Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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6	
7	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2009

Physics (Specification A) PHYA2

Unit 2 Mechanics, Materials and Waves

Friday 5 June 2009 9.00 am to 10.15 am

For this paper you must have:
- a calculator
- a pencil and a ruler
- a data and formulae booklet.

Time allowed
- 1 hour 15 minutes

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. Answers written in margins or on blank pages will not be marked.
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

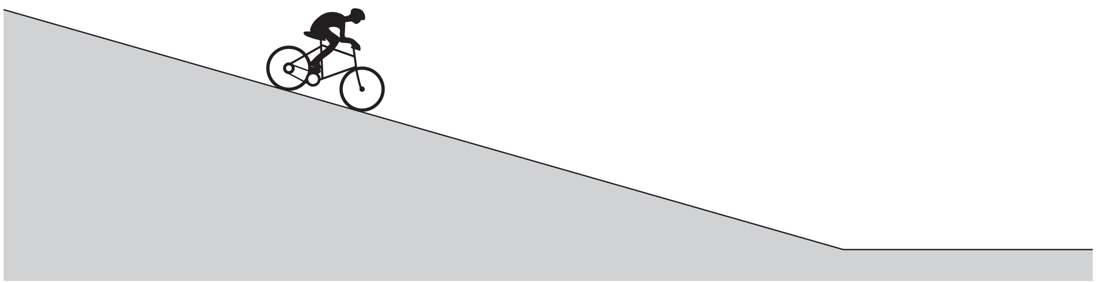
Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.
- A *Data and Formulae Booklet* is provided as a loose insert to this question paper.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

Areas outside the box will not be scanned for marking

Answer all questions in the spaces provided.

1 A cyclist **pedals** downhill on a road, as shown in **Figure 1**, from rest at the top of the hill and reaches a horizontal section of the road at a speed of $16\,\text{m s}^{-1}$. The total mass of the cyclist and the cycle is 68 kg.

Figure 1



1 (a) (i) Calculate the total kinetic energy of the cyclist and the cycle on reaching the horizontal section of the road.

answer............................J
(2 marks)

1 (a) (ii) The height difference between the top of the hill and the horizontal section of road is 12 m.
Calculate the loss of gravitational potential energy of the cyclist and the cycle.

answer...........................J
(2 marks)

Areas outside the box will not be scanned for marking

1 (a) (iii) The work done by the cyclist when pedalling downhill is 2400 J. Account for the difference between the loss of gravitational potential energy and the gain of kinetic energy of the cyclist and the cycle.

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(3 marks)

1 (b) The cyclist stops pedalling on reaching the horizontal section of the road and slows to a standstill 160 m further along this section of the road. Assume the deceleration is uniform.

1 (b) (i) Calculate the time taken by the cyclist to travel this distance.

answer.................................s

(3 marks)

1 (b) (ii) Calculate the average horizontal force on the cyclist and the cycle during this time.

answer..........................N

(3 marks)

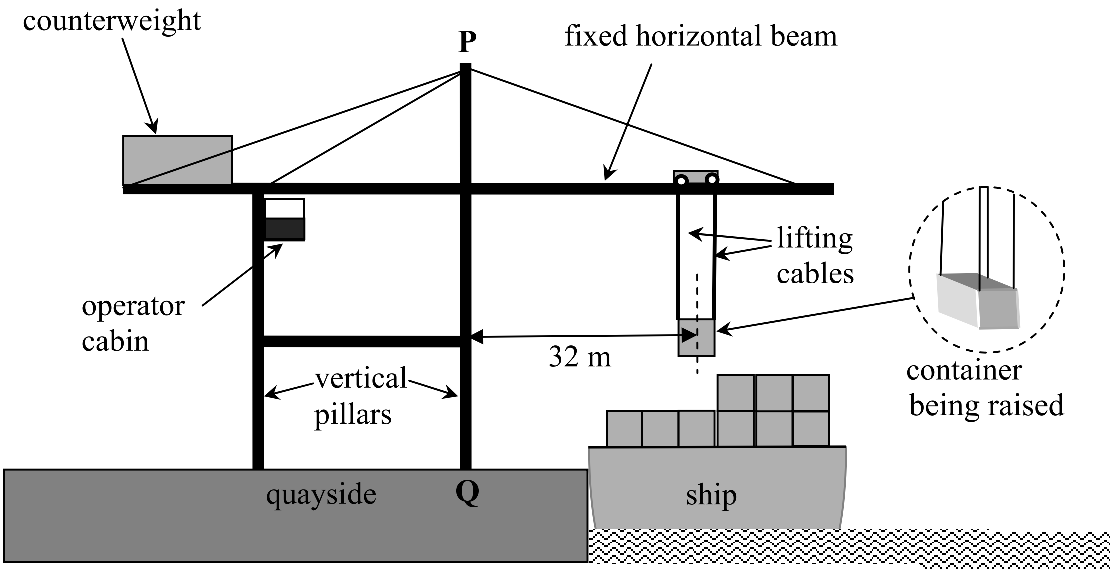
Turn over for the next question

13

Turn over ▸

2 **Figure 2** shows a dockside crane that is used to lift a container of mass 22000 kg from a cargo ship onto the quayside. The container is lifted by four identical 'lifting' cables attached to the top corners of the container.

