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AQA

Please write clearly in block capitals.

Centre number	
Candidate number	
Surname	
Forename(s)	
Candidate signature	

A-level
PHYSICS
Paper 1

Thursday 15 June 2017 Morning Time allowed: 2 hours

Materials
For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae booklet.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 85.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8–32	
TOTAL	

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Section A

Answer **all** questions in this section.

An isotope of potassium $^{40}_{19}\mathrm{K}$ is used to date rocks. The isotope decays into an isotope of argon (Ar) mainly by electron capture.

electron capture
charge is conserved
lepton number is conserved.

The decay is represented by this equation:

$$^{40}_{19}\mathrm{K} + {}^{0}_{-1}\mathrm{e} \rightarrow {}^{40}_{18}\mathrm{Ar} + {}^{0}_{0}\nu_e$$

Complete the equation to show the decay by filling in the gaps.

[2 marks]

Explain which fundamental interaction is responsible for the decay in question **1**.

[2 marks]

Weak interaction because the interaction is between hadrons and leptons.

One decay mechanism for the decay of $^{40}_{19}\mathrm{K}$ results in the argon nucleus having an excess energy of $1.46\ \mathrm{MeV}$. It loses this energy by emitting a single gamma photon.

Calculate the wavelength of the photon released by the argon nucleus.

[3 marks]

$E = 1.46\ \mathrm{MeV} = 1.46 \times 10^{6}\ \mathrm{eV}$
$= 1.46 \times 10^{6} \times 1.60 \times 10^{-19}\ \mathrm{J}$

$E = hf \rightarrow f = \frac{E}{h}$
$c = f\lambda \rightarrow c = \frac{E\lambda}{h} \rightarrow \lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.46 \times 1.6 \times 10^{6} \times 10^{-19}}$

$\lambda = 8.51 \times 10^{-13}\ \mathrm{m}$

wavelength = 8.51×10^{-13} m

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The potassium isotope can also decay by a second decay process to form a calcium-40 nuclide ($^{40}_{20}\text{Ca}$).

$^{40}_{19}K \longrightarrow {}^{40}_{20}Ca + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}_e$

Suggest how the emissions from a nucleus of decaying potassium can be used to confirm which decay process is occurring.

[3 marks]

This is a beta minus decay, an electron is released, as well as an antineutrino, which is not released in the previous decay, potassium to argon.

10

Turn over for the next question

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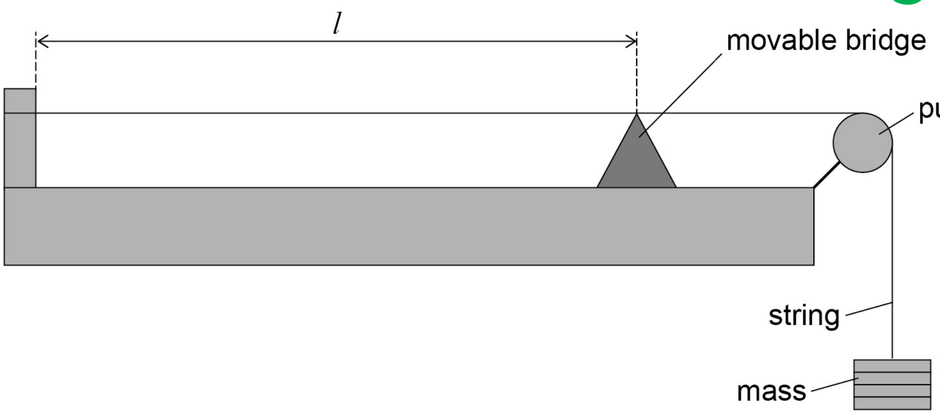
0 2 **Figure 1** shows an arrangement used by a student to investigate vibrations in a stretched nylon string of fixed length l. He measures how the frequency f of first-harmonic vibrations for the string varies with the mass m suspended from it.

Figure 1



$T = mg$

T

mg

$T = mg$

Table 1 shows the results of the experiment.

Table 1

	m / kg	f / Hz
1	0.50	110
2	0.80	140
3	1.20	170

$f = K\sqrt{T}$

$(T_1, f_1),\ (T_2, f_2)$

$f_1 = K\sqrt{T_1}$

$f_2 = K\sqrt{T_2}$

$\frac{f_2}{f_1} = \frac{\sqrt{T_2}}{\sqrt{T_1}} = \sqrt{\frac{T_2}{T_1}}$

Show that the data in **Table 1** are consistent with the relationship

$$f \propto \sqrt{T} \qquad T = mg$$

where T is the tension in the nylon string.

[2 marks]

$f \propto \sqrt{mg} \propto \sqrt{m}$

1 and 2:

$m: \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{0.8}{0.5}} = 1.264\ldots,\ \simeq 1.3\ (2s.f.)$ $f: \frac{f_2}{f_1} = \frac{140}{110} = 1.273\ldots \simeq 1.3\ (2s.f.)$

1 and 3

$m: \sqrt{\frac{m_3}{m_1}} = \sqrt{\frac{1.2}{0.5}} = 1.548\ldots,\ \simeq 1.5\ (2s.f.)$ $f: \frac{f_3}{f_1} = \frac{170}{110} = 1.545 \simeq 1.5\ (2s.f.)$

ratio of square root of masses is equal to ratio of frequencies therefore $f \propto \sqrt{m} \propto \sqrt{T}$.

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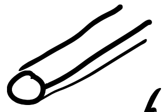
The nylon string used has a density of $1150\ \mathrm{kg\ m^{-3}}$ and a uniform diameter of 5.0×10^{-4} m.

Determine the length l of the string used.

[3 marks]

$\rho = \frac{m}{V}$, $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

$\rho = \frac{\mu l}{A \times l} = \frac{\mu}{A}$



$A = \pi \times \left(\frac{5\times10^{-4}}{2}\right)^2$

$= \pi r^2$

$\mu = \rho A = 1150 \times \pi \times (2.5\times10^{-4})^2$

$= 2.258... \times 10^{-4}\ \mathrm{kg\ m^{-1}}$

$l = \frac{1}{2f}\sqrt{\frac{T}{\mu}} = \frac{1}{2f}\sqrt{\frac{mg}{\mu}}$

$l = \frac{1}{2\times110}\sqrt{\frac{0.5\times9.81}{2.258...\times10^{-4}}}$

$= 0.669938... = 0.67$

l = 0.67 m

0 2 . 3 The student uses the relationship in question **1** to predict frequencies for tensions that are much larger than those used in the original experiment.

Explain how the actual frequencies produced would be different from those that the student predicts.

[2 marks]

As the tension is increased to large values, the diameter of the wire is decreased. As a result, the linear density decreases so the frequency must increase

7

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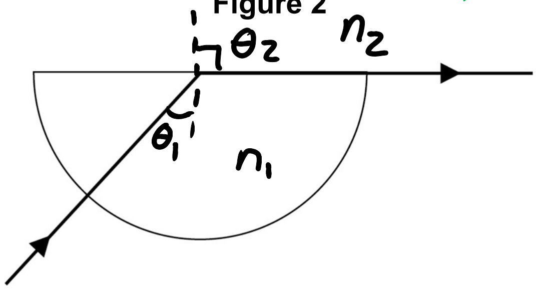
0 3 **Figure 2** shows a ray of monochromatic green light incident normally on the curved surface of a semicircular glass block.

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

Figure 2



The angle of refraction of the ray at the plane surface is 90°.

Refractive index of the glass used = 1.6

Calculate the angle of incidence of the ray on the flat surface of the block.

[1 mark]

$n_1 \sin\theta_1 = n_2 \sin\theta_2$, $\theta_2 = 90°$, $\sin\theta_2 = 1$

$n_2 = 1$

$\sin\theta_1 = \frac{n_2}{n_1} = \frac{1}{1.6}$

$\theta_1 = \sin^{-1}\left(\frac{1}{1.6}\right) = 38.682...$

$= 39°$ (2s.f.)

angle of incidence = 39 degrees

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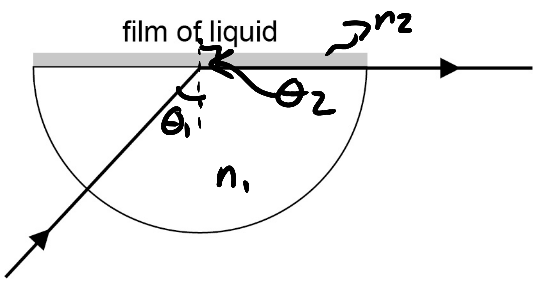
0 3 . 2 A thin film of liquid is placed on the flat surface of the glass block as shown in **Figure 3**.

Figure 3



The angle of incidence is changed so that the angle of refraction of the green light ray at the glass–liquid interface is again 90°. The angle of incidence is now 58°.

Calculate the refractive index of the liquid.

[2 marks]

$n_1 \sin\theta_1 = n_2 \sin\theta_2$, $\sin\theta_2 = \sin 90° = 1$

$n_2 = 1.6 \sin 58°$

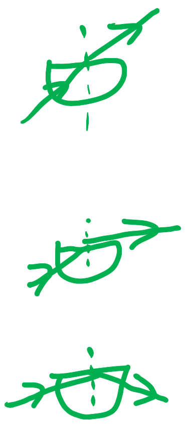
$n_2 = 1.35687... = 1.4$ (2 s.f.)

refractive index = 1.4

0 3 . 3 The source of green light is changed for one that contains only red and blue light. For any material red light has a lower refractive index than green light, and blue light has a higher refractive index than green light. The angle of incidence at the glass–liquid interface remains at 58°.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$\sin\theta_1 = \frac{n_3}{n_1}$

Describe and explain the paths followed by the red and blue rays immediately after the light is incident on the glass–liquid interface. Consider:



$n_1 \to 3n_1$, $n_2 \to 2n_2$
$\sin\theta_1 = \frac{2n_2}{3n_1}$

$n_1 \to 2n_1$, $n_2 \to 2n_2$
$\sin\theta_1 = \frac{2n_2}{2n_1} = \frac{n_2}{n_1}$

[3 marks]

We do not know by what factor the refractive indices n_1 and n_2 change. Therefore we cannot predict how the critical angle will change for red and blue light, and thus cannot predict how the paths of the light rays change.

