RAFFLES INSTITUTION
2021 YEAR 5 PROMOTIONAL EXAMINATION

30 September 2021 Time: 2 hr 30 min

H2 PHYSICS

Section A

INSTRUCTIONS TO CANDIDATES

There are 3 sections in this paper.

Section A consists of **15** multiple-choice questions. For each question, four suggested answers are given. You are to choose the most appropriate one and shade your answer on the OMR form, using a soft pencil.

You are advised to attempt Section A first. The **OMR form will be collected at the end of the first 30 minutes**.

Section B consists of **5** structured questions. You are to write your answers in the spaces provided.

Section C consists of **2** longer structured questions. You are to write your answers in the spaces provided.

Attempt ALL questions in Sections A, B and C.

Data

speed of light in free space	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}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T / ^\circ\text{C} + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{\frac{1}{2}}$

Section A (15 marks)

1 The resistive force F acting on a sphere of radius r travelling with speed v through a liquid is given by the equation

$$F = 6\pi\eta r v$$

where η is a constant.

What are the SI units of η?

A kg m^{-1} s^{-1} **B** kg m^{2} s^{-1} **C** kg m^{-1} s^{-2} **D** kg^{-1} s^{-3}

2 Two lengths X and Y are measured to be (51.0 ± 0.1) cm and (49.0 ± 0.1) cm respectively.

Which of the following quantities has the largest percentage uncertainty?

A $X + Y$ **B** $X - Y$ **C** XY **D** $\frac{X}{Y}$

3 Jack and Jill are standing 15 m apart on level ground when Jack throws a ball with speed u at an angle above the horizontal towards Jill.

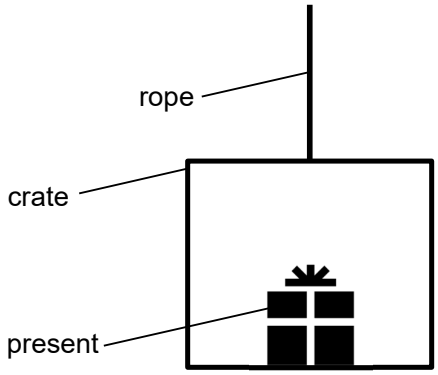
At the same time when Jack throws the ball, Jill runs towards it with a speed of 8.9 m s^{-1} and catches the ball 0.49 s after it is thrown.

The ball is thrown and caught at the same height above the ground.

What is the speed u of the ball?

A 11 m s^{-1} **B** 22 m s^{-1} **C** 31 m s^{-1} **D** 40 m s^{-1}

4 A piece of rope with a maximum allowable tension of 30 N is used to lift a 2.0 kg crate containing a 0.30 kg present.



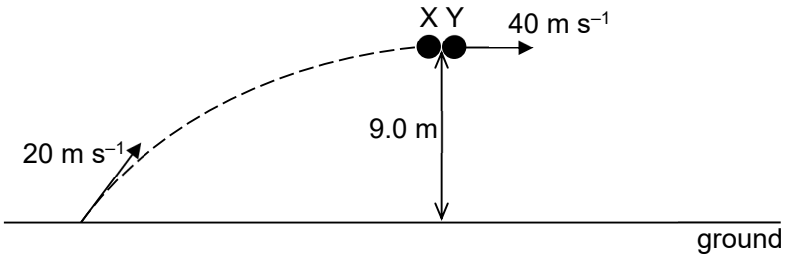
The crate is accelerated upwards at an increasing rate until the rope breaks.

What is the force that the present exerts on the crate just before the rope breaks?

A 3.9 N **B** 4.5 N **C** 9.5 N **D** 26 N

5 A projectile of mass $2m$ is launched at an angle to the ground with a speed of 20 m s^{-1}.

When the projectile is at the peak of its trajectory, 9.0 m above the ground, it explodes into two pieces, X and Y, each of equal mass m.

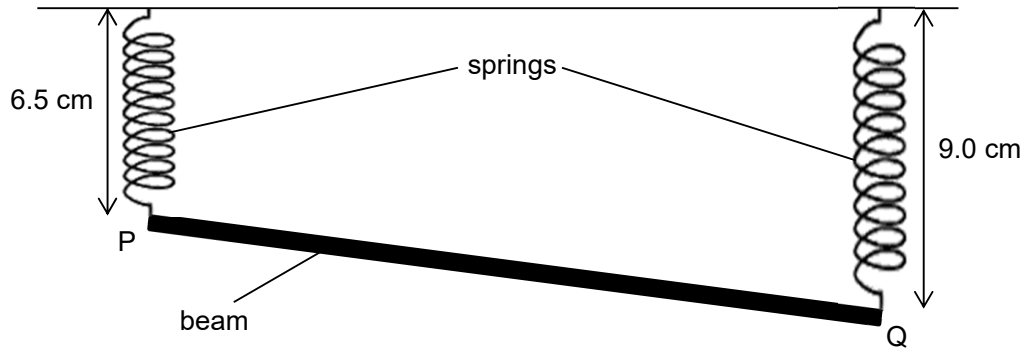


If Y has a speed of 40 m s^{-1} horizontally to the right immediately after the explosion, what is the speed of X immediately after the explosion? Ignore the effects of air resistance.