Figure 2



2 (a) When the container is being raised, its centre of mass is at a horizontal distance 32 m from the nearest vertical pillar **PQ** of the crane's supporting frame.

2 (a) (i) Assume the tension in each of the four lifting cables is the same. Calculate the tension in each cable when the container is lifted at constant velocity.

answer.........................N

(2 marks)

2 (a) (ii) Calculate the moment of the container's weight about the point **Q** on the quayside, stating an appropriate unit.

answer.........................

(3 marks)

2 (a) (iii) Describe and explain **one** feature of the crane that prevents it from toppling over when it is lifting a container.

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(2 marks)

2 (b) Each cable has an area of cross-section of $3.8 \times 10^{-4} m^2$.

2 (b) (i) Calculate the tensile stress in each cable, stating an appropriate unit.

answer.................................

(3 marks)

2 (b) (ii) Just before the container shown in **Figure 2** was raised from the ship, the length of each lifting cable was 25 m. Show that each cable extended by 17 mm when the container was raised from the ship.

Young modulus of steel = 2.1×10^{11} Pa

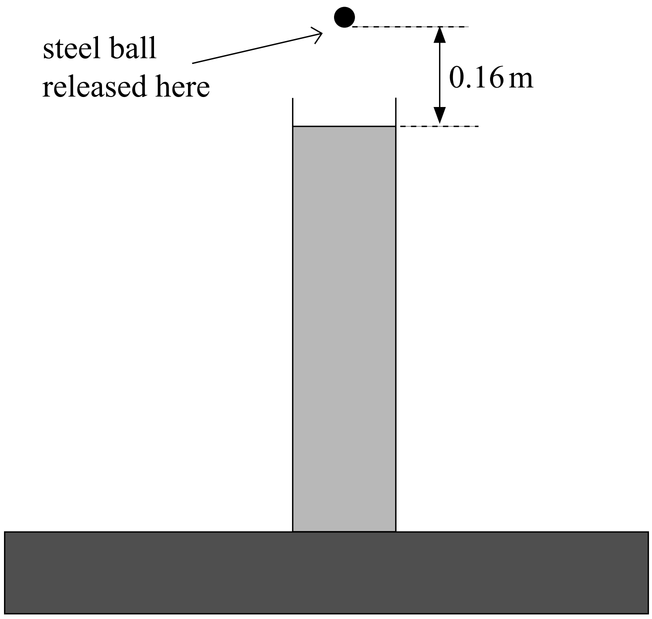
(2 marks)

12

Turn over for the next question

3 A steel ball is released from rest above a cylinder of liquid, as shown in **Figure 3**. The ball descends vertically in the air then in the liquid until it reaches the bottom of the cylinder.

Figure 3



3 (a) The vertical distance from the bottom of the ball at the point where it is released to the liquid surface is 0.16 m.

3 (a) (i) Calculate the time taken, t_o, by the ball to fall to the liquid surface from the point where it is released. Give your answer to an appropriate number of significant figures.

answer.................................s

(3 marks)

3 (a) (ii) Calculate the velocity, v_o, of the ball on reaching the liquid.

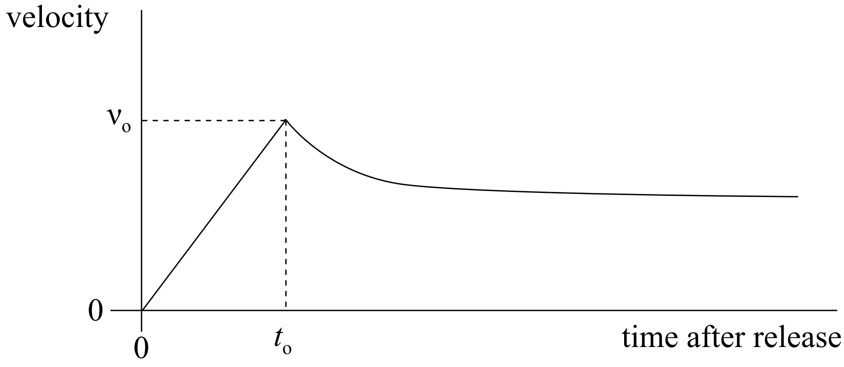
answer.................................m s^{-1}

(2 marks)

Areas outside the box will not be scanned for marking

3 (b) **Figure 4** below shows how the velocity of the ball changed after it was released.

