A-level

Physics

Practice paper for AQA

Paper 1

Time allowed: 2 hours

Materials

For this paper you must have:

- a pencil
- a ruler
- a calculator
- a data and formulae booklet.

Instructions

- Answer **all** questions.
- Show **all** your working.

Information

- The maximum mark for this paper is 85.

Name: ……………………………………………………………………

Section A

Answer **all** questions in this section.

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0 1 A strange particle, the K^- kaon, reacts with a proton and forms a particle X and a K^+ kaon.

0 1 · 1 Write an equation for this reaction.

[1 mark]

....

0 1 · 2 Show that the charge of particle X is –1.

[1 mark]

....

....

0 1 · 3 Deduce the baryon number and strangeness of particle X.

[2 marks]

baryon number ....

strangeness ....

0 1 · 4 Determine the quark structure of particle X.

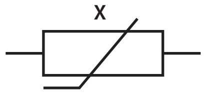
[3 marks]

quark structure ....

0 2 · 1 A student wants to find the resistance of component X, shown in **Figure 1**. There is no ohmmeter, but other electrical equipment is available. Complete this circuit diagram to show how you would measure the resistance of X.

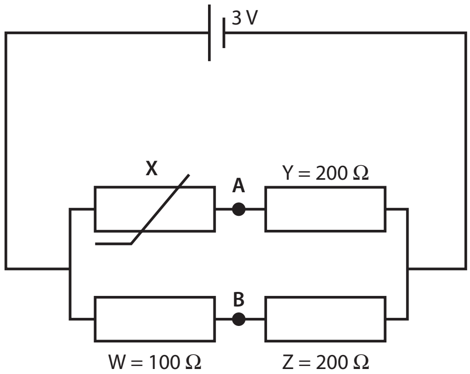
[2 marks]

Figure 1



The student sets up the circuit in **Figure 2**, which contains component X.

Figure 2



The resistance of X is 100 Ω.

0 2 · 2 Calculate the total resistance and the current in the circuit.

[4 marks]

resistance .... Ω

current .... mA

0 2 · 3 An ammeter is connected between points A and B. State and explain the current recorded by the ammeter.

[2 marks]

0 2 · 4 The resistance of component X decreases to 50 Ω.

Suggest why the resistance decreased. Explain your answer.

[2 marks]

0 2 · 5 State and explain the effect of this change on the current between A and B.

[3 marks]

0 3 Gliders move along a horizontal linear air track with negligible friction supported by a cushion of air.

0 3 · 1 A glider of mass 0.40 kg is moving with velocity 0.30 m s^{-1} towards a stationary glider of mass 0.25 kg. The gliders collide and stick together. Show that their final velocity is about 0.2 m s^{-1}.

[3 marks]

0 3 · 2 The gliders reach the end of the track and rebound from a fixed barrier, travelling back at the same speed. Determine the change in momentum when the gliders rebound.

[1 mark]

momentum .... kg m s^{-1}

0 3 · 3 In the next experiment two gliders C and D each of mass 0.20 kg are travelling towards each other and make an elastic collision.

Compare and contrast an elastic collision and an inelastic collision.

[2 marks]

....

....

0 3 · 4 The velocity of C is 0.30 m s^{-1} and of D is –0.20 m s^{-1}. After collision the final velocity of D is 0.30 m s^{-1}. Calculate the final velocity of C and show whether the collision is elastic.

[5 marks]

final velocity of C .... m s^{-1}

elastic or inelastic? ....

0 4 A spring is suspended vertically and extends 0.14 m when a mass of 0.31 kg is hung on its lower end.

0 4 · 1 Show that the spring constant of the spring is about 20 N m^{-1}.

[2 marks]

0 4 · 2 The spring is pulled down slightly and released so that it oscillates with simple harmonic motion about the equilibrium position with an amplitude of 0.025 m.

Calculate the period of the oscillation.

[1 mark]

period .... s

0 4 · 3 Explain at what point in the oscillation the tension in the spring will be at maximum value and calculate this maximum tension.

[3 marks]

....

....

maximum tension .... N

0 4 · 4 The mass and spring are taken to the Moon. Vertical oscillations with the same amplitude are set up in exactly the same way. Without further calculation, comment on the changes, if any, that you would expect to the period of oscillation and the maximum tension.