A 0 m s^{-1} **B** 10 m s^{-1} **C** 25 m s^{-1} **D** 40 m s^{-1}

6 A 2.0 m beam with a non-uniform mass distribution is supported at its ends P and Q by two identical vertical springs of unstretched length 4.0 cm.

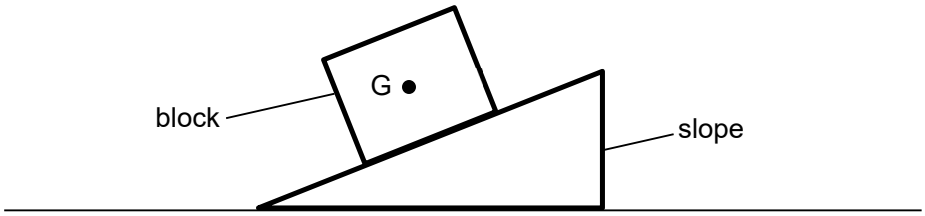
When the beam is in equilibrium, the lengths of each spring are 6.5 cm and 9.0 cm as shown.



What is the distance between the beam's centre of gravity and end P?

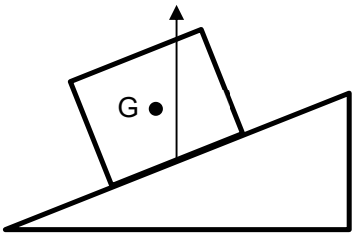
A 1.0 m **B** 1.2 m **C** 1.3 m **D** 1.4 m

7 A block is at rest on a slope. Point G represents the centre of gravity of the wooden block.

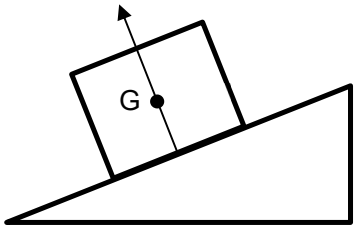


Which of the following shows the direction of the force the slope exerts on the block?

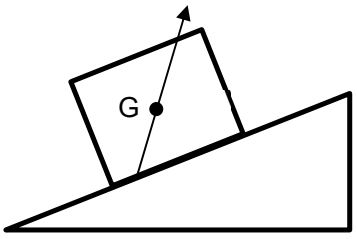
A



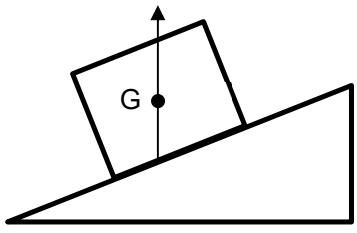
B



C



D

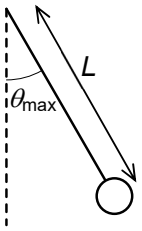


8 Two objects P and Q of masses m and $2m$ respectively are initially at rest on a smooth, horizontal surface.

If the same force acts on each of them for the same duration, the ratio $\frac{\text{gain in kinetic energy by P}}{\text{gain in kinetic energy by Q}}$ is

A 0.25 **B** 0.50 **C** 1.0 **D** 2.0

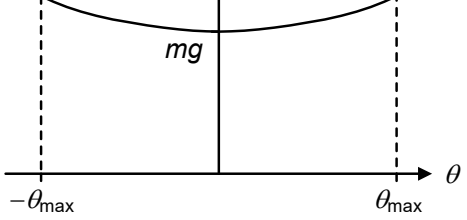
9 A pendulum of length L and mass m is displaced at an angular displacement θ_{max} from the vertical as shown.



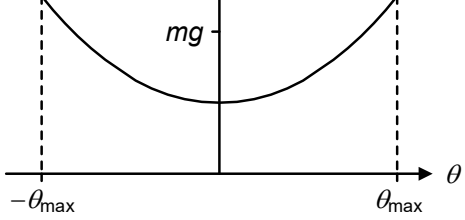
The pendulum is released.

Which of the following graph best represents the variation with angular position θ of the tension T in the string?