Figure 4



Describe and explain how the acceleration of the ball changed after it entered the liquid until it reached the bottom of the cylinder.

The quality of your written answer will be assessed in this question.

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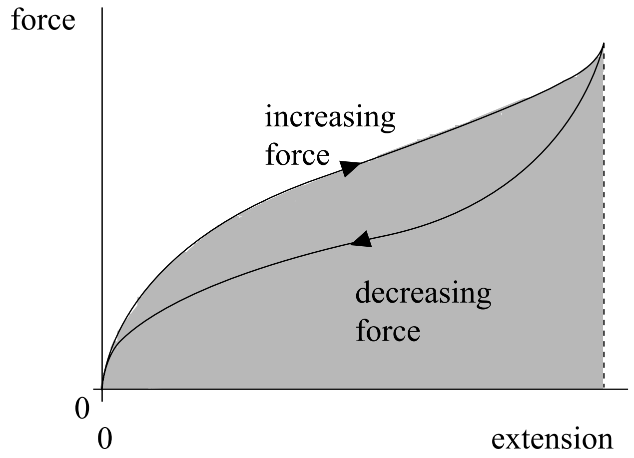
(6 marks)

11

Turn over ▸

4 A student investigated how the extension of a rubber cord varied with the force used to extend it. She measured the extension for successive increases of the force and then for successive decreases. **Figure 5** shows a graph of her results.

Figure 5



4 (a) (i) Give a reason why the graph shows the rubber cord does not obey Hooke's law.

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(1 mark)

4 (a) (ii) Give a reason why the graph shows the rubber cord does not exhibit plastic behaviour.

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(1 mark)

4 (a) (iii) What physical quantity is represented by the area shaded on the graph between the loading curve and the extension axis?

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(1 mark)

4 (b) Describe, with the aid of a diagram, the procedure and the measurements you would make to carry out this investigation.

The quality of your written answer will be assessed in this question.

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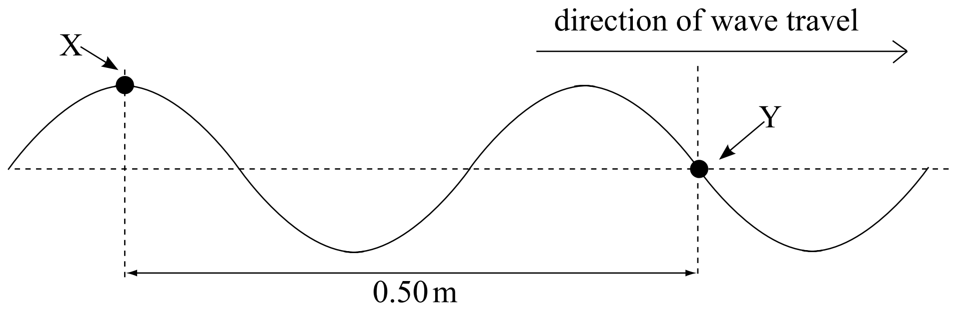
(6 marks)

9

Turn over for the next question

5 (a) **Figure 6** represents a progressive wave travelling from left to right on a stretched string.

Figure 6



5 (a) (i) Calculate the wavelength of the wave.

answer.................................m
(1 mark)

5 (a) (ii) The frequency of the wave is 22 Hz. Calculate the speed of the wave.

answer...........................m s^{-1}
(2 marks)

5 (a) (iii) State the phase difference between points X and Y on the string, giving an appropriate unit.

answer.............................
(2 marks)

Areas outside the box will not be scanned for marking

5 (b) Describe how the displacement of point **Y** on the string varies in the next half-period.