6

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ANSWER IN THE SPACES PROVIDED**

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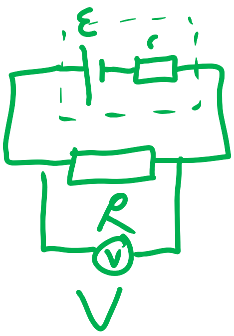
An engineer wants to use solar cells to provide energy for a filament lamp in a road sign.

The engineer first investigates the emf and internal resistance of a solar cell under typical operating conditions.

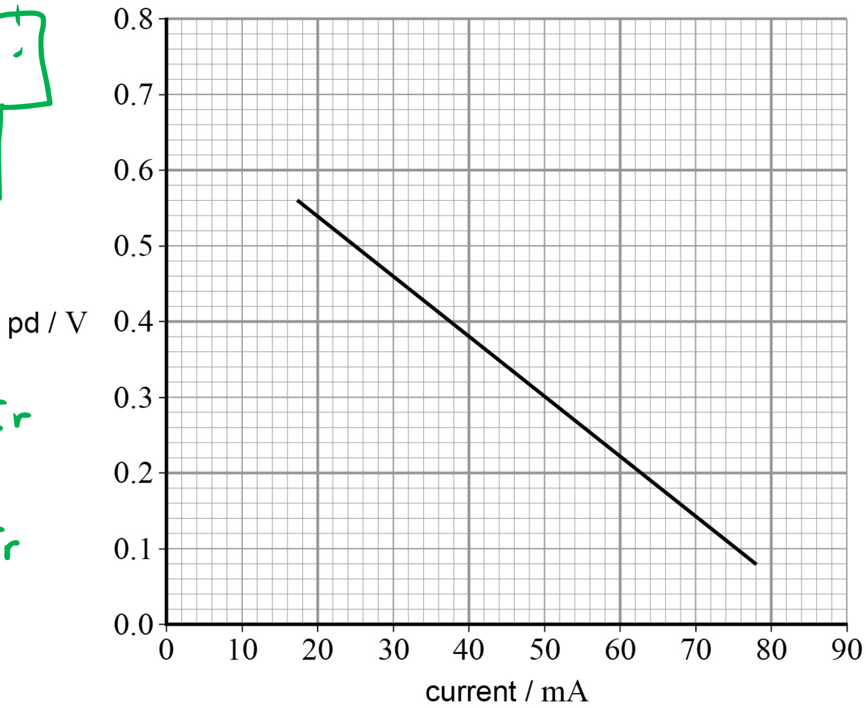
The engineer determines how the potential difference across the solar cell varies with current. The results are shown in the graph in **Figure 4**.



$\varepsilon = \underbrace{IR}_{V} + Ir$

$V = \varepsilon - Ir$

Figure 4



The engineer uses the graph to deduce that when operating in typical conditions a single solar cell produces an emf of 0.70 V and has an internal resistance of 8.0 Ω.

Explain how the engineer uses the graph to obtain the values for the emf and internal resistance of the solar cell.

[2 marks]

The emf is the y-intercept of the graph, and the internal resistance is the negative of the gradient of the graph (minus the gradient).

Question 4 continues on the next page

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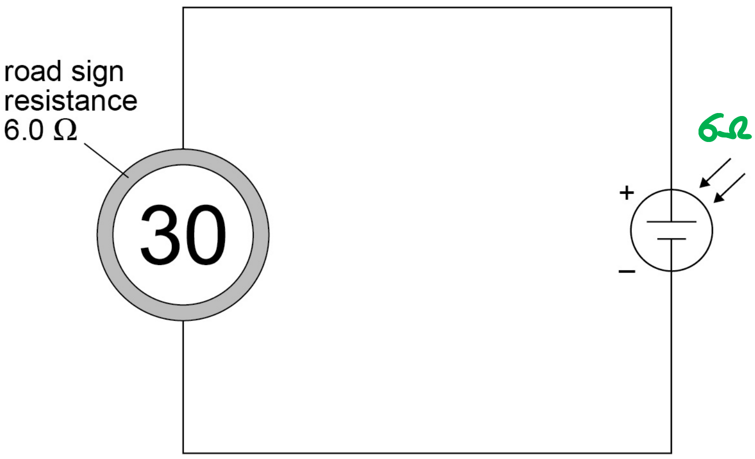
To operate effectively the lamp in the road sign needs a minimum current of 75 mA. At this current the resistance of the filament lamp is 6.0 Ω.

The engineer proposes to try the two circuits shown in **Figure 5** and **Figure 6**.

Figure 5



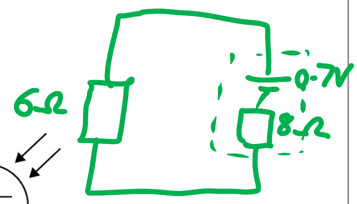
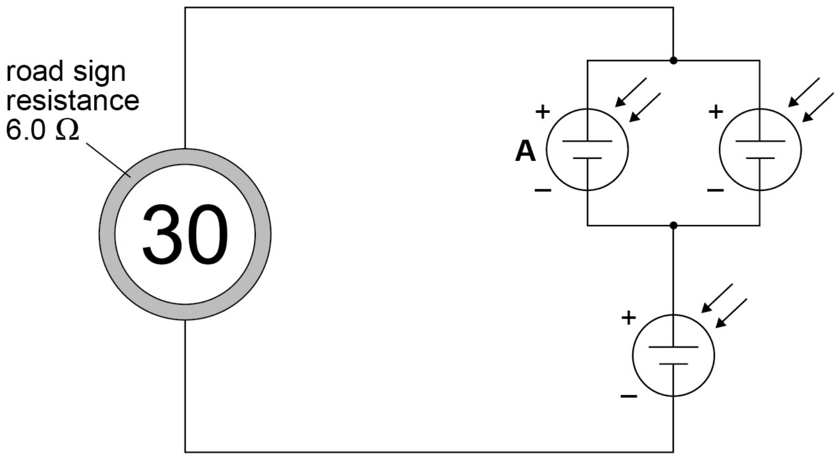
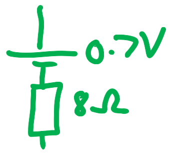
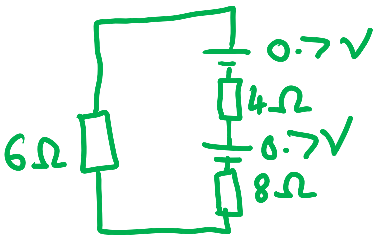
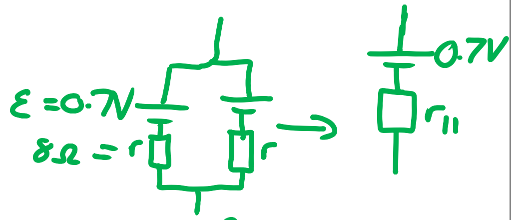


Figure 6









$$\frac{1}{r_{\parallel}} = \frac{1}{r} + \frac{1}{r} = \frac{2}{8}$$

Total emf is 1.4 V

Total internal resistance is 12Ω.

$$r_{\parallel} = 4\,\Omega$$

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Deduce, using calculations, whether the circuits in **Figure 5** and **Figure 6** are suitable for this application.

[4 marks]

Figure 5

$V = -rI + \varepsilon$

$V = IR$

$IR = -rI + \varepsilon$

$I(R+r) = \varepsilon$

$I = \frac{\varepsilon}{R+r} = \frac{0.7}{6.0+8.0} = 0.05A = 50mA$

$50mA < 75mA$

$\Rightarrow$ not suitable.

Figure 6

Emf in fig 6 is 1.4V

Internal resistance is 12Ω

$I = \frac{\varepsilon}{R+r} = \frac{1.4}{6+12} = 0.078A = 78mA$

$78mA > 75mA$

So the circuit in figure 6 is suitable.

Solar cells convert solar energy to useful electrical energy in the road sign with an efficiency of 4.0%. (0.04)

The solar-cell supply used by the engineer has a total surface area of 32 cm^2.

Calculate the minimum intensity, in $W\ m^{-2}$, of the sunlight needed to provide the minimum current of 75 mA to the road sign when it has a resistance of 6.0 Ω.