[3 marks]

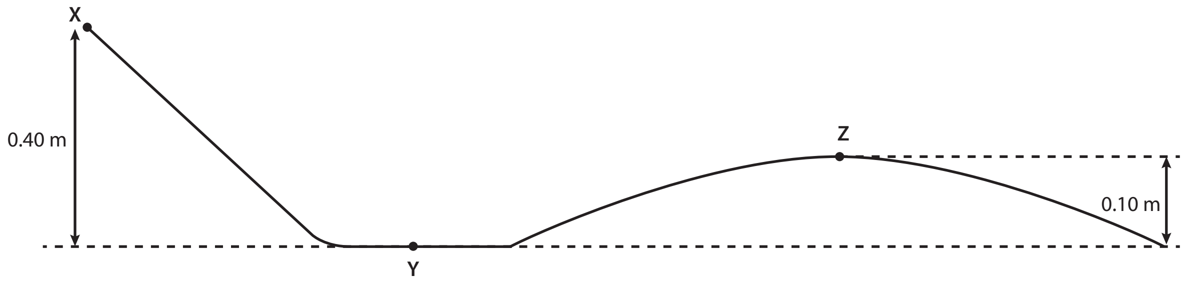
....

....

....

0 5 A marble of mass 6.0 g is rolled down the plastic track shown in **Figure 3**. Z is 0.10 m higher than Y. The path through Z is part of a circle of radius 0.75 m. Assume that friction is negligible.

Figure 3



A marble is released at X, which is 0.40 m higher than Y.

0 5 · 1 Calculate the speed of the marble at Y.

[2 marks]

speed .... $m\ s^{-1}$

0 5 · 2 Calculate the speed of the marble at Z.

[2 marks]

speed .... $m\ s^{-1}$

0 5 · 3 Draw a diagram showing the forces on the marble at Z and calculate the reaction between the track and the marble at Z.

[4 marks]

reaction .... N

0 6 Read through the following passage and answer the questions that follow it.

The invention of the blue LED

Light-emitting diode (LED) technology is based on electroluminescence, which is a phenomenon discovered in 1907 by Henry Joseph Round. Electroluminescence is light emitted when an electric current passes through a material. In 1955 Rubin Braunstein reported that some simple semiconductor diodes emit radiation when current passes through them, but it was not until 1961 that the first practical device – a pure gallium arsenide (GaAs) crystal with a 900 nm wavelength output – was reported.

In 1962 Nick Holonyack developed the first visible red LED, with a wavelength of 660 nm. New semiconductor materials led to LEDs with other colours, but the blue LED was more difficult to achieve. In 1979, Shuji Nakamura invented the first blue LED using gallium nitride (GaN), but it was too expensive for commercial use. He improved the design and in 1994 he invented the first low-cost bright blue LED.

The blue LED made white light possible because our eyes see a combination of red, green and blue, or of yellow and blue, as white light. One way to make a white LED is to use a phosphor coating to absorb some of the blue light and emit yellow light. This results in a spectrum of yellow (maximum output at wavelength 580 nm) and blue (maximum output at 450 nm), which we see as white light.

0 6 · 1 State the wavelength region of the electromagnetic spectrum of the radiation from the first practical device (line 6).

[1 mark]

....

0 6 · 2 Show that the frequency of the first red LED (line 7) is 4.5×10^{-14} Hz and calculate the energy of 1 photon in electronvolts.

[3 marks]

energy .... eV

0 6 . 3 Describe the process that takes place in an atom in the phosphor coating that produces yellow light (line 14).

[2 marks]

0 6 . 4 A student suggests that the red LED could be used with phosphor coatings that emit green light of wavelength 550 nm, and blue light of wavelength 450 nm to produce white light. Explain whether this is possible.

[2 marks]

0 6 . 5 The white light LED described in lines 13 to 16 is viewed using a spectrometer and a diffraction grating with 1500 lines per mm. Calculate the first order angle at which the centre of the blue line is seen.

[2 marks]

angle .... °

0 6 . 6 Describe the spectrum that would be seen with the spectrometer.

[2 marks]

END OF SECTION A

Section B

Each of questions 7 to 31 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.

0 7 A nucleus of $^{204}_{82}Pb$ absorbs an alpha particle and emits a positron. What is the product nucleus?

[1 mark]

A $^{206}_{85}At$

B $^{208}_{85}At$

C $^{208}_{83}Bi$

D $^{207}_{84}Po$

0 8 The drag force F on a spherical object of radius r falling with terminal velocity v is given by:

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

What are the units of η?