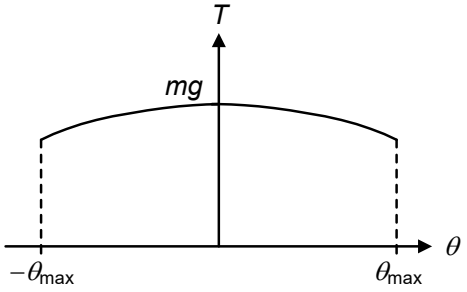
A



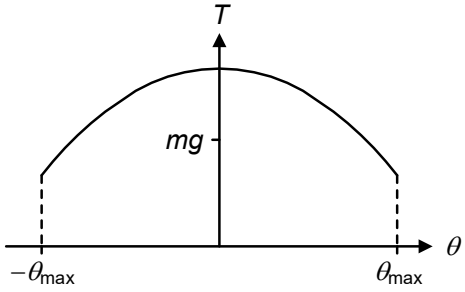
B



C



D



10 Which row describes the effect of atmospheric drag on a satellite's orbit?

	orbital speed	orbital radius	total energy
A	increases	increases	increases
B	increases	decreases	decreases
C	decreases	increases	increases
D	decreases	decreases	decreases

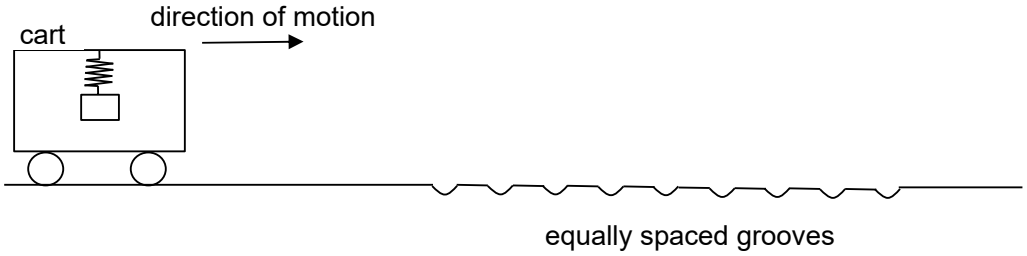
11 A 1.0 kg mass is attached to a horizontal spring on a smooth table. The mass is then displaced horizontally from its equilibrium position by 0.10 m and released from rest. The mass next comes to rest again after 0.50 s.

What is the maximum speed of the mass?

A $0.31\ \text{m s}^{-1}$ **B** $0.39\ \text{m s}^{-1}$ **C** $0.63\ \text{m s}^{-1}$ **D** $0.99\ \text{m s}^{-1}$

12 A 50 g mass is suspended from one end of a light spring of force constant $25\ \text{N m}^{-1}$. The other end of the spring is fixed to the roof of a 200 g cart.

When the cart moves over a series of equally spaced grooves, the mass oscillates vertically. The amplitude of oscillation is largest when the speed of the cart is $8.0\ \text{m s}^{-1}$.



What is the separation of the grooves?

(The frequency of oscillation of a loaded spring is given by $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ where m is the mass suspended from the spring and k is the force constant.)

A 0.20 m **B** 0.44 m **C** 2.2 m **D** 5.0 m

13 A sound wave of frequency 500 Hz is travelling at a speed of $300\ \text{m s}^{-1}$.

What is the phase difference between two points 0.75 m apart along the direction of travel?

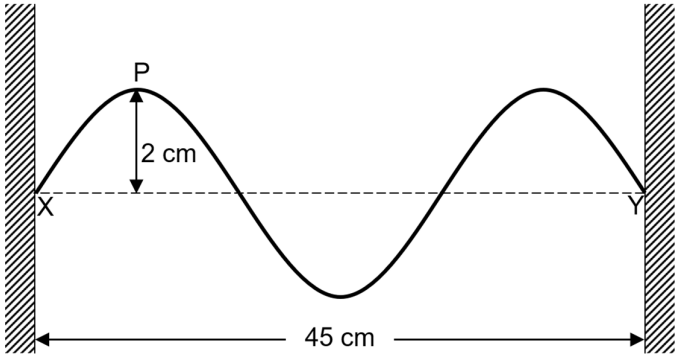
A 0.50π rad **B** 0.90π rad **C** 1.3π rad **D** 1.6π rad

14 Which row correctly compares the characteristics of progressive and stationary waves?

	progressive wave	stationary wave
A	all particles within one wavelength have different phases	particles between adjacent segments have the same phase
B	energy is transported at a speed given by the frequency divided by the wavelength	no net transport of energy
C	distance between two adjacent points that have the same phase is one wavelength	distance between a node and the adjacent antinode is half a wavelength
D	amplitude of vibration is the same at all points	amplitude of vibration varies with position

15 Two sinusoidal waves, travelling in opposite directions along a string XY that is fixed at both ends, form a stationary wave. The separation between X and Y is 45 cm.

The diagram shows the shape of the string at an instant when the antinode P attains its maximum displacement of 2 cm from the equilibrium position.



What is the amplitude and wavelength of each of the sinusoidal wave travelling on the string?

	amplitude	wavelength
A	2 cm	30 cm
B	2 cm	15 cm
C	1 cm	30 cm
D	1 cm	15 cm

END OF SECTION A