[3 marks]

$P = I^2R$

solar intensity $= \frac{\text{solar power}}{\text{area}}$

power dissipated in roadsign $P = (0.075)^2 \times 6 = 0.03375\ W$

solar power received $= \frac{0.03375}{0.04} = 0.84375W$

solar intensity $= \frac{0.84375}{32 \times (10^{-2})^2} = 263.6718...$

intensity = 260 $W\ m^{-2}$

9

Turn over ►

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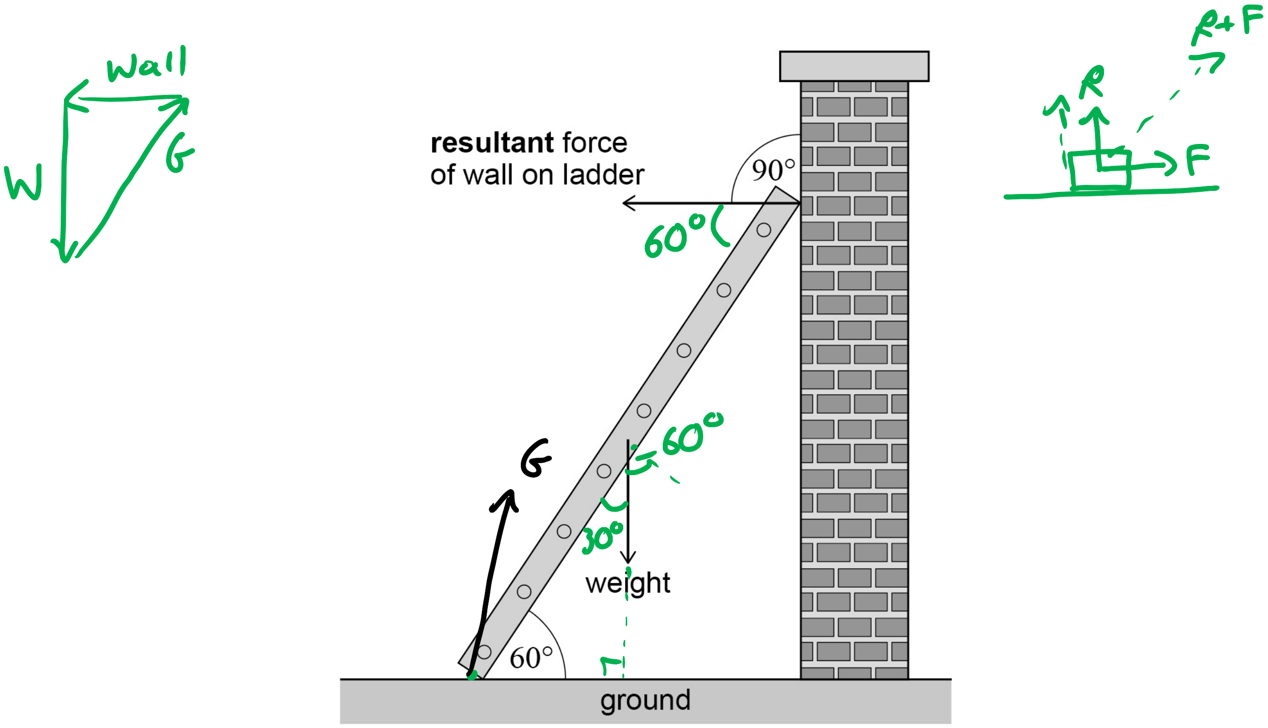
Figure 7 shows two of the forces acting on a uniform ladder resting against a vertical wall. The ladder is at an angle of 60° to the ground.

Figure 7



Explain how **Figure 7** shows that the friction between the ladder and the wall is negligible.

[1 mark]

The resultant force of the wall acting upon the ladder is at right angles to the wall.

The forces acting on the ladder are in equilibrium.

Draw an arrow on **Figure 7** to show the direction of the resultant force from the ground acting on the ladder. Label your arrow **G**.

[2 marks]

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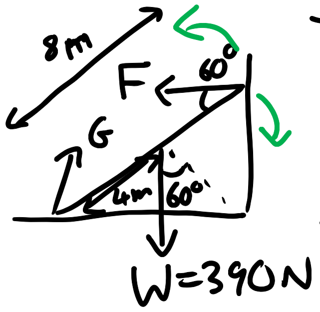
The ladder is 8.0 m long and weighs 390 N.

Calculate the magnitude of the resultant force from the wall on the ladder.

[2 marks]



Take moments about point of contact with ground.

Anticlockwise:

$F \times 8 \times \sin 60°$

Clockwise:

$W \times 4 \times \cos 60°$

$8F\sin 60° = 390 \times 4 \times \cos 60°$

$F = \dfrac{4 \times 390 \times \cos 60°}{8 \times \sin 60°}$

$F = 112.583...$

resultant force = 113 N

Suggest the changes to the forces acting on the ladder that occur when someone climbs the ladder.

[3 marks]

Normal force from the ground increases, which means that the frictional force from the ground also increases in magnitude. This means that the resultant force from the wall acting upon the ladder also increases to keep the ladder+person in equilibrium.

8

Turn over ▶

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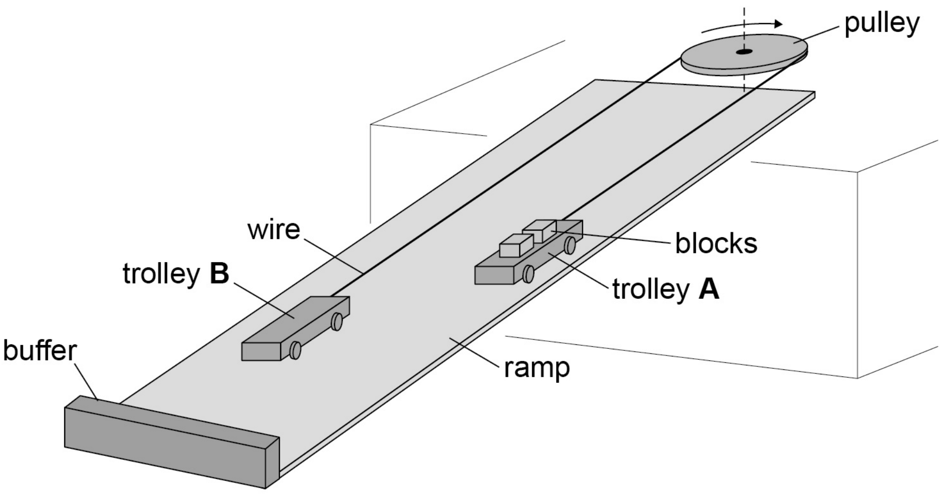
Figure 8 shows a model of a system being designed to move concrete building blocks from an upper to a lower level.

Figure 8



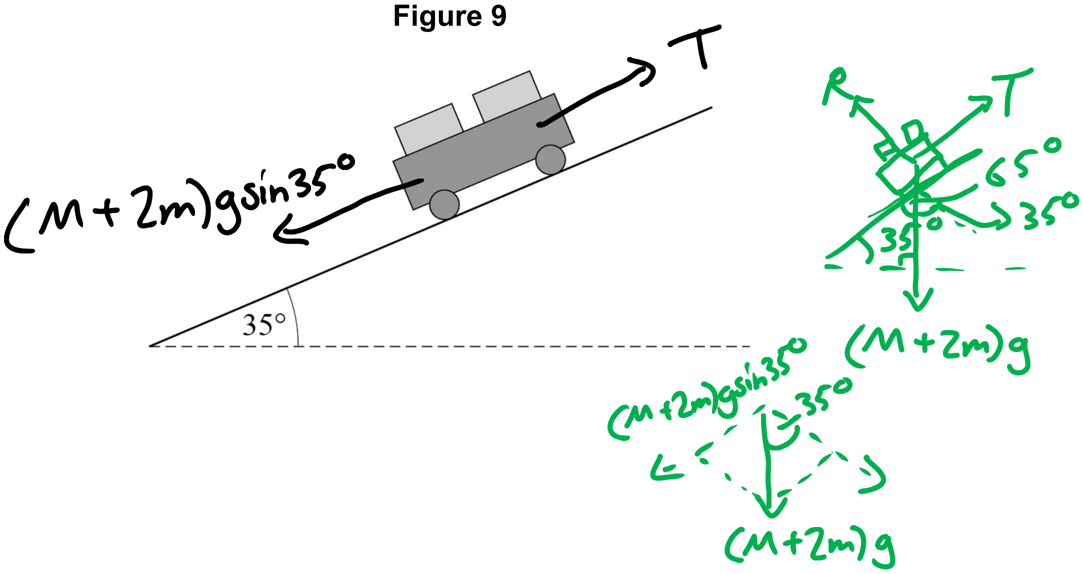
The model consists of two identical trolleys of mass M on a ramp which is at $35°$ to the horizontal. The trolleys are connected by a wire that passes around a pulley of negligible mass at the top of the ramp.

Two concrete blocks each of mass m are loaded onto trolley **A** at the top of the ramp. The trolley is released and accelerates to the bottom of the ramp where it is stopped by a flexible buffer. The blocks are unloaded from trolley **A** and two blocks are loaded onto trolley **B** that is now at the top of the ramp. The trolleys are released and the process is repeated.

Figure 9 shows the side view of trolley **A** when it is moving **down** the ramp.

$W = \text{mass} \times g$

Figure 9



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The tension in the wire when the trolleys are moving is T.

Draw and label arrows on **Figure 9** to represent the magnitudes and directions of any forces and components of forces that act on trolley **A** parallel to the ramp as it travels down the ramp.

[1 mark]

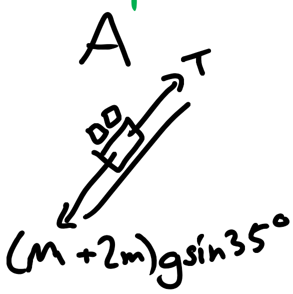
Assume that no friction acts at the axle of the pulley or at the axles of the trolleys and that air resistance is negligible.

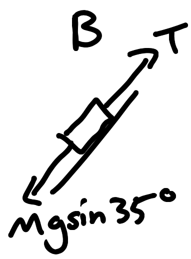
Show that the acceleration a of trolley **B** along the ramp is given by

$$a = \frac{mg\sin 35^{o}}{M+m}$$

[2 marks]

a is the same for A and B
T is the same for A and B





$F = \frac{\Delta p}{\Delta t} = \text{mass} \times a$

A: $(M+2m)g\sin 35^{o} - T = (M+2m)a$

B: $T - Mg\sin 35^{o} = Ma$

$(M+2m)g\sin 35^{o} - T + T - Mg\sin 35^{o} = (M+2m)a + Ma$

$2mg\sin 35^{o} = 2(M+m)a$

$a = \frac{mg\sin 35^{o}}{(M+m)}$

Compare the momentum of loaded trolley **A** as it moves downwards with the momentum of loaded trolley **B**.

[2 marks]

Both trolleys have the same mass, therefore have the same acceleration, and thus have the same momentum.

$p = \text{mass} \times v$

Turn over ►

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In practice, for safety reasons there is a friction brake in the pulley that provides a resistive force to reduce the acceleration to 25% of the maximum possible acceleration.

The distance travelled for each journey down the ramp is 9.0 m.

