Parent's Signature …………………………………

Candidate's Name ………………………………………… CTG ……………

YISHUN JUNIOR COLLEGE

2014 JC 1 BLOCK TEST

PHYSICS **9646 / 2**

HIGHER 2 **25 June 2014**
Wednesday

Paper 2 **1 hour 15 minutes**

INSTRUCTIONS TO CANDIDATES

Do not open this booklet until you are told to do so.

Write your name and CTG in the spaces provided above.

Write in dark blue or black pen on both sides of the paper.

Do not use paper clips, highlighters, glue or correction fluid.

The use of approved scientific calculator is expected, where appropriate.

Answer **all** questions.

All working must be shown clearly in the spaces provided.

Paper 2	
Q1	**/6**
Q2	**/10**
Q3	**/11**
Q4	**/11**
Q5	**/8**
Q6	**/4**
Penalty	
Total	
	/50
Paper 1	
	/20
Final Total	
	/70
	%

This question paper consists of 12 printed pages.

Data

speed of light in free space, $c = 3.00 \times 10^8 \text{ m s}^{-1}$

permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} 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	=	$\rho g h$
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
Displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
resistors in series,	R	=	$R_1 + R_2 + \ldots\ldots\ldots$
resistors in parallel,	$\dfrac{1}{R}$	=	$\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots\ldots$
electric potential,	V	=	$\dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$, where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{0.693}{t_{\frac{1}{2}}}$

1 (a) Give a reasonable estimate for the mass of water in an eight-laned Olympic-sized swimming pool.

mass = …………………… kg [1]

(b) The amplitude of waves on water is A. The waves have speed v. The average power P of waves in a wavelength of length L is given by

$$P = \frac{1}{2} kA^2vL + c$$

where k and c are constants.

(i) Show that the SI base units of k is kg m^{-2} s^{-2}.

[2]

(ii) An observer makes the following estimates while standing on a cliff overseeing the incoming waves:

Amplitude of waves, $A = (4.0 \pm 0.1)$ m,
Speed of wave, $v = (5 \pm 1)$ m s^{-1},
Wavelength, $L = (3.0 \pm 0.6)$ m,

The values of the constant k and c are 9800 kg m^{-2} s^{-2} and 1000 W respectively.

Calculate the estimated power P and its associated uncertainty.

P = (………………… ± ………………) W [3]

2 In Fig. 2, a ball rolls off a roof that slopes downward at an angle of 40°. The edge **A** of the roof is 14.0 m above the ground. The ball leaves the roof with a speed u of 7.00 m s^{-1}. Neglect air resistance.