[1 mark]

A kg m^{-1}

B kg m^{-1} s^{-1}

C kg m^{2} s^{-1}

D m s^{-2} kg^{-1}

0 9 A metal sheet is placed in a beam of electromagnetic radiation. Photoelectrons are emitted from the surface of the metal. Which list contains all the factors that determine the maximum speed of the emitted electrons?

[1 mark]

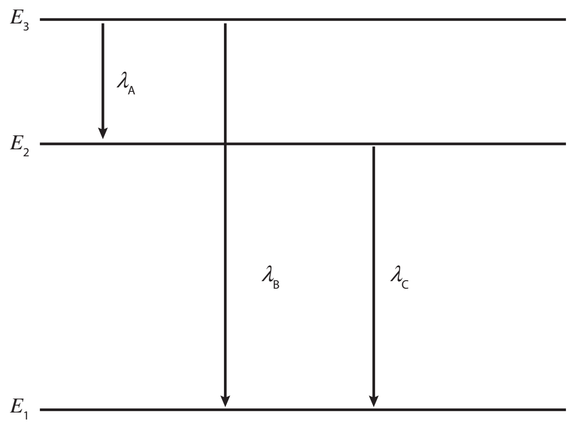
A The frequency of the electromagnetic radiation.

B The frequency and the intensity of the electromagnetic radiation.

C The frequency of the electromagnetic radiation and the work function of the metal.

D The frequency and the intensity of the electromagnetic radiation and the work function of the metal.

1 0 The diagram shows three energy levels for the outermost electron in an atom. λ_A λ_B and λ_C are the wavelengths of the photons emitted when the electrons drop from one energy level to another.



Which of the following statements is correct?

[1 mark]

A $\lambda_B = \lambda_A + \lambda_C$

B If λ_A is in the visible region, then λ_C could be in the infrared region.

C The frequency of the radiation with wavelength λ_A is less than the frequency of the radiation with wavelength λ_B.

D If λ_B is in the visible region, then λ_A could be in the ultraviolet region.

1 1 The diameter of a sphere is measured to be 0.025 (±0.001) m. The volume of the sphere is correctly calculated to be

$$V = \frac{4\pi}{3}\left(\frac{d}{2}\right)^3 = 8.81 \times 10^{-6}\ \text{m}$$

How should the percentage uncertainty in the volume, resulting from the uncertainty in the diameter, be calculated?

[1 mark]

A $\frac{0.001}{0.025} \times 100\%$ ⬭

B $3 \times \frac{0.001}{0.025} \times 100\%$ ⬭

C $\frac{0.001}{8.181 \times 10^{-6}} \times 100\%$ ⬭

D $3 \times \frac{0.001}{8.181 \times 10^{-6}} \times 100\%$ ⬭

1 2 Considering the alpha particle, the proton and the positron, which particle has the largest charge-to-mass ratio and which has the smallest?

[1 mark]

	Largest charge-to-mass ratio, Q/m	**Smallest charge-to-mass ratio, Q/m**	
A	alpha particle	positron	⬭
B	positron	alpha particle	⬭
C	positron	proton	⬭
D	proton	alpha particle	⬭

1 3 The frequency of the first harmonic of a string fixed at both ends is 200 Hz. The tension in the wire is doubled. What is the new fundamental frequency?

[1 mark]

A 283 Hz

B 141 Hz

C 400 Hz

D 800 Hz

1 4 A wire with resistance R and length l has a circular cross-section with diameter d. A second wire with resistance R is made of the same material and has a square cross-section of side d. What is the length of this second wire?

[1 mark]

A $2\pi l$

B $\frac{2l}{\pi}$

C $4\pi l$

D $\frac{4l}{\pi}$

1 5 A beam of light passes through a polarising filter with its axis of polarisation at 0° and a second polarising filter with its axis of polarisation at 90°. No light is transmitted. A third polarising filter is placed between the two crossed filters and rotated through 360°.

As the third filter is rotated, which of the following is true?