The following data apply to the arrangement.

Mass of a trolley M = 95 kg
Mass of a concrete block m = 30 kg

Calculate the time taken for a loaded trolley to travel down the ramp.

[3 marks]

$a = \frac{mg\sin 35°}{M+m}$

actual acceleration $= 0.25 \frac{mg\sin 35°}{M+m}$

$a' = 0.25 \frac{30 \times 9.81 \times \sin 35°}{95+30} = 0.3376...$

want t, distance s, acceleration a'. initial velocity $u = 0$. $s = \underbrace{ut}_{\to 0} + \frac{1}{2}a't^2$

$s = \frac{1}{2}a't^2 \Rightarrow \frac{2s}{a'} = t^2 \Rightarrow t = \sqrt{\frac{2s}{a'}}$

$t = \sqrt{\frac{2 \times 9}{0.3376...}} = 7.3018...$

time = 7.3 s

It takes 12 s to remove the blocks from the lower trolley and reload the upper trolley.

Calculate the number of blocks that can be transferred to the lower level in 30 minutes.

[2 marks]

Time taken for two

$12 + 7.3 = 19.3$ s

Total time is $30 \times 60 = 1800$ s

Total number of blocks is $\frac{1800}{19.3} \times 2$

$= 186.511$

$\to 186$

number = 186

10

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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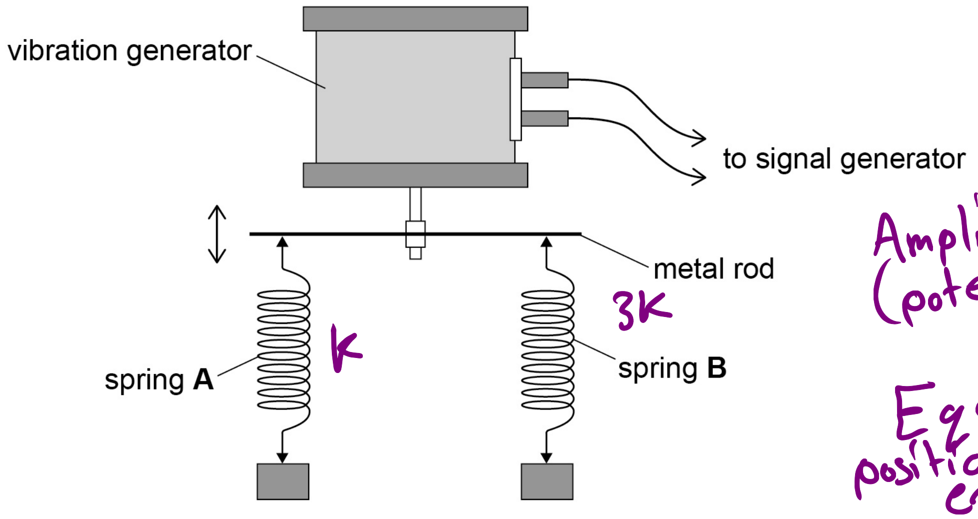
0 7 A student is investigating forced vertical oscillations in springs.
Two springs, **A** and **B**, are suspended from a horizontal metal rod that is attached to a vibration generator. The stiffness of **A** is k, and the stiffness of **B** is $3k$.
Two equal masses are suspended from the springs as shown in **Figure 10**.

Figure 10



Amplitude (potential energy only)
Equilibrium position (kinetic energy only)

The vibration generator is connected to a signal generator. The signal generator is used to vary the frequency of vibration of the metal rod. When the signal generator is set at 2.0 Hz, the mass attached to spring **A** oscillates with a maximum amplitude of 2.5×10^{-2} m and has a maximum kinetic energy of 54 mJ.

0 7 . 1 Deduce the spring constant k for spring **A** and the mass m suspended from it.

[4 marks]

Conservation of energy

$$54\,\text{mJ} = \frac{1}{2}k \times (2.5 \times 10^{-2})^2 \quad (\Delta L \text{ is } A)$$

$$k = \frac{2 \times 54 \times 10^{-3}}{(2.5 \times 10^{-2})^2} = 170\,\text{Nm}^{-1} \quad (172.8)$$

Potential energy in sping
$E_p = \frac{1}{2}k(\Delta L)^2$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \rightarrow 2\pi f = \sqrt{\frac{k}{m}}$$

$$(2\pi f)^2 = \frac{k}{m}$$

$$m = \frac{k}{(2\pi f)^2} = \frac{172.8}{(2\pi \times 2)^2} = 1.0942607\ldots$$

k = 170 N m^{-1}

m = 1.1 kg

Oscillates at maximum amplitude at natural

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0 7 . 2 Calculate the frequency at which the mass attached to spring **B** oscillates with maximum amplitude.

[2 marks]

frequency,

$$f = \frac{1}{2\pi}\sqrt{\frac{\text{spring constant}}{\text{mass}}}$$

$$\left[f = \frac{1}{T} \quad T = 2\pi\sqrt{\frac{\text{mass}}{\text{spring constant}}} \right]$$

$$f = \frac{1}{2\pi}\sqrt{\frac{3 \times 172.8}{1.0942687\ldots}}$$

$$= 3.46\ldots$$

(alternative method)

$f \propto \sqrt{k}$

$f = 2 \times \sqrt{3}$

frequency = 3.5 Hz

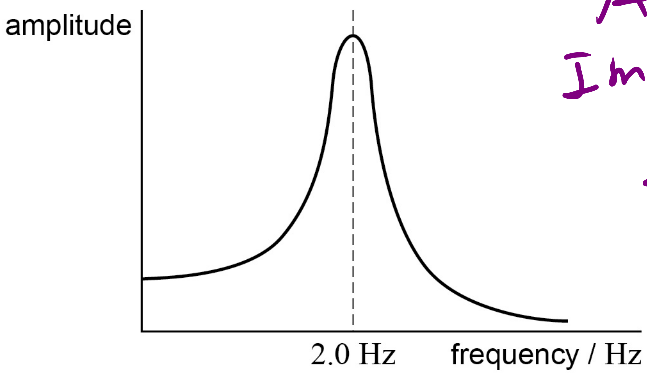
0 7 . 3 **Figure 11** shows how the amplitude of the oscillations of the mass varies with frequency for spring **A**.

(3.5 Hz)

Changed from A → B: higher natural frequency

Immersed in oil → more drag

Figure 11



The investigation is repeated with the mass attached to spring **B** immersed in a beaker of oil.

A graph of the variation of the amplitude with frequency for spring **B** is different from the graph in **Figure 11**.

Explain **two** differences in the graph for spring **B**.

[4 marks]

Difference 1 The peak is at a higher natural frequency, because B has a larger spring constant.

Difference 2 Amplitude is lower at all frequencies due to energy losses due to the mass moving through viscous oil.

10

Turn over ▶

Section B

Each of Questions **8** to **32** is followed by four responses, **A**, **B**, **C** and **D**.
For each question select the best response.

Only **one** answer per question is allowed.
For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD ⬬ WRONG METHODS

If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sh

neutral charge on the ion

$$\text{specific charge} = \frac{\text{amount of charge}}{\text{mass of ion}}$$

An atom of $^{16}_{7}N$ gains 3 electrons.

What is the specific charge of the ion?

[1 mark]

A $1.80 \times 10^{7}\ \mathrm{C\,kg^{-1}}$ ○

B $-1.80 \times 10^{7}\ \mathrm{C\,kg^{-1}}$ ●

C $4.19 \times 10^{7}\ \mathrm{C\,kg^{-1}}$ ○

D $-4.19 \times 10^{7}\ \mathrm{C\,kg^{-1}}$ ○

proton mass neutron mass

$$\text{mass} = 7 \times m_p + (16 - 7) \times m_n$$

$$\text{specific charge} = \frac{-3 \times e}{7 \times 1.673 \times 10^{-27} + 9 \times 1.675 \times 10^{-27}}$$

$$\simeq -1.8 \times 10^{7}\ \mathrm{C\,kg^{-1}}$$

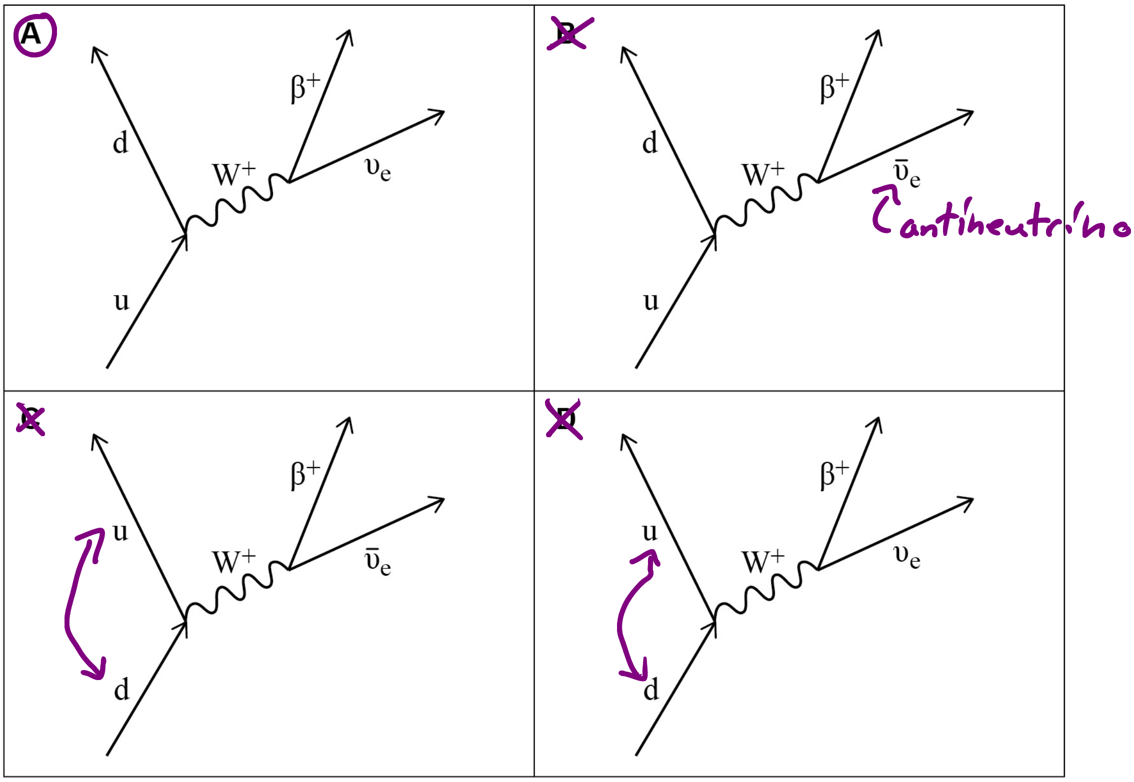
$^1_1p \longrightarrow {}^1_0n + {}^0_{+1}e^+ + {}^0_0\nu_e$

p : uud
n : udd

Do not write outside the box

0 9 Which diagram represents the process of beta-plus decay?