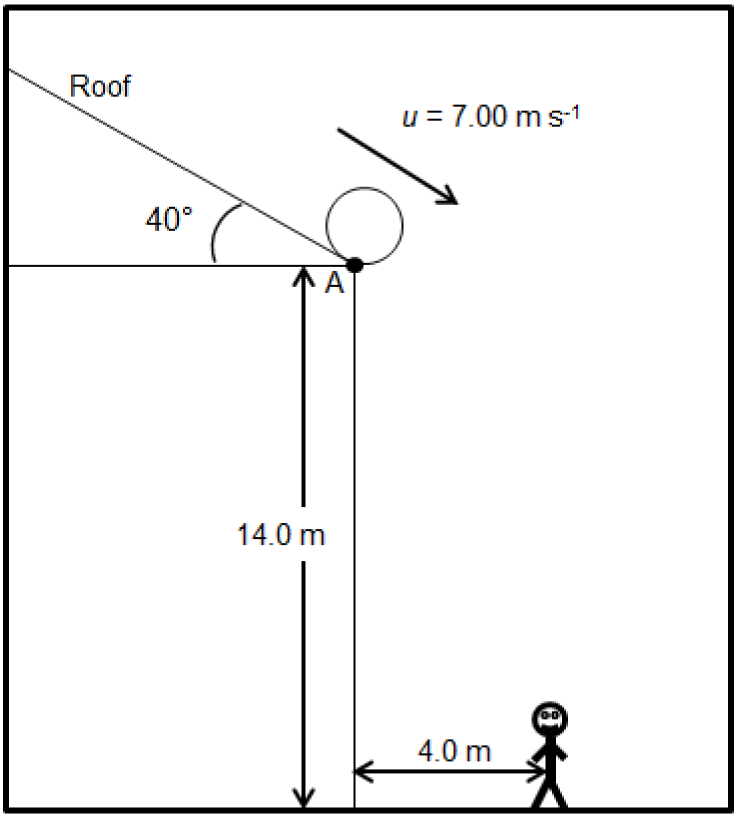


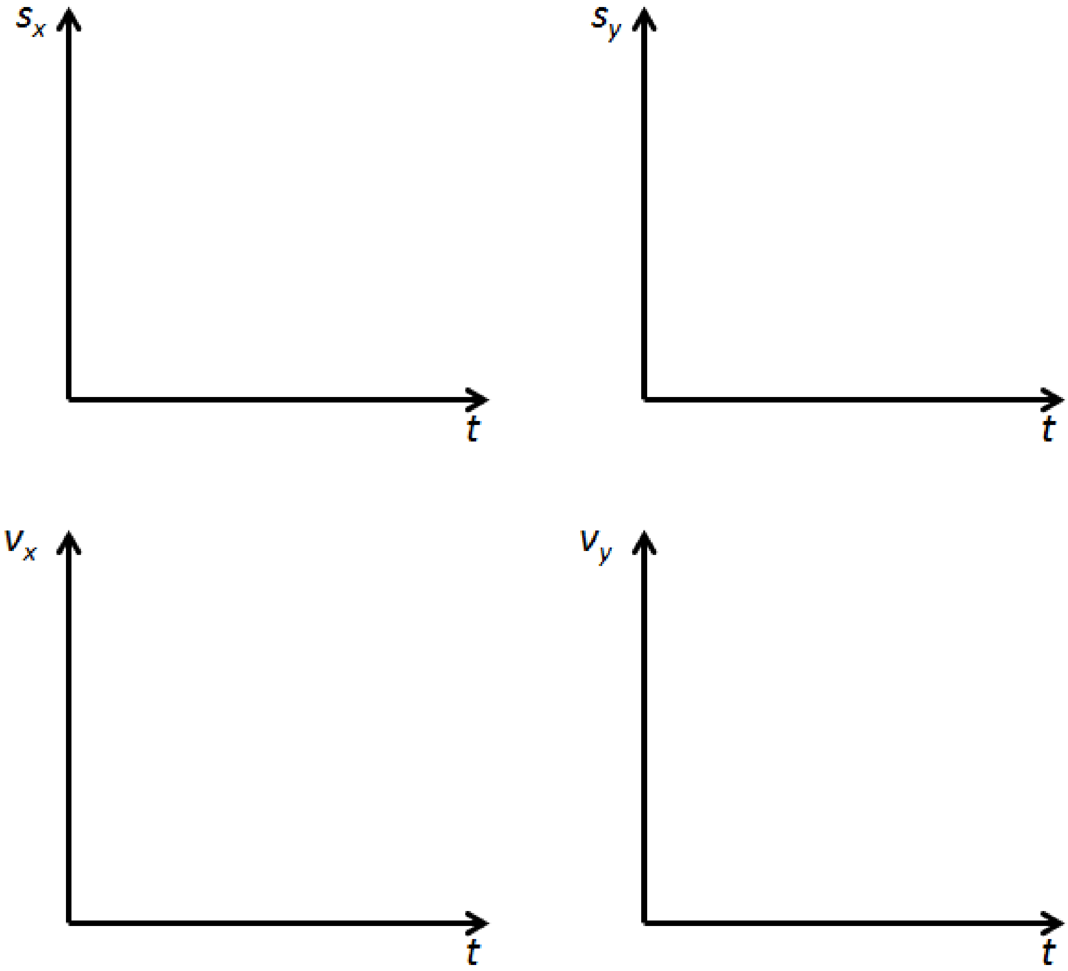
Fig. 2

(a) Calculate the horizontal distance from the edge of the roof when the ball hits the ground without striking anything else.

