stress of the strain of the rod as the stress is reduced from 2.5×10^6 Pa to zero. No further calculations are expected. [1]

Straight line same gradient
[illegible] through X ✓①.

(b) The walls of the tyres on a car are made of a rubber compound.
The variation with stress of the strain of a specimen of this rubber compound is shown in Fig. 5.2.

For Examiner's Use

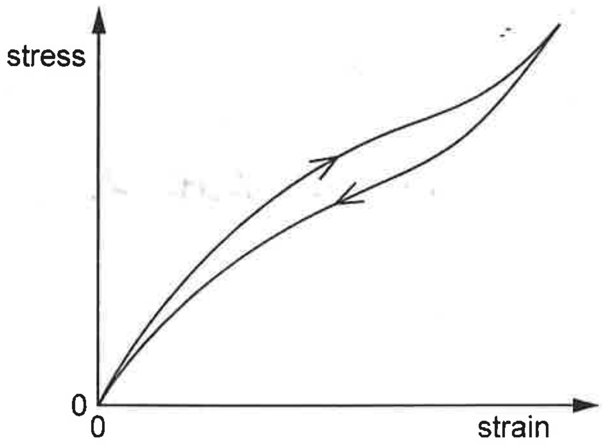


Fig. 5.2

As the car moves, the walls of the tyres bend and straighten continuously.

Use Fig. 5.2 to explain why the walls of the tyres become warm.

✓① Area under line = work done (per unit volume)

✓① Work done on material when stretching > work performed by the material on release

✓① Difference between two converted to heat

.... [3]

[Total : 7]

B6. Starbase Ulysses and Starbase Pikachu have zero velocity relative to each other. A radio signal takes 8 days to travel from one to the other. Camp Ewok is a small base half-way between them, which is also stationary with respect to the starbases.

a. Captain Zep of the starship Condor travels at 80% of the speed of light from Starbase Ulysses to Starbase Pikachu. Showing your working:

i. calculate the time in days taken for the journey in Starbase Ulysses's frame of reference.

8 days × ~~4/5~~ 5/4 = ~~6.4~~ 10 days ✓① ✓①

[2]

ii. calculate the time in days taken for the journey in Captain Zep's frame of reference.

$t' = \frac{t}{\sqrt{1-v^2/c^2}}$ ✓①

t' is Starbase time, t is Zep time (i.e. time is less for Zep) ✓①

$t = $ ~~6.4~~ 10 days $\times \sqrt{1-(\frac{4}{5})^2} = $ ~~3.84~~ 6 days ✓①

[3]

b. As Captain Zep passes Camp Ewok, he sends out two radio signals – one towards Starbase Ulysses and one towards Starbase Pikachu.

State and explain which radio signal arrives at its destination first:

i. in Camp Ewok's frame of reference

They arrive simultaneously ✓① since they both travel at speed c OWTTE ✓①

[2]

ii. in Captain Zep's frame of reference

The signal arrives at Starbase Pikachu first ✓①

since in Zep's frame of reference Pikachu is moving towards the signal OWTTE ✓①

[2]

NOT the signal is moving at more than c.

c. While in flight, the starship Condor is 160m long from beak to tail in Camp Ewok's frame of reference. State and explain whether it is longer, shorter or the same length in Captain Zep's frame of reference.

LONGER ✓①

because from Camp Ewok's frame of reference it is length-contracted ✓①. [2]

[Total: 11]

B 7. When light falls on a metal surface, it may cause the emission of electrons. This is known as the *photoelectric effect*. It was discovered in the 1880s but not until 1905 did a satisfactory explanation emerge, when Einstein suggested a *photon* model of light.

a) Explain *two* ways in which observations of the photoelectric effect support a photon model of light rather than a classical wave model.

* Threshold frequency (existence of) : no reason for this in classical model (energy doesn't depend on f) in photon model explained by hf must exceed Φ

* Max KE of electrons depends on f not A/intensity : in classical model intensity controls energy : but in photon model E = hf − Φ.

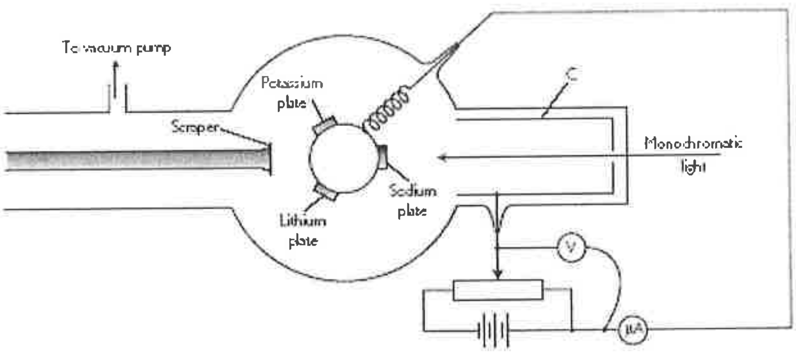
* Electrons may be emitted immediately : in classical model would take time to build up sufficient energy

in photon model always a non-zero probability of photon arrival.