[1 mark]



A ☒

B ☐

C ☐

D ☐

Photoelectric effect: Each photon interacts with one e^-, exciting it.

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1 0 A beam of light of wavelength λ is incident on a clean metal surface and photoelectrons are emitted. The wavelength of the light is halved but energy incident per second is kept the same.

Incident energy $= nE_{photon}$

Which row in the table is correct?

[1 mark]

Before: λ, n number of photons

$E_{photon} = hf$, $c = f\lambda \rightarrow f = \frac{c}{\lambda}$ $\rightarrow E_{photon} = \frac{hc}{\lambda}$

	Maximum kinetic energy of the emitted photoelectrons	Number of photoelectrons emitted per second	
A	Increases	Unchanged	⬭
B	Decreases	Increases	⬭
C	Increases	Decreases	⬬
D	Decreases	Unchanged	⬭

Incident $E = \frac{nhc}{\lambda}$

Incident E the same:

$\frac{nhc}{\lambda} = \frac{n_{new}hc}{\lambda_{new}}$

$\frac{n}{\lambda} = \frac{n_{new}}{\lambda/2}$

$n_{new} = \frac{n}{2}$ = new number of photo e^-

Afterwards:

$\lambda_{new} = \frac{\lambda}{2}$

n_{new}

1 1 Electrons moving in a beam have the same de Broglie wavelength as protons in a separate beam moving at a speed of 2.8×10^4 m s^{-1}.

What is the speed of the electrons?

[1 mark]

A	1.5×10^1 m s^{-1}	⬭
B	2.8×10^4 m s^{-1}	⬭
C	1.2×10^6 m s^{-1}	⬭
D	5.1×10^7 m s^{-1}	⬬

$\lambda = \frac{h}{p}$, $\lambda_e = \frac{h}{p_e}$, $\lambda_p = \frac{h}{p_p}$

$\lambda_e = \lambda_p$, $\frac{h}{p_e} = \frac{h}{p_p} \rightarrow p_p = p_e$

$p = mv$, $m_p v_p = m_e v_e$

$v_e = \frac{m_p v_p}{m_e} = \frac{1.673 \times 10^{-27} \times 2.8 \times 10^4}{9.109 \times 10^{-31}}$

$\approx 5.1 \times 10^7$ m s^{-1}

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1 2 The diagram shows an energy level diagram for a hydrogen atom.

Electrons with energy 13.0 eV collide with atoms of hydrogen in their ground state.

What is the number of different wavelengths of electromagnetic radiation that could be emitted when the atoms de-excite?

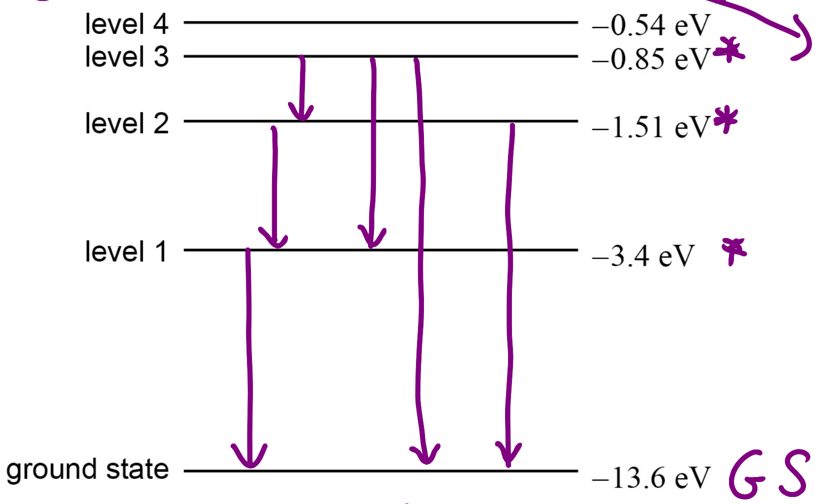
[1 mark]

$E=hf$, $c=f\lambda$ $f=\frac{c}{\lambda}$ $\Rightarrow E=\frac{hc}{\lambda}$

GS and 4 energy difference 13.06eV

GS and 3 " " 12.75eV

so can excite to level 3 and drop down by following paths:



A	0	○
B	3	○
C	6	●
D	7	○

$3 \rightarrow GS$

$3 \rightarrow 1 \rightarrow GS$

$3 \rightarrow 2 \rightarrow 1 \rightarrow GS$

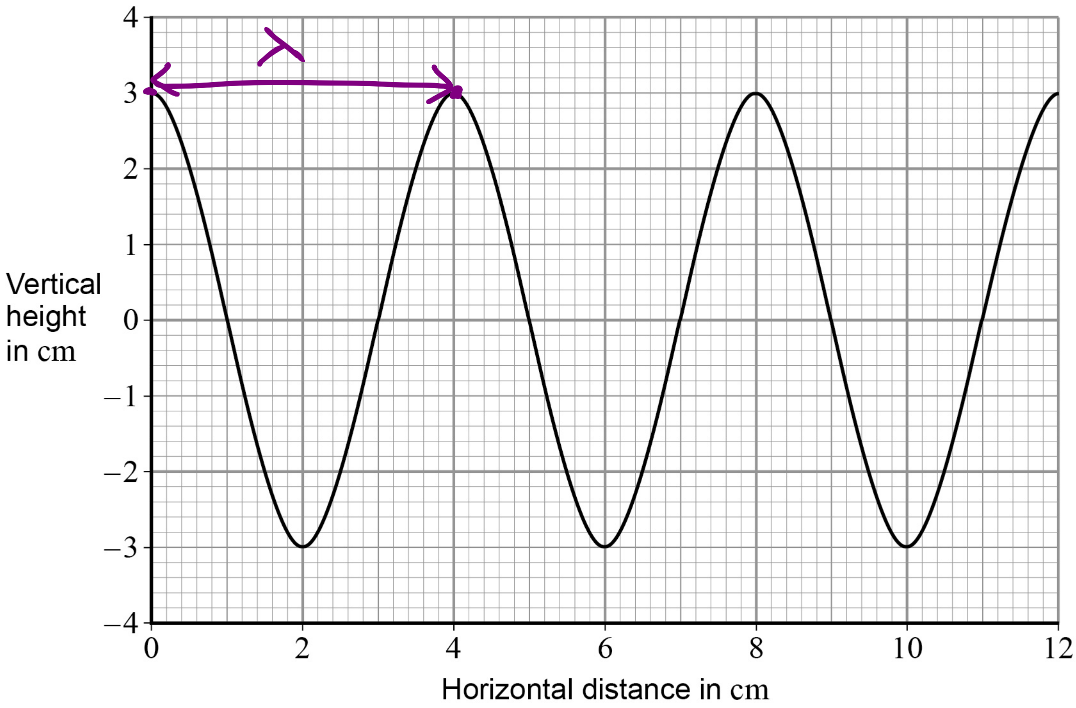
Each arrow corresponds to emission of a photon with different energy, by $E=\frac{hc}{\lambda}$, this gives a different wavelength

$\Rightarrow$ 6 photons.

Do not write outside the box

1 3 The graph shows how the vertical height of a travelling wave varies with distance along the path of the wave.

$c = f\lambda$ $f = \frac{1}{T} \rightarrow c = \frac{\lambda}{T}$



$T = \frac{\lambda}{c}$

$\lambda = 4\,cm$

$T = \frac{4\,cm}{20\,cm\,s^{-1}}$

$T = 0.2\,s$

The speed of the wave is 20 cm s^{-1}.

What is the period of the wave?

[1 mark]

A 0.1 s

B 0.2 s ●

C 5.0 s

D 10.0 s

1 4 Which statement is **not** correct for ultrasound and X-rays?

[1 mark]

A Both can be refracted

B Both can be diffracted

C Both can be polarised ●

D Both can be reflected

Longitudinal cannot be polarised (oscillation along direction of energy propagation)
Transverse can be polarised.

Ultrasound: Mechanical Longitudinal

X-Rays: EM Transverse

Do not write outside the box

1 5 A stationary wave is set up on a stretched string of length l and diameter d. Another stationary wave is also set up on a second string made from the same material and with the same tension as the first.

What length and diameter are required for the second string so that both strings have the same first-harmonic frequency?

$A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2$

$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$, $\mu = \rho A$ $\xrightarrow{\text{into } f}$ $f = \frac{1}{2l}\sqrt{\frac{T}{\rho\left(\frac{d}{2}\right)^2}}$ *

[1 mark]

	Length of second string	Diameter of second string		Original ld
A	$2l$	$2d$	○	$4ld$ ×
B	l	$2d$	○	$2ld$ ×
C	$\frac{l}{2}$	$2d$	●	ld ✓
D	l constant	$\frac{d}{2}$	○	$\frac{ld}{2}$ ×

* $f = \frac{1}{ld}\sqrt{\frac{T}{\pi\rho}}$ ⇒ ld = constant for f cst.