Horizontal distance = ………………….. m [3]

(b) Taking point **A** as starting point and downwards as positive, sketch the $s_x - t$, $s_y - t$, $v_x - t$ and $v_y - t$ graphs.

Labeling of values on the axes is not necessary. [4]



(c) A man 1.9 m tall stands 4.0 m from the edge of the roof. Determine whether the ball would hit the man on its way down.

[3]

3 **(a)** For two forces to be an action-reaction pair, they must be equal in magnitude. State three other characteristics which they must possess.

………………………………………………………………………………………………………...

………………………………………………………………………………………………………...

………………………………………………………………………………………………………... [2]

(b) A helicopter is a unique aircraft that achieves flight without wings. It does so from overhead blades that rotates continuously.

(i) Draw a free body diagram of a helicopter accelerating upwards. Label all forces clearly.

(Assume air resistance is negligible)

[2]

(ii) This helicopter of total mass 2.5×10^3 kg now hovers by imparting a downward velocity v to the air displaced by its rotating blades. The circular area swept out by the rotating blades is 113 m^2.

(Density of air = 1.3 kg m^{-3})

1. Show that the change in momentum of the downward displaced air in each second is approximately 150 v^2.

[2]

2. Calculate the downward velocity v required for the helicopter to accelerate upwards at 3.0 m s^{-2}.

v = ……………………..m s^{-1} [3]

(iii) A helicopter tilts downwards at an angle as shown in Fig. 3 when it is about to move forward. Suggest why.

Fig. 3

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

……………………………………………………………………………………………………. [2]

4 **(a)** The arrangement shown in Fig. 4.1 is used to determine the length l of a spring when different masses M are attached to the spring.

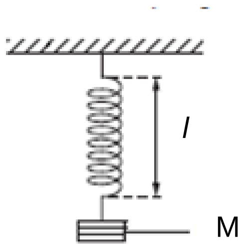


Fig. 4.1

The variation with mass M of l is shown in Fig. 4.2.