[1 mark]

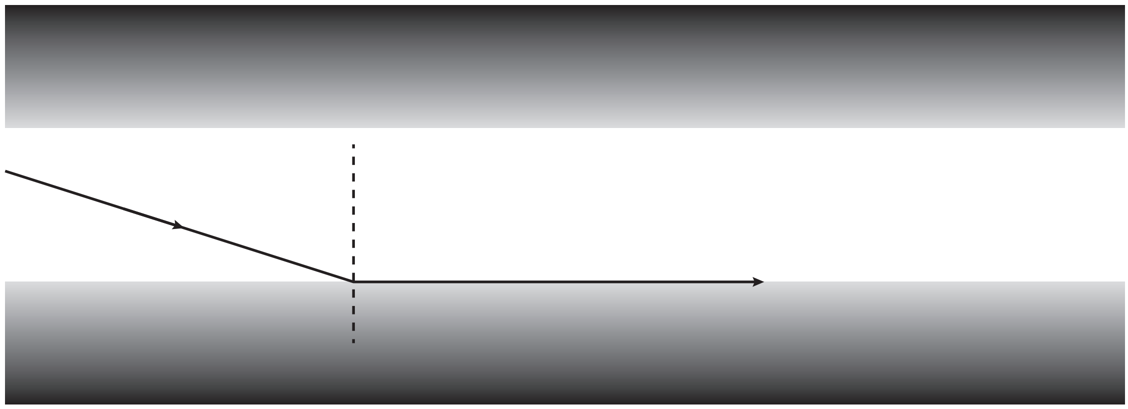
A No light is transmitted at any angle.

B Some light is transmitted at all angles.

C Some light is transmitted, but only when the third filter has its axis of polarisation at 0°, 45°, 225° or 315°.

D Some light is transmitted whenever the axis of polarisation of the third filter is not 0° or is a multiple of 90°.

1 6 A light ray incident on the cladding of an optical fibre refracts along the core-cladding boundary as shown.



What is the critical angle at the boundary between the core and the cladding?

speed of light in the core = 2.02×10^{8} m s^{-1}

speed of light in the cladding = 2.08×10^{8} m s^{-1}

[1 mark]

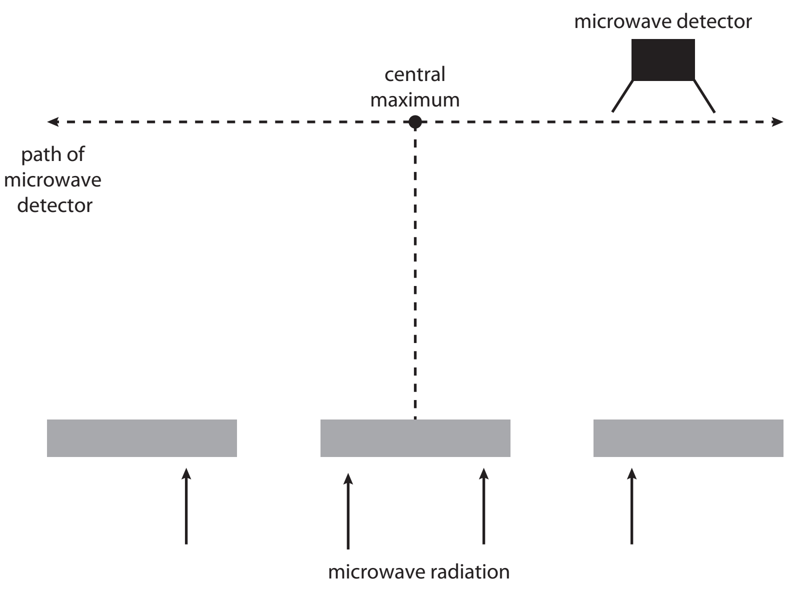
A 14°

B 42°

C 44°

D 76°

1 7 An experiment in which microwaves pass through two narrow slits is done in a vacuum.



The slits act as coherent sources. The microwave detector is moved along the path shown. There is a central maximum intensity. On either side there are evenly spaced intensity maxima and minima.

When the microwave frequency is halved, what change in the pattern is observed?

[1 mark]

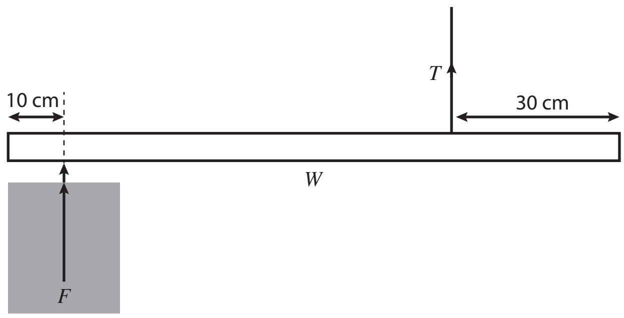
A The pattern is unchanged. ⬭

B The spacing of the maxima is unchanged, but there is a central minimum. ⬭

C The spacing of the maxima is doubled. ⬭

D The spacing of the maxima is halved. ⬭

1 8 A uniform 1.0 m beam of weight W is supported on a pillar 10 cm from one end and by a rope attached 30 cm from the other end.