1 6 When a monochromatic light source is incident on two slits of the same width an interference pattern is produced.

One slit is then covered with opaque black paper.

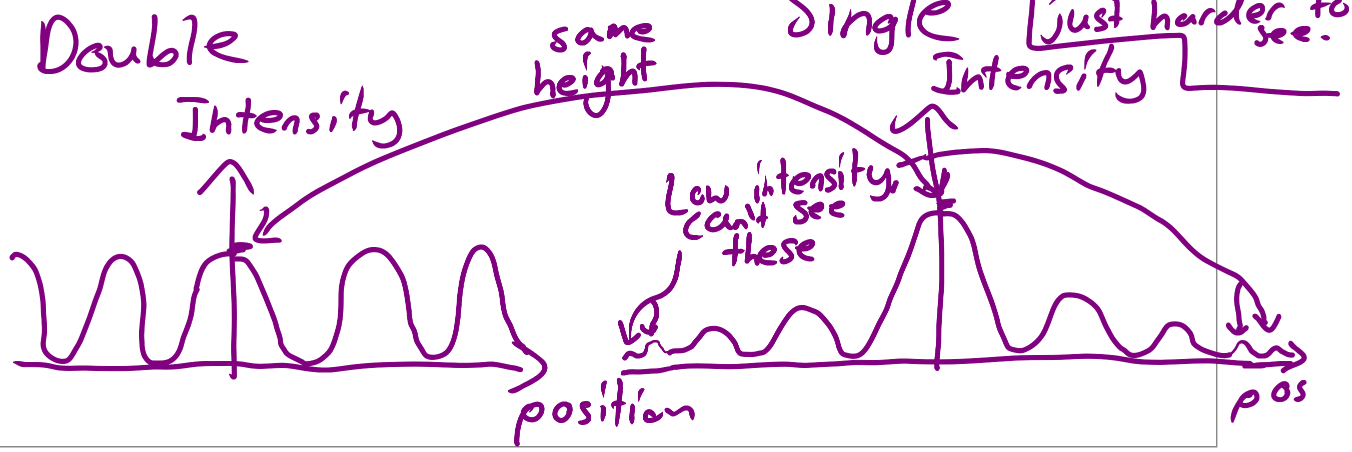
What is the effect of covering one slit on the resulting interference pattern?

[1 mark]

A: same amount of energy so intensity is the same
B: width is the same

A	The intensity of the central maximum will increase	○
B	The width of the central maximum decreases	○
C	Fewer maxima are observed	●
D	The outer maxima become wider	○

D: width is the same, just harder to see.



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1 7 When light of wavelength 5.0×10^{-7} m is incident normally on a diffraction grating the fourth-order maximum is observed at an angle of 30°.

λ

$n=4$

What is the number of lines per mm on the diffraction grating?

$1\,m = 10^3\,mm$

$1\,m^{-1} = 10^{-3}\,(mm)^{-1}$

[1 mark]

$n\lambda = d\sin\theta$

$d = \dfrac{1}{\text{lines per distance}}$

$d = \dfrac{n\lambda}{\sin\theta} = \dfrac{4 \times 5 \times 10^{-7}}{\sin 30^\circ}$

$d = 4 \times 10^{-6}\,m \rightarrow$ lines per m $= 2.5 \times 10^5\,m^{-1}$

$d = 2.5 \times 10^2\,mm^{-1}$

- **A** 2.5×10^2 ●
- **B** 2.5×10^5 ○
- **C** 1.0×10^3 ○
- **D** 1.0×10^6 ○

1 8 A light uniform rigid bar is pivoted at its centre. Forces act on the bar at its ends and at the centre.

For A:

Resultant force is zero ($F=ma$)

Which diagram shows the bar in equilibrium?

[1 mark]

$F = 4+4+2-(2+8) = 0N$

Rotational equilibrium (sum of moments is equal to zero)

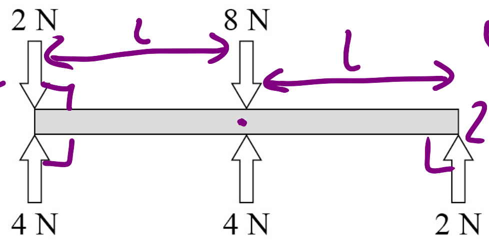
$2L$

$\circlearrowleft M = 2L$

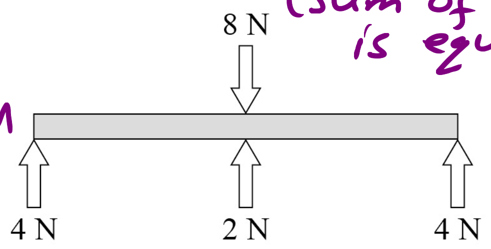
$\circlearrowright M = 4L$

add M:

$4L - 2L - 2L = 0$

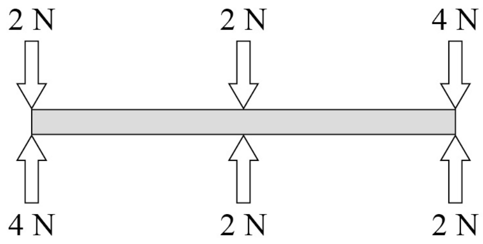


A

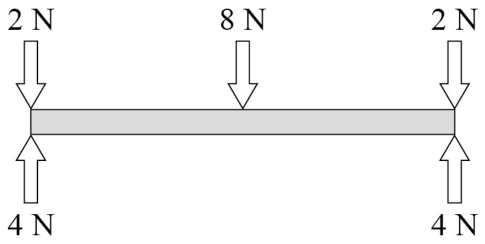


B

$M = Fd\sin\theta$, $\sin\theta = 1$ $(\theta = 90^\circ)$



C



D

- **A** ●
- **B** ○
- **C** ○
- **D** ○

d - t $\xrightarrow{\text{gradient}}$ v - t $\xrightarrow{\text{gradient}}$ a - t
$\xleftarrow{\text{area}}$ $\xleftarrow{\text{area}}$
(relation between the graphs)

Do not write outside the box

1 9 Which row gives two features of graphs that provide the same information?

[1 mark]

	Feature 1	Feature 2	
~~A~~	Gradient of a displacement–time graph v	Area under a velocity–time graph d	○
B	Gradient of a displacement–time graph v	Area under an acceleration–time graph v	●
~~C~~	Gradient of a velocity–time graph a	Area under a displacement–time graph physically irrelevant	○
~~D~~	Gradient of a velocity–time graph a	Area under an acceleration–time graph v	○

2 0 A rocket of mass 12 000 kg accelerates vertically upwards from the surface of the Earth at $1.4\ \text{m s}^{-2}$.

What is the thrust of the rocket?

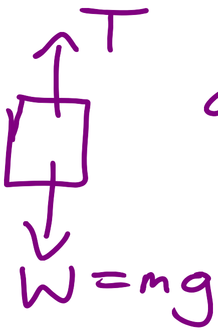
[1 mark]

A 1.7×10^4 N ○

B 1.0×10^5 N ○

C 1.3×10^5 N ●

D 1.6×10^5 N ○



acceleration due to gravity is $g = 9.81\ \text{m s}^{-2}$

$T - W = ma$

$T = ma + mg = m(a+g)$

$T = 12000 \times (1.4 + 9.81)$

$= 134520 \cong 1.3 \times 10^5\ \text{N}$

Find time to reach maximum height:
$25\sin 42^\circ = u_\uparrow$, $a = -g$, $t = ?$, $v_\uparrow = 0$

$v_\uparrow = u_\uparrow + at$

$t = \frac{v_\uparrow - u_\uparrow}{a} = \frac{-25\sin 42^\circ}{-9.81}$

$t \simeq 1.71\,s$

Total flight time is $2 \times 1.71.. = 3.41\,s$.

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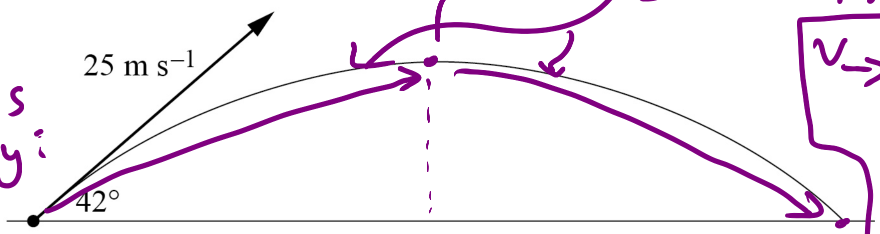
2 1 **Figure 12** shows the path of a projectile launched from ground level with a speed of 25 m s^{-1} at an angle of 42° to the horizontal.

Figure 12



Components of velocity: $(25\cos 42^\circ, 25\sin 42^\circ)\,ms^{-1}$

Horizontal distance

$v_\rightarrow = \frac{d}{2t}$

$d = 2 \times v_\rightarrow \times t$
$= 25\cos 42^\circ \times 3.41..$

What is the horizontal distance from the starting point of the projectile when it hits the ground?

[1 mark]

$d = 63.4\,m$
$\simeq 63\,m$

A 23 m

B 32 m

C 47 m

D 63 m

2 2 A car of mass 580 kg collides with the rear of a stationary van of mass 1200 kg.

Following the collision, the van moves with a velocity of 6.20 m s^{-1} and the car recoils in the opposite direction with a velocity of 1.60 m s^{-1}.

What is the initial speed of the car?

Conservation of momentum (vector sum of momentum before = vector sum of momentum after)

momentum $p = mv$

[1 mark]

A 5.43 m s^{-1}

B 11.2 m s^{-1}

C 12.8 m s^{-1}

D 14.4 m s^{-1}

$580 \times u + 1200 \times 0 = 1200 \times 6.2 + 580 \times (-1.6)$

$u = \frac{1200 \times 6.2 - 580 \times 1.6}{580}$

$u = 11.2\,ms^{-1}$

Before

580kg c $\rightarrow u$ | 1200kg b

After

580kg c, 1.60ms^{-1} $\leftarrow$ | 1200kg b, 6.20ms^{-1} $\rightarrow$

Do not write outside the box

2 3 Which graph best represents the velocity–time graph for a ball that is dropped from rest and bounces repeatedly?