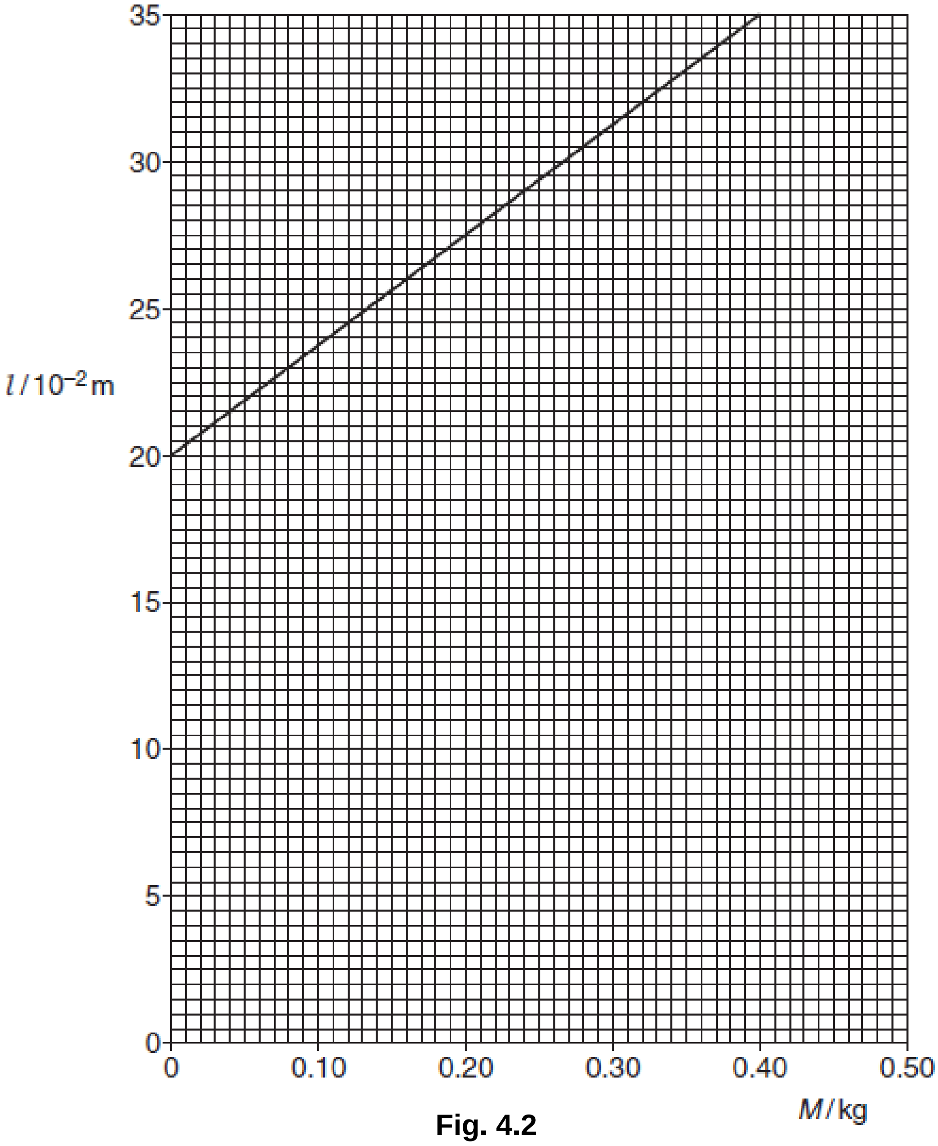


Fig. 4.2

(i) State and explain whether the spring obeys Hooke's law.

....

....

.... [2]

(ii) Show that the spring constant of the spring is 26 N m^{-1}.

[1]

(iii) A mass of 0.40 kg is attached to the spring. Calculate the energy stored in the spring.

Energy = …………………. J [2]

(b) A wheel is supported by a pin P at its centre of gravity as shown in Fig. 4.3.

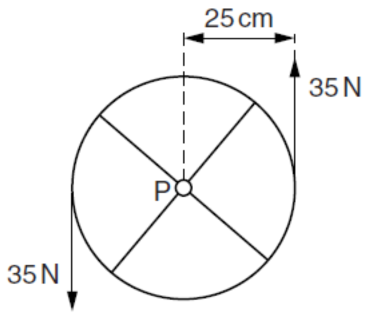


Fig. 4.3

The plane of the wheel is vertical. The wheel has radius 25 cm. Two parallel forces each of 35 N act on the edge of the wheel in the vertical directions shown in Fig. 4.3.

Friction between the pin and the wheel is negligible.

(i) List two other forces that act on the wheel. State the direction of these forces and where they act.

1. ……………………………………………………………………………………………..............

2. ……………………………………………………………………………………………...…[2]

(ii) Calculate the torque of the couple acting on the wheel.

Torque of the couple = …………………….N m [2]

(iii) State and explain whether the wheel is in equilibrium.

……………………………………………………………………………………………..............

…………………………………………………………………………………………………… [2]

5 (a) Consider an object of mass *m* initially at rest, acted by a constant resultant force *F*, which causes it to accelerate and displace in the same direction as *F*.

By using the equations of motion, show that the kinetic energy E_k of the object travelling with speed *v* is given by

$$E_k = \frac{1}{2}mv^2$$

State any assumption(s) made.

[3]

(b) Fig. 5.1 shows two bodies **X** of mass 2.00 kg and **Y** of mass 3.00 kg connected by a light inelastic cord running over a smooth pulley. A spring of spring constant 500 N m^{-1} is placed 0.500 m below **Y. X** starts from rest and moves up a rough plane inclined at an angle 40.0° to the horizontal. When moving, **X** experiences a constant frictional force 10.0 N.