The reaction force from the pillar is F and the tension in the rope is T.

What is the ratio T:F?

[1 mark]

A 1:3

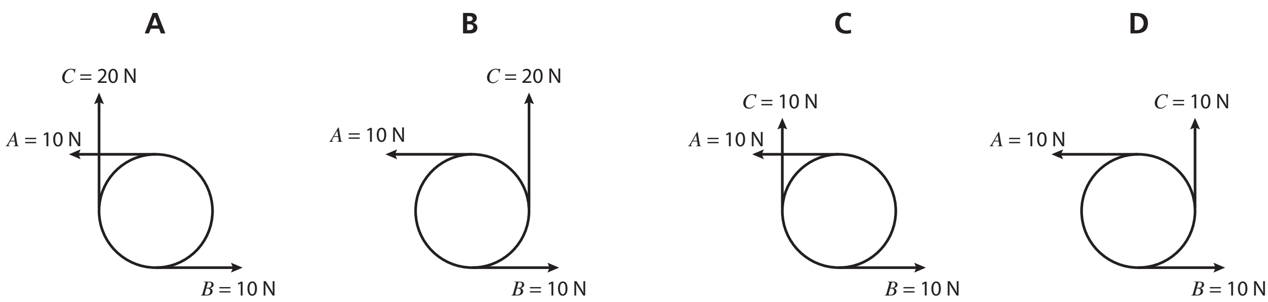
B 1:2

C 2:1

D 3:1

1 9 Three forces A, B and C act on the rim of a disc. Forces A and B are both 10 N and form a couple. Which diagram shows the correct force C for the disc to be in equilibrium?

[1 mark]



A

B

C

D

2 0 An object of mass 0.5 kg moves due South on a horizontal frictionless table with a speed of 3 m s^{-1}. A constant force 0.2 N due East acts on it for 10 s. What is the resultant velocity of the object?

[1 mark]

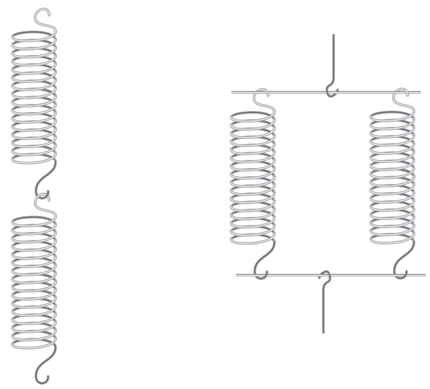
A 3.6 m s^{-1} due East

B 3.6 m s^{-1} 53° East of South

C 5 m s^{-1} due East

D 5 m s^{-1} 53° East of South

2 1 Two identical springs with spring constant k can be joined in parallel or in series.



Which line of the table correctly shows the spring constant in each case?

[1 mark]

	Series combination	Parallel combination	
A	$2k$	$2k$	
B	$2k$	$\frac{k}{2}$	
C	$\frac{k}{2}$	$2k$	
D	$\frac{k}{2}$	$\frac{k}{2}$	

2 2 Two spheres of equal volume, one plastic and one metal, are projected horizontally from the top of a tall building at the same time and with the same velocity. Air resistance is negligible. Which statement correctly describes when and where they will land?

[1 mark]

A The metal sphere will land first and closer to the building.

B The metal sphere will land first and further from the building.

C The plastic sphere will land first and closer to the building.

D They will both land at the same time and at the same distance from the building.

2 3 Two projectiles P and Q are projected upwards at an angle with the same velocity v. The ground is horizontal. Projectile P is projected at angle θ to the horizontal and projectile Q at angle $(90° - \theta)$ to the horizontal. The time of flight of projectile P is t_p. What is the time of flight of projectile Q?

[1 mark]

A t_p

B $t_p \tan\theta$

C $\dfrac{t_p}{\tan\theta}$

D $t_p \dfrac{2v}{g} \tan\theta$

2 4 A person travels up and down in a lift, stopping at each floor of the building. Which statement about the reaction force from the floor on the person is true?