Before After $(v = u + at, a = g, u = 0)$

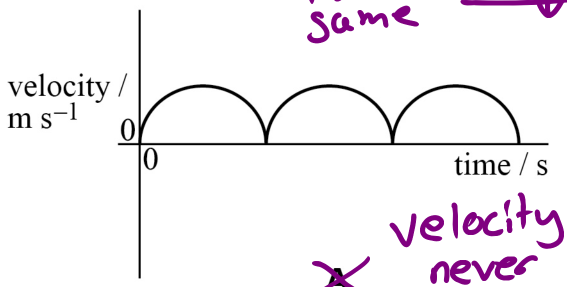
[1 mark]

speed is the same

ground ground

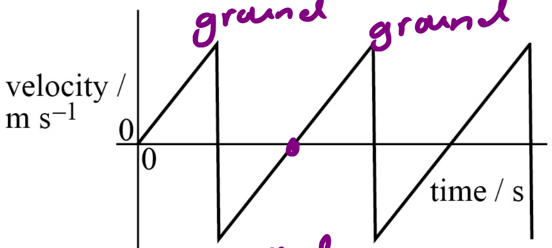
$v = gt$ for first bounce. *

$W = mg$



~~A~~

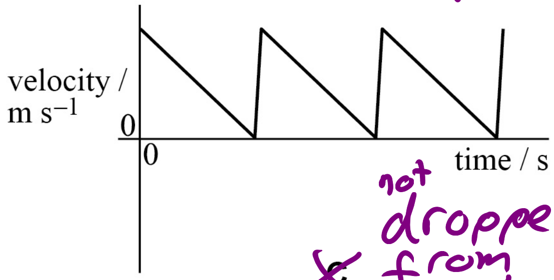
velocity never changes direction



B

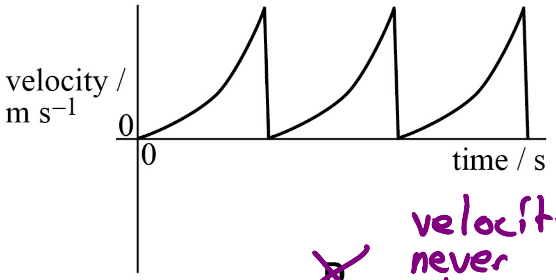
reversed upon hitting the ground.

*and is a straight line for all further bounces



~~C~~

not dropped from rest



~~D~~

velocity never changes direction

A ○

B ●

C ○

D ○

2 4 A sample of wire has a Young modulus E. A second sample of wire made from an identical material has three times the length and half the diameter of the first sample.

What is the Young modulus of the second sample of wire in terms of E?

ΔL changes, not L_0!

[1 mark]

A $0.25E$ ○

B E ●

C $6E$ ○

D $12E$ ○

Young modulus is a property of a material and thus is not affected by changing the dimensions

Before: $E = \frac{\sigma}{\varepsilon}$, $\sigma = \frac{F}{A}$, $A = \pi r^2$, $A = \pi\left(\frac{d}{2}\right)^2$

$\varepsilon = \frac{\Delta L}{L_0}$

$\rightarrow E = \frac{\frac{F}{A}}{\frac{\Delta L}{L_0}}$

$\Delta L = \frac{F L_0}{A E}$

After: $L_0 \rightarrow 3L_0$

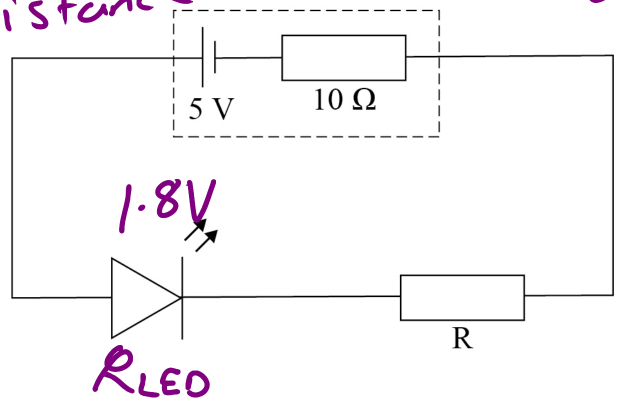
$d \rightarrow \frac{d}{2}$, $A \rightarrow \frac{A}{4}$, new $\Delta L = \frac{12 F L_0}{A E}$

2 5 In the circuit below, the potential difference across the light emitting diode (LED) is 1.8 V when it is emitting light.

$V = IR_T$ (for circuit)

$5V = 20mA \times R_T$

Total resistance is R_T



(for LED)

$V = IR_{LED}$

$1{\cdot}8 = 20mA \times R_{LED}$

$R_{LED} = \frac{1{\cdot}8}{20\times10^{-3}}$

$= 90\Omega$

The current in the circuit is 20 mA.

(series circuit)

What is the value of the resistor R?

$R_T = \frac{5}{20\times10^{-3}} = R + 90 + 10$

[1 mark]

$R = \frac{5}{20\times10^{-3}} - 90 - 10$

$R = 150\Omega$

A 80 Ω

B 90 Ω

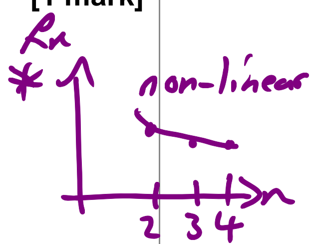
C 150 Ω

D 160 Ω

2 6 The combined resistance of n identical resistors connected in parallel is R_n.

Which statement correctly describes the variation of R_n as n increases?

[1 mark]



A R_n decreases linearly as n increases

B R_n decreases non-linearly as n increases

C R_n increases linearly as n increases

D R_n increases non-linearly as n increases

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$

$\frac{1}{R_n} = n \times \frac{1}{R}$

$R_1 = R_2 = R_3 \ldots = R$

$R_n = \frac{R}{n}$

$\frac{1}{R_n} = \frac{1}{R} + \frac{1}{R} + \ldots$

n copies of $\frac{1}{R}$

$n = 2$ vs. $n = 1000$ gives R_n

n	2	3	4
R_n	$\frac{R}{2}$	$\frac{R}{3}$	$\frac{R}{4}$

*

Do not write outside the box

2 7 The table shows the resistivity, length and cross-sectional area of wires P and Q.

	resistivity	**length**	**cross-sectional area**
wire P	ρ	L	A
wire Q	$\frac{\rho}{4}$	L	$\frac{A}{2}$

Resistances of wires $\downarrow$ Combine in parallel

The resistance of wire P is R.

What is the total resistance of the wires when they are connected in parallel?

[1 mark]

$P: R = \frac{\rho L}{A}$

A $\frac{R}{9}$ ○

B $\frac{R}{3}$ ●

C $\frac{2R}{3}$ ○

D $\frac{3R}{2}$ ○

$Q: R_Q = \frac{\rho_Q L_Q}{A_Q} = \frac{\frac{\rho}{4} L}{\frac{A}{2}}$

$R_Q = \frac{\rho L}{2A} = \frac{R}{2}$

$\frac{1}{R_T} = \frac{1}{R_P} + \frac{1}{R_Q} = \frac{1}{R} + \frac{1}{\frac{R}{2}} = \frac{1}{R} + \frac{2}{R} = \frac{3}{R}$

$\Rightarrow R_T = \frac{R}{3}$

Do not write outside the box

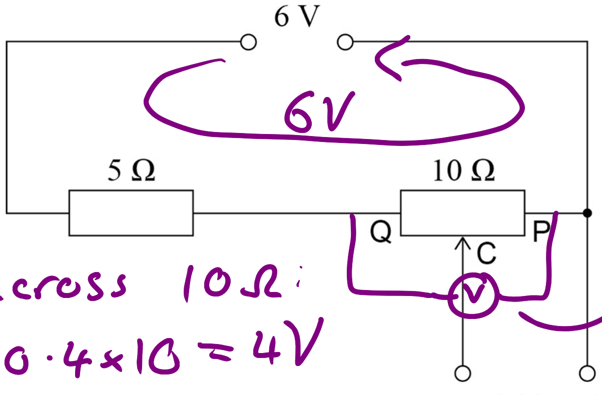
2 8 The circuit shown is used to supply a variable potential difference (pd) to another circuit.

$V = IR$

$6 = I \times (5 + 10)$

$I = \frac{6}{15} = 0.4A.$

(current in the circuit)

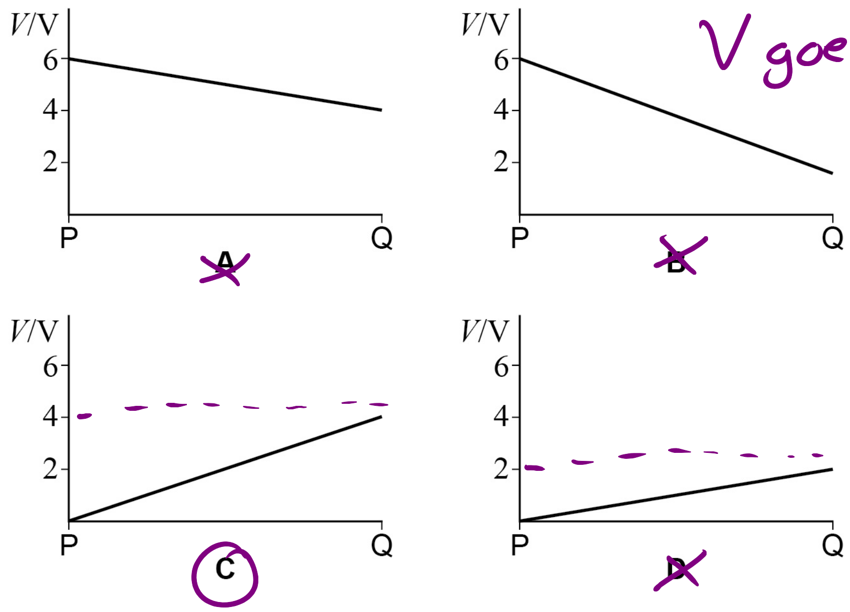


V across 10Ω:
$V = 0.4 \times 10 = 4V$

$R \propto L$ (length of resistor)
contact at Q: 4V
contact at P: 0V

Which graph shows how the pd supplied V varies as the moving contact C is moved from position P to position Q?