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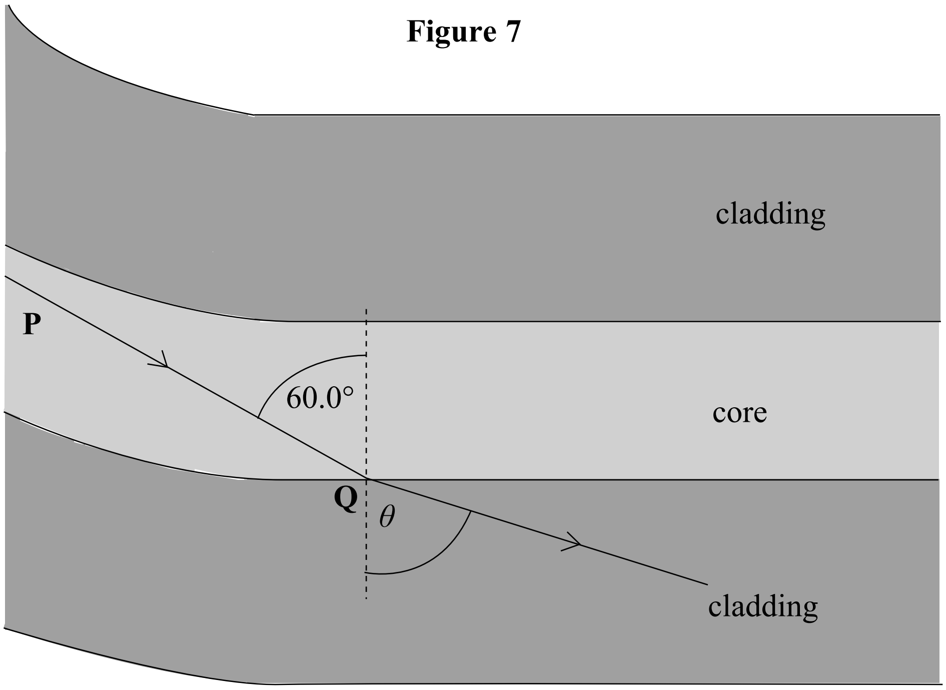
(2 marks)

7

Turn over for the next question

6 An optical fibre used for communications has a core of refractive index 1.55 which is surrounded by cladding of refractive index 1.45.

Figure 7



6 (a) **Figure 7** shows a light ray **P** inside the core of the fibre. The light ray strikes the core-cladding boundary at **Q** at an angle of incidence of 60.0°.

6 (a) (i) Calculate the critical angle of the core-cladding boundary.

answer............................degrees
(3 marks)

6 (a) (ii) State why the light ray enters the cladding at **Q**.

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(1 mark)

Areas outside the box will not be scanned for marking

6 (a) (iii) Calculate the angle of refraction, θ, at **Q**.

answer..............................degrees

(3 marks)

6 (b) Explain why optical fibres used for communications need to have cladding.

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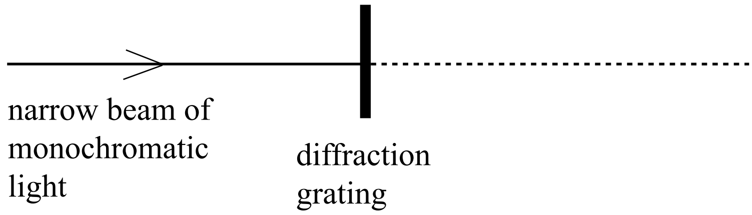
(2 marks)

9

Turn over for the next question

7 A narrow beam of monochromatic light of wavelength 590 nm is directed normally at a diffraction grating, as shown in **Figure 8**.

Figure 8



7 (a) The grating spacing of the diffraction grating is 1.67×10^{-6} m.

7 (a) (i) Calculate the angle of diffraction of the second order diffracted beam.

answer.................................... degrees
(4 marks)

7 (a) (ii) Show that no beams higher than the second order can be observed at this wavelength.

(3 marks)

7 (b) The light source is replaced by a monochromatic light source of unknown wavelength. A narrow beam of light from this light source is directed normally at the grating. Measurement of the angle of diffraction of the second order beam gives a value of 42.1°.

Calculate the wavelength of this light source.

answer......................................m

(2 marks)

9

END OF QUESTIONS

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Advanced Subsidiary Examination
June 2009

Physics A PHYA2

Unit 2 Mechanics, Materials and Waves

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}	$F\,m^{-1}$
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	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	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 931.3 MeV)	u	1.661×10^{-27}	kg

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	$= \pi r^2$
surface area of cylinder	$= 2\pi rh$
volume of cylinder	$= \pi r^2 h$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3}\pi r^3$

This insert page should **not** be sent to the examiner

AS FORMULAE

PARTICLE PHYSICS

Rest energy values

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

ELECTRICITY

current and pd $I = \frac{\Delta Q}{\Delta t}$ $V = \frac{W}{Q}$ $R = \frac{V}{I}$

emf $\varepsilon = \frac{E}{Q}$ $\varepsilon = I(R + r)$

resistors in series $R = R_1 + R_2 + R_3 + \ldots$

resistors in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$

resistivity $\rho = \frac{RA}{L}$

power $P = VI = I^2R = \frac{V^2}{R}$

alternating current $I_{rms} = \frac{I_0}{\sqrt{2}}$ $V_{rms} = \frac{V_0}{\sqrt{2}}$

MECHANICS

moments moment $= Fd$

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

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

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

force $F = ma$

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

$E_K = ½\, m\, v^2$ $\Delta E_P = mg\Delta h$

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

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

WAVES

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

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 $n_1 > n_2$