[1 mark]

Compared to the reaction force when the lift is stationary:

A the reaction force is greater when the lift is going down and slowing down.

B the reaction force is greater when the lift is going down and speeding up.

C the reaction force is greater when the lift is going up and slowing down.

D the reaction force is less when the lift is going up and speeding up.

2 5 A rope is used to raise a large crate of mass M to a platform at a height h above the ground. A ramp with negligible friction is set up at an angle of 45°, so that the rope can be used to pull the same mass up the ramp from the ground to the platform. What effect will this have on the work done in raising the crate?

[1 mark]

A The work done will be less.

B The work done will be more.

C The work done will be the same.

D The work done will depend on how quickly the crate is raised.

2 6 A crane motor X raises 30 kg a height of 120 m in 2 minutes. A winch motor Y raises 8 kg a height of 6 m in 1.5 s and a lift motor Z raises 4 kg a height of 15 m in 10 s. Which motor delivers the most output power?

[1 mark]

A crane X

B winch Y

C lift Z

D They are all the same.

2 7 In an open circuit the potential difference across the terminals of a cell is 9.0 V and when a current of 1.5 A passes through it is 7.8 V. What is the internal resistance of the cell?

[1 mark]

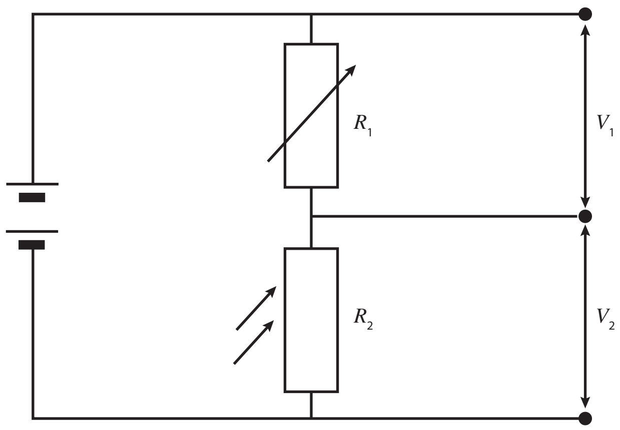
A 0.8 Ω

B 1.8 Ω

C 5.2 Ω

D 6.0 Ω

2 8 This circuit is used to operate a light switch.



Which of the following statements correctly describes what happens as the amount of light and the resistance of R_1 is changed?

[1 mark]

A It gets dark, V_1 increases and can be used to switch on a lamp. When R_1 is decreased it is darker before the lamp switches on.

B It gets dark, V_1 increases and can be used to switch on a lamp. When R_1 is increased it is darker before the lamp switches on.

C It gets dark, V_2 increases and can be used to switch on a lamp. When R_1 is decreased it is darker before the lamp switches on.

D It gets dark, V_2 increases and can be used to switch on a lamp. When R_1 is increased it is darker before the lamp switches on.

2 9 A simple pendulum consisting of a small mass on the end of an inextensible string swings with simple harmonic motion. Which of the following statements correctly describes the energy in the system?

[1 mark]

A The energy is at its maximum as the object passes through the mid-point of the oscillation.

B The energy is at its minimum as the object passes through the mid-point of the oscillation.

C The energy is at its maximum as the object reaches the highest point of the oscillation.

D The energy will not change with the position of the object.

3 0 An object oscillates with damped simple harmonic motion. Which of the following statements about the damping force is true?

[1 mark]

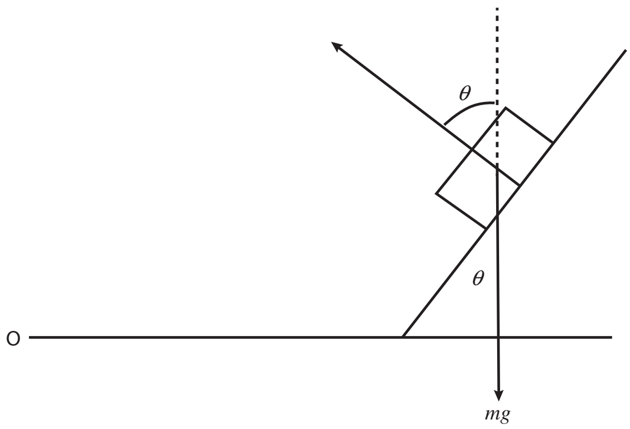
A It is always in the opposite direction to the displacement.