[1 mark]



Then criteria:
V goes from 0V at P to 4V at Q (and straight line).

A ○

B ○

C ●

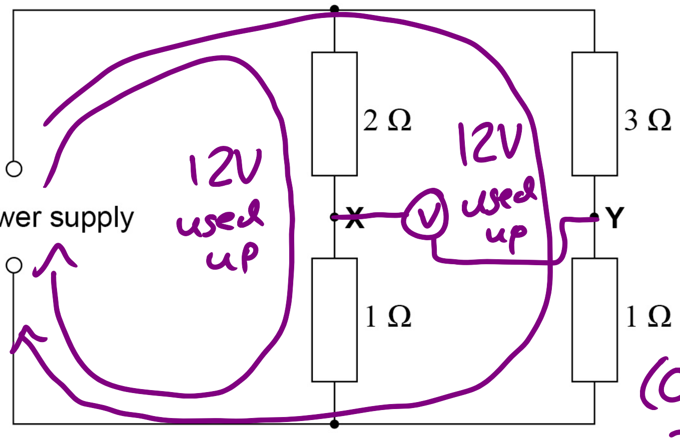
D ○

Do not write outside the box

2 9 In this resistor network, the emf of the supply is 12 V and it has negligible internal resistance.

Y: Current in branch
(Ohm) $12V = (3+1) \times I$
$I = 3A$
Voltage drop before Y is the voltage drop across 3Ω resistor:
(Ohm) $3 \times 3 = 9V$
voltage remaining is $12 - 9 = 3V$
Potential at Y is 3V.

$V = IR$
X: Current in branch
(Ohm's Law) $12V = (2+1) \times I$
$I = 4A$
Voltage drop before X is voltage across 2Ω resistor:
(Ohm's Law)
$2 \times 4 = 8V$
voltage remaining is $12 - 8 = 4V$
Potential at X: 4V



What is the reading on a voltmeter connected between points **X** and **Y**?

[1 mark]

A 0 V

B 1 V

C 3 V

D 4 V

Voltmeter subtracts V at Y from V at X. $\Delta V = 4 - 3 = 1V$

Turn over ▶

Do not write outside the box

3 0 A bob of mass 0.50 kg is suspended from the end of a piece of string 0.45 m long. The bob is rotated in a vertical circle at a constant rate of 120 revolutions per minute.

m

$\omega = \frac{120}{60} \times 2\pi = 4\pi$ rads^{-1}

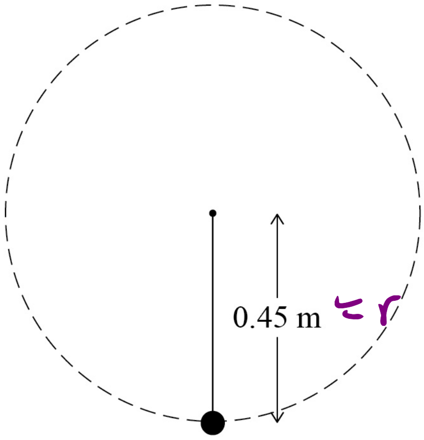
$F = m\omega^2 r$

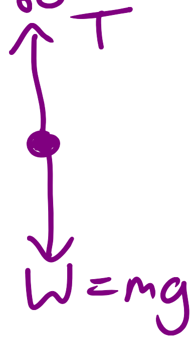
(Newton's 2nd law)

$F = ma$

To keep an object moving in circle

$a = \omega^2 r$





$g = 9.81\ ms^{-2}$

What is the tension in the string when the bob is at the bottom of the circle?

[1 mark]

A	5.8 N	○
B	31 N	○
C	36 N	○
D	40 N	●

$F = m\omega^2 r = T - mg$

$T = mg + m\omega^2 r$

$T = m(g + \omega^2 r)$

$= 0.5 \times (9.81 + (4\pi)^2 \times 0.45)$

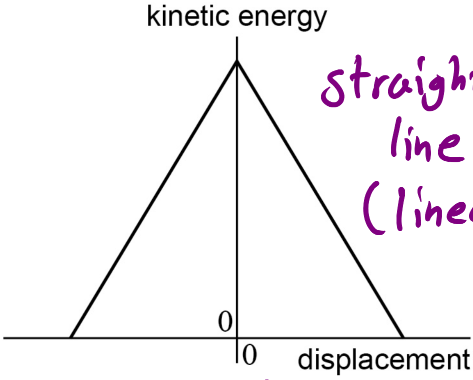
$= 40.435... \approx 40\ N$

Do not write outside the box

3 1 Which graph best shows how the kinetic energy of a simple pendulum varies with displacement from the equilibrium position?

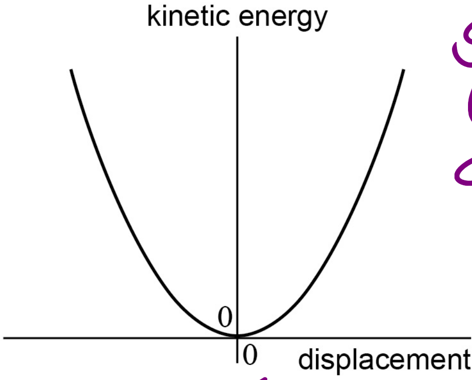
[1 mark]

$E_K = \frac{1}{2}m\omega^2(A^2 - x^2)$ → Quadratic graph (x^2) and ∩ shaped ($-x^2$)

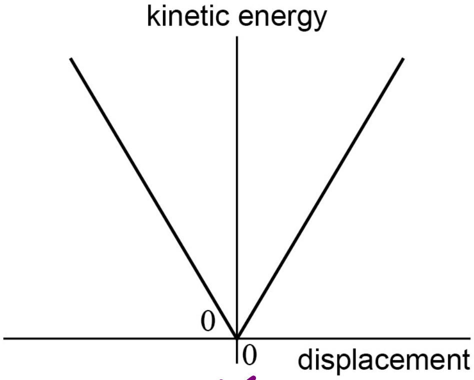


~~A~~

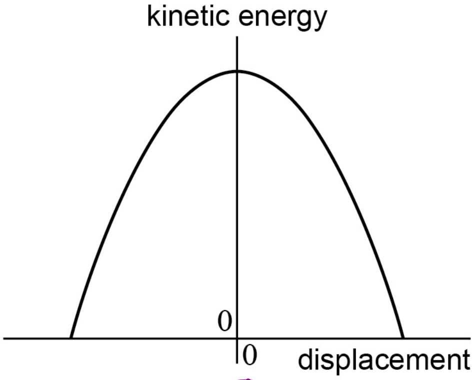
straight line (linear)



~~B~~



~~C~~



D

A ☐

B ☐

C ☐

D ■

Simple harmonic motion

$v = \omega\sqrt{A^2 - x^2}$ (speed)

Kinetic energy $E_K = \frac{1}{2}mv^2$

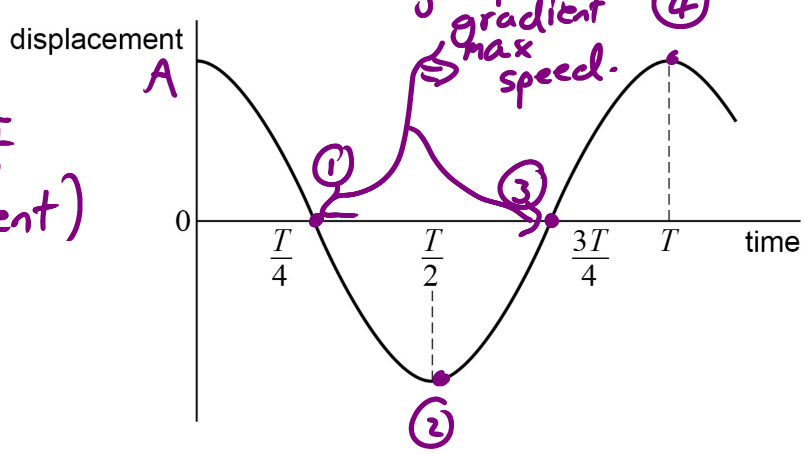
$= \frac{1}{2}m\omega^2(A^2 - x^2)$

displacement from eqm position.

Do not write outside the box

3 2 The graph shows how the displacement of a particle performing simple harmonic motion varies with time.

$v = \frac{\Delta s}{\Delta t}$ (gradient)



①: −A A — graph is steepest here so speed largest. + (and at $\frac{3T}{4}$),

③: −A A — has no potential energy, all has been converted into kinetic energy.

Which statement is **not** correct?

[1 mark]

① ~~A~~ The speed of the particle is a maximum at time $\frac{T}{4}$ ☐

③ ~~B~~ The potential energy of the particle is zero at time $\frac{3T}{4}$ ☐

② ~~C~~ The acceleration of the particle is a maximum at time $\frac{T}{2}$ ☐

④ **D** The restoring force acting on the particle is zero at time T ■

②: −A A

④: −A A

SHM:
$a = -\omega^2 x$
$x = -A$, $a = \omega^2 A \Rightarrow a$ is largest as $-A \leq x \leq A$.
as distance from eqm position increases, so too does restoring force
(Newton $F = ma = -m\omega^2 x$)
$\Rightarrow$ D incorrect

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