(4)

Any TWO ✓ phenomenon ✓ explan

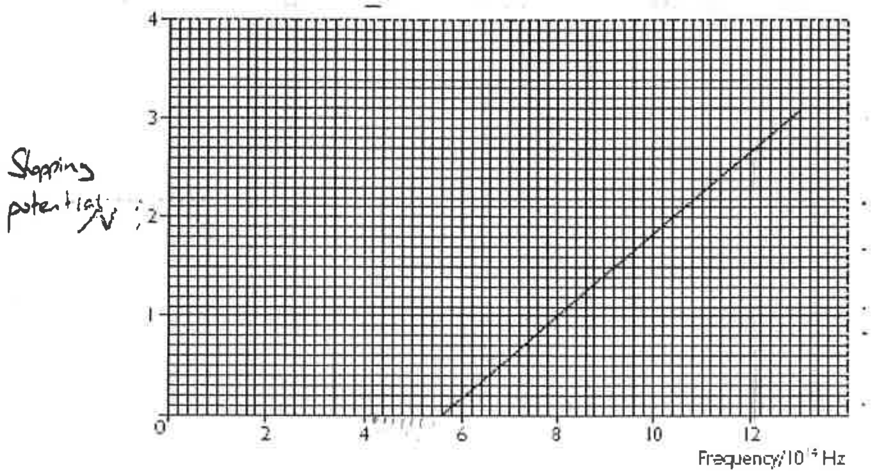
The diagram below shows an experiment conducted by Robert Millikan to test some of the predictions of Einstein's model.



As light falls on the sodium plate, electrons are emitted. The apparatus allows the sodium target to be replaced by one made of potassium or lithium. The scraper enables the metal surface to be cleaned before the experiment.

Millikan adjusted the potential divider until the current through the microammeter was zero. Using the voltmeter, he was able to measure the "stopping potential": that is, the p.d. between the surface of the anode and the cathode. In this way he was able to calculate the maximum kinetic energy of the electrons emitted.

A graph of stopping potential versus frequency is shown below



For light of frequency 1.15 x 10^{15} Hz, Millikan's results suggest a stopping voltage of 2.5V.

b) Showing your working, calculate:

✓①

i. The wavelength of this light

$v = f\lambda$ $\lambda = \frac{3.0 \times 10^{8}\ m/s}{1.15 \times 10^{15}\ Hz}$ $= 2.6 \times 10^{-7}\ m$

....

....(2)

ii. The energy of a photon of this light

$E = hf$ ✓① $E = 6.63 \times 10^{-34}\ Js \times 1.15 \times 10^{15}\ Hz$

....

$E = 7.6 \times 10^{-19}\ J$ ....(2)

c) Multiplying the stopping voltage of 2.5V by the charge on an electron (1.6×10^{-19} C) gives 4.0×10^{-19} J.

Explain why this value represents the maximum kinetic energy of the emitted photoelectrons.

The kinetic energy of the electrons is converted to electric potential energy ✓① E = QV OWTTE ✓①

....(2)

d) Showing your working, use the graph to find:

i. the threshold frequency for sodium. 5.6×10^{14} Hz ✓① ....(1)

ii. the value of Planck's constant

find gradient ✓① (Ch/e) which is $\frac{3.0\text{ V}}{(12.8 - 5.6) \times 10^{14}\text{ Hz}}$ $= 4.17 \times 10^{-15}$ Js/C ✓① ....(3)

✓① multiply by e (6.67×10^{-34} Js). Nothing for just copying out h.

iii. the work function of sodium

✓① $\Phi = hf_0$ $= 3.7 \times 10^{-19}$ J ✓①

or other valid method ....(2)

allow answer in eV.

e) Explain the meaning of the term *work function*.

The (minimum) quantity of energy required to remove an electron from the surface of the material. ✓✓②

✓① if slightly confused ......(2)

or clear answer.

f) The work function for lithium is a little larger than it is for sodium. On the graph, sketch a line showing how the results might be expected to differ if the lithium target were used. (2)

Same gradient, straight line ①✓

displaced to the right ✓①

[Total: 20]