B It is always in the opposite direction to the velocity.

C It is always proportional to the displacement.

D It is always in the same direction as the acceleration.

3 1 An object travels around a circle with radius r. The centre of the circle is at O.



The edge of the circle is banked at an angle θ so that, at speed, v, the object cannot slip.
What is the value of tan θ?

[1 mark]

A $\frac{mg}{rv^2}$ ⬭

B $\frac{rg}{v^2}$ ⬭

C $\frac{rv^2}{mg}$ ⬭

D $\frac{v^2}{rg}$ ⬭

END OF QUESTIONS

Data and formulae booklet

DATA – FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^{8}	$m\ s^{-1}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$H\ m^{-1}$
permittivity of free space	ε_0	8.85×10^{-12}	$F\ m^{-1}$
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$N\ m^{2}\ kg^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$J\ K^{-1}\ mol^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	$J\ K^{-1}$
the Stefan constant	σ	5.67×10^{-8}	$W\ m^{-2}\ K^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	$C\ kg^{-1}$
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^{7}	$C\ kg^{-1}$
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	$N\ kg^{-1}$
acceleration due to gravity	g	9.81	$m\ s^{-2}$
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

ALGEBRAIC EQUATION

quadratic equation $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

ASTRONOMICAL DATA

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^{8}
Earth	5.98×10^{24}	6.37×10^{6}

GEOMETRICAL EQUATIONS

arc length	$= r\theta$
circumference of circle	$= 2\pi r$
area of circle	$= \pi r^2$
curved surface area of cylinder	$= 2\pi rh$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3}\pi r^3$

Particle physics

Class	Name	Symbol	Rest energy/MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	π meson	$\pi^\pm$	139.576
		π^0	134.972
	K meson	$K^\pm$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	–1

Properties of Leptons

		Lepton number
Particles:	e^-, ν_e ; μ^-, ν_μ	+1
Antiparticles:	e^+, $\overline{\nu}_e$, μ^+, $\overline{\nu}_\mu$	–1

Photons and energy levels

photon energy $E = hf = hc / \lambda$

photoelectricity $hf = \phi + E_{k(max)}$

energy levels $hf = E_1 - E_2$

de Broglie Wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

Waves

wave speed $c = f\lambda$ *period* $f = \frac{1}{T}$

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

fringe spacing $w = \frac{\lambda D}{s}$ *diffraction grating* $d \sin \theta = n\lambda$

refractive index of a substance s, $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 *and* n_2,

law of refraction $n_1 \sin \theta_1 = n_2 \sin \theta_2$

critical angle $\sin \theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

Mechanics

moments moment = Fd

velocity and acceleration $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$

equations of motion $v = u + at$ $s = \left(\frac{u+v}{2}\right)t$

$v^2 = u^2 + 2as$ $s = ut + \frac{at^2}{2}$

force $F = ma$

force $F = \frac{\Delta(mv)}{\Delta t}$

impulse $F\Delta t = \Delta(mv)$

work, energy and power $W = F s \cos\theta$

$E_k = \frac{1}{2}mv^2$ $\Delta E_p = mg\Delta h$

$P = \frac{\Delta W}{\Delta t}$, $P = Fv$

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

Materials

density $\rho = \frac{m}{V}$ *Hooke's law* $F = k\,\Delta L$

Young modulus $= \frac{\text{tensile stress}}{\text{tensile strain}}$ tensile stress $= \frac{F}{A}$ tensile strain $= \frac{\Delta L}{L}$

energy stored $E = \frac{1}{2}F\Delta L$

Electricity

current and pd	$I = \frac{\Delta Q}{\Delta t}$ $\quad V = \frac{W}{Q}$ $\quad R = \frac{V}{I}$
resistivity	$\rho = \frac{RA}{L}$
resistors in series	$R_T = R_1 + R_2 + R_3 + \ldots$
resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$
power	$P = VI = I^2 R = \frac{V^2}{R}$
emf	$\varepsilon = \frac{E}{Q}$ $\quad \varepsilon = I(R + r)$

Circular motion

magnitude of angular speed	$\omega = \frac{v}{r}$
	$\omega = 2\pi f$
centripetal acceleration	$a = \frac{v^2}{r} = \omega^2 r$
centripetal force	$F = \frac{mv^2}{r} = m\omega^2 r$