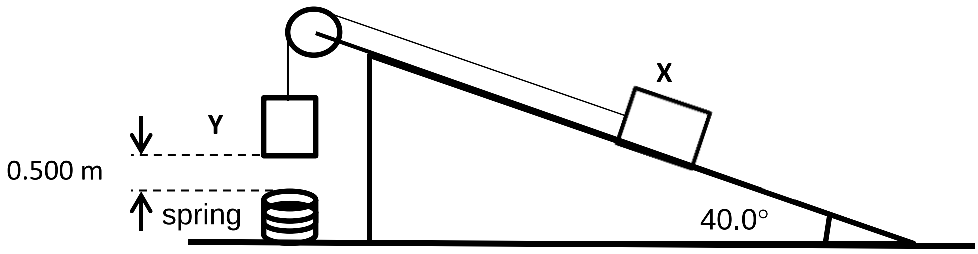


Fig. 5.1

(i) **1.** Calculate the work done against friction when **X** has moved 0.500 m along the plane.

work done = ………………….. J [1]

2. Determine the total kinetic energy of the system when **X** has moved 0.500 m along the plane, just before **Y** hits the spring.

kinetic energy = ………………….. J [2]

(ii) Calculate the maximum compression of the spring when **Y** hits the spring and comes to a rest.

maximum compression = ………………….. m [2]

6 An electron goes round a nucleus in a circular path with angular velocity of 4.1×10^{16} rad s^{-1}. The radius of the path is 5.3×10^{-11} m.

Determine the

(a) linear speed of the electron,

speed = …………………… m s^{-1} [1]

(b) the time for one revolution,

time = ……………………. s [1]

(c) the force acting on the electron.

force = ……………………. N

direction = ……………………. [2]

- End of Paper -

Paper 2 Suggested Solutions

1 **(a)** Volume of the swimming pool = 50 m x 20 m x 2 m = 2000 m^3 **1**

Mass of water = 2000 x 1000 = 2.0 x 10^6 kg **1**

Range acceptable – order of magnitude of 10^6

(b) **(i)** [k] = [P] / ([A]^2 [v] [L]) **1**

= (kg m^2 s^{-3}) (m^2 m s^{-1} m)$^{-1}$

= (kg m^2 s^{-3}) (m^4 s^{-1})$^{-1}$

= kg m^2 s^{-3} m^{-4} s^1 **1**

= kg m^{-2} s^{-2}

(ii) P = ½ (9800) (8.0 / 2)^2 (5) (3.0) + 1000 **1**

= 1177000 W

$$\frac{\Delta P}{P} = 2\frac{\Delta A}{A} + \frac{\Delta v}{v} + \frac{\Delta L}{L}$$

$$\frac{\Delta P}{1177000} = 2\left(\frac{0.1}{4.0}\right) + \frac{1}{5} + \frac{0.6}{3.0}$$ **1**

ΔP = 529650 W

P = (1.2 ± 0.6) x 10^6 W **1**

2 **(a)**

	X	Y
u	7.00 cos40	7.00 sin40
a	0	9.81
v	7.00 cos40	?
t	?	
s	?	14.0

Using $S_y = u_y t + \frac{1}{2} a_y t^2$,

$14.0 = (7.00 \sin 40\,)\mathrm{t} + \frac{1}{2}(9.81)\mathrm{t}^2$ **1**

$t = 1.29$ s

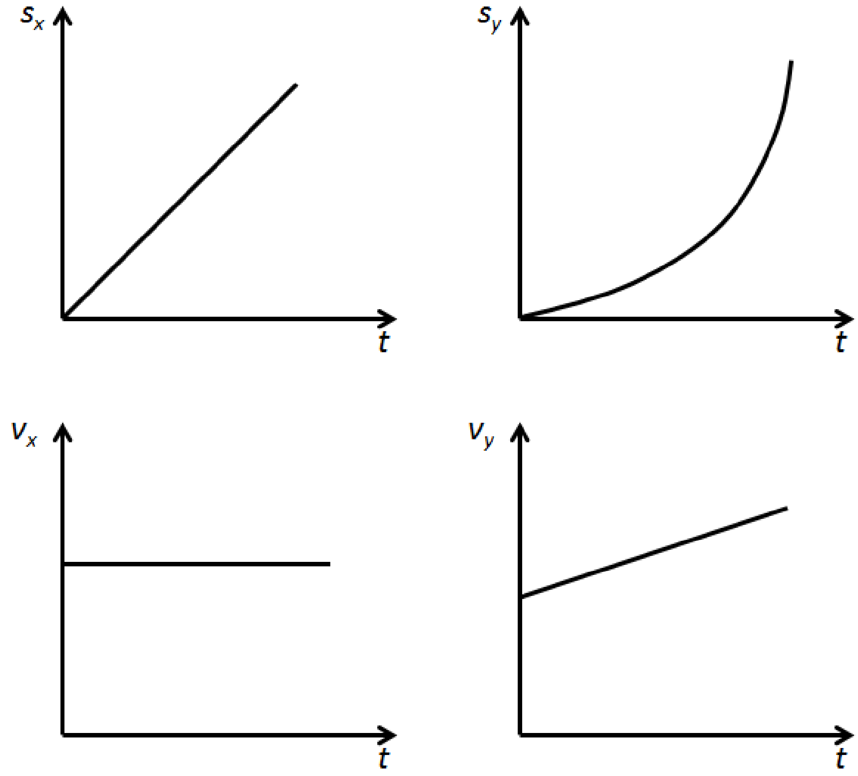
using $S_x = u_x t + \frac{1}{2} a_x t^2$ or $S_x = \frac{1}{2}(u_x + v_x)t$ **1**

$S_x = 6.92$ m **1**

2 **(b)**

Take downwards as positive and origin to be the initial position.

1 mark for each correct diagram.



2 **(c)** **Approach 1** (obtain time taken to travel 4.0m in x direction then determine vertical displacement in this period):

$$S_x = u_x t + \frac{1}{2} a_x t^2$$

$4.0 = 7.00 \cos 40\ t$ **1**

$t = 0.75\ s$

$at\ t = 0.75\ s,$

$S_y = 7.00 sin40\ (0.75) + \frac{1}{2}(9.81)(0.746)^2$ **1**

$= 6.1\ m$

Therefore, at a horizontal displacement of 4.0m, the ball is,
$14.0 - 6.1 = 7.9\ m$ above the ground

The ball did not hit the man. **1**

Award only if above 2 marks are awarded

Approach 2 (obtain time taken to travel 12.1m in y direction then determine horizontal displacement in this period):

$$S_y = u_y t + \frac{1}{2} a_y t^2$$

$14 - 1.9 = 7.00 sin40t + \frac{1}{2}(9.81)t^2$ **1**

$t = 1.178\ s$ or -2.095 s (rej.)

$at\ t = 1.18\ s,$

$S_x = 7.00\ cos40\ (1.18) + \frac{1}{2}(0)(1.18)^2$ **1**

$= 6.3\ m$

Therefore, at vertical displacement of 12.1m, the ball is,
$6.3 - 4.0 = 2.3\ m$ to the left of the man.

The ball did not hit the man. **1**

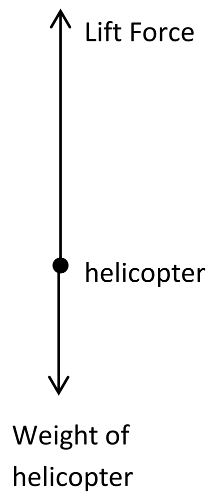
Award only if above 2 marks are awarded

3 (a)

- Same nature
- Opposite in directions
- Act on two different bodies

Deduct 1m for any missing point. Max 2m.

(b) (i)



All two forces correct direction and labeled.

Lift force > Weight of helicopter

Deduct 1m for any missing point. Max 2m.