Simple harmonic motion

acceleration	$a = -\omega^2 x$
displacement	$x = A\cos(\omega t)$
speed	$v = \pm\omega\sqrt{(A^2 - x^2)}$
maximum speed	$v_{max} = \omega A$
maximum acceleration	$a_{max} = \omega^2 A$
for a Mass-spring system	$T = 2\pi\sqrt{\frac{m}{k}}$
for a simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$

Thermal physics

energy to change temperature	$Q = mc\Delta\theta$
energy to change state	$Q = m\,l$
gas law	$pV = nRT$
	$pV = NkT$
kinetic theory model	$pV = \frac{1}{3} N m (c_{rms})^2$
kinetic energy of gas molecule	$\frac{1}{2} m (c_{rms})^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$

Gravitational fields

force between two masses	$F = \frac{Gm_1 m_2}{r^2}$
gravitational field strength	$g = \frac{F}{m}$
magnitude of gravitational field strength in a radial field	$g = \frac{GM}{r^2}$
work done	$\Delta W = m\Delta V$
gravitational potential	$V = -\frac{GM}{r}$
	$g = -\frac{\Delta V}{\Delta r}$

Electric fields and capacitors

force between two point charges	$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$
force on a charge	$F = EQ$
field strength for a uniform field	$F = \frac{V}{d}$
work done	$\Delta W = Q\Delta V$
field strength for a radial field	$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$
electric potential	$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$
	$E = \frac{\Delta V}{\Delta r}$
capacitance	$C = \frac{Q}{V}$
	$C = \frac{A\varepsilon_0\varepsilon_r}{d}$
capacitor energy stored	$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$
capacitor charging	$Q = Q_0(1 - e^{-t/RC})$
decay of charge	$Q = Q_0 e^{-t/RC}$
time constant	RC

Magnetic fields

force on a current	$F = BIl$
force on a moving charge	$F = BQv$
magnetic flux	$\Phi = BA$
magnetic flux linkage	$N\Phi = BAN\cos\theta$
magnitude of induced emf	$\varepsilon = N\frac{\Delta\Phi}{\Delta t}$ $N\Phi = BAN\cos\theta$
emf induced in a rotating coil	$\varepsilon = BAN\omega\sin\omega t$
alternating current	$I_{rms} = \frac{I_0}{\sqrt{2}}$ $V_{rms} = \frac{V_0}{\sqrt{2}}$
transformer equations	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$ $efficiency = \frac{I_s V_s}{I_p V_p}$

Nuclear physics

the inverse square law for γ radiation	$I = \frac{k}{x^2}$
radioactive decay	$\frac{\Delta N}{\Delta t} = \lambda N$, $N = N_0 e^{-\lambda t}$
activity	$A = \lambda N$
half-life	$T_{1/2} = \frac{\ln 2}{\lambda}$
nuclear radius	$R = R_0 A^{1/3}$
energy-mass equation	$E = mc^2$

Astrophysics

1 astronomical unit = 1.50×10^{11} m

1 light year = 9.46×10^{15} m

1 parsec = 206265 AU = 3.08×10^{16} m

= 3.26 light years

Hubble constant, H = 65 km s^{-1} Mpc^{-1}

$$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$$

in normal adjustment	$M = \frac{f_0}{f_e}$
Rayleigh criterion	$\theta \approx \frac{\lambda}{D}$
magnitude equation	$m - M = 5\log\frac{d}{10}$
Wien's law	$\lambda_{max} T = 2.9 \times 10^{-3}$ m K
Stefan's law	$P = \sigma A T^4$
Schwarzschild radius	$R_s \approx \frac{2GM}{c^2}$
Doppler shift for $v << c$	$\frac{\Delta f}{f} = -\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
red shift	$z = -\frac{v}{c}$
Hubble's law	$v = Hd$

Medical physics

lens equations	$P = \frac{1}{f}$ $m = \frac{v}{u}$ $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
threshold of hearing	$I_0 = 1.0 \times 10^{-12}$ W m^{-2}
intensity level	intensity level = $10\log\frac{I}{I_0}$
absorption	$I = I_0 e^{-\mu x}$ $\mu_m = \frac{\mu}{\rho}$
ultrasound imaging	$Z = \rho c$ $\frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$
half-lives	$\frac{1}{T_E} = \frac{1}{T_B} + \frac{1}{T_P}$