(ii) 1. Assuming air above the blades is originally at zero velocity,

Change in momentum of air = final momentum – initial momentum

= (Mass × final velocity) – 0 **1**

= (density × [Volume of air per second] × final velocity)

= (1.3 × [Area × distance pushed per second] × v **1**

= 1.3 × 113 × v × v = $150v^2$ (2 sf) (Shown)

2. $(\downarrow)\Sigma F = ma$

W – L = ma **1**

$2.5 \times 10^3 \times 9.81 - L = (2.5 \times 10^3)(-3)$

L = 32025 N **1**

By Newton's 3rd law. Lift on helicopter = force acting on air by blades

= rate of change of momentum of air

32025 = $150v^2$ / (1) **1**

v = 15 m s^{-1} (2 sf)

(iii) Lift force on the helicopter perpendicular to the blade plane of spin.

Vertical component of Lift force needed to balance the downward weight so that it remains at rest vertically. **1**

Horizontal component of Lift force needed to provide horizontal resultant force to accelerate horizontally. **1**

Hence the plane of the blades needs to be tilted from the horizontal position to provide for the angled Lift force, thus body of helicopter is angled. **0**

4 **(a)** **(i)** Linear/straight line graph hence obeys Hooke's law **1**

which states that extension of spring is proportional to the applied force (weight of M) **1**

(ii) K = (0.4 x 9.81) / (15 x 10^{-2}) **1**

= 26 (.1) Nm^{-1} or choose any other appropriate point on graph

(iii) Energy = ½ ke^2 **1**

= ½ (26) (15 x 10^{-2}) ^{2} = 0.294 J (allow 2 s.f) **1**

(b) **(i)** **1.** weight at P (vertically) down **1**

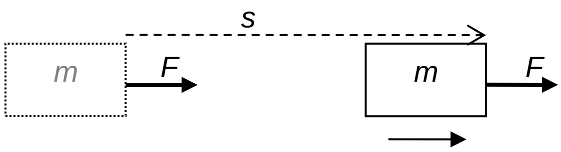
2. normal reaction OR contact force at (point of contact with the pin) P (vertically) up **1**

(ii) torque = 35 × 0.25 (or 25) × 2 **1**

= 18 (17.5) N m **1**

(iii) not in equilibrium [1] as the (resultant) torque is not zero [1] **2**

5 **(a)** Consider an object of mass *m* initially at rest, acted upon by a <u>constant</u> <u>resultant force</u> *F*, which causes it to accelerate and displace in the same direction as *F*.



Initial velocity, u = 0 Final velocity v

Work done by F on mass m, $W_{by\,F} = Fs$

From Newton's second law, $= (ma)s$ --- (1)

For constant acceleration, $v^2 = u^2 + 2as$

$as = \frac{1}{2}v^2$ (since u = 0) --- (2) **1**

Substitute (2) into (1): $W_{by\,F} = m(\frac{1}{2}v^2)$ **1**

Assuming there is no change in other forms of energy *(e.g. the object is not deformed due to F)*, all the work done is used to increase the kinetic energy of mass *m*. **1**

Hence, $E_k = \frac{1}{2}mv^2$

(b) **(i)** 1. Work done against friction = $Fs = 10.0 \times 0.500 = 5.00\,\text{J}$ **1**

2. Total KE = $m_Y gs - M_{mx} gs \sin\theta - Fs$

$= 3.00 \times 9.81 \times 0.500 - 2.00 \times 9.81 \times 0.500 \sin 40.0 - 5.00$ **1**

$= 3.41\,\text{J}$ **1**

(ii) Taking Y as system, (string will no longer be taut)

Loss KE + Loss in GPE = Gain EPE

$$\left(\frac{3.00}{5.00}\right)3.41 + m_y gx = \frac{1}{2}kx^2$$ **1**

$$\left(\frac{3.00}{5.00}\right)3.41 + 3.00 \times 9.81 \times x = \frac{1}{2} \times 500 \times x^2$$

$x = 0.167\,\text{m}$ **1**

6

(a) v = r ω = … = 2.17 × 10^6 m s^{-1} = 2.2 × 10^6 m s^{-1} (to 2 s.f.) **1**

(b) T = 2π / ω = … = 1.53 × 10^{-16} s = 1.5 × 10^{-16} s (to 2 s.f.) **1**

(c) F = m r ω^2 = … = 8.1 × 10^{-8} N **1**

Directed towards center of nucleus **1**