Question 1

diagram:	**two bodies and track**	**(3)**
	labelled means of attaching the two bodies	**(3)**
	timer / motion sensor	**(3)**
measurements:	**masses**	**(3)**
	time for n gaps // time for body to pass through light gate // approp. time	**(3)**
	length of n gaps // length of (card)body // approp. distance	**(3)**
calculate:	**distance ÷ time // appropriate slope = velocity**	**(3)**

Using the recorded data, show how the experiment verifies the principle of conservation of momentum.

$0.3251 \times 0.84 = 0.273$ kg m s^{-1} **(3)**

$(0.3251 + 0.3498) \times 0.41 = 0.277$ kg m s^{-1} **(3)**

0.273 kg m s^{-1} ≈ 0.277 kg m s^{-1}/ or equivalent **(3)**

(3 marks for formula only)

(–1 for omission of or incorrect units)

When carrying out this experiment the student ensures that there is no net external force acting on the bodies.

What are the two forces that the student needs to take account of to ensure this?

Describe how the student reduced the effects of these forces.

weight (gravitational force) **(4)**

friction **(4)**

horizontal (air)track / cushion of air / (small) slope / polish runway / oil wheels **(2)**

Question 2

vectors have direction **(2)**
scalars have no direction **(2)**
e.g. velocity and speed **(2 × 2)**

Describe an experiment to find the resultant of two vectors.

apparatus and arrangement e.g. 3 weights and pulleys **(3)**
procedure and measurements e.g. adjust and read each force **(3)**
observation and result e.g. statement *(–1 if correct direction not shown)* **(3)**

A golfer pulls his trolley and bag along a level path. He applies a force of 277 N at an angle of 24.53° to the horizontal. The weight of the trolley and bag together is 115 N and the force of friction is 252 N.

Calculate the net force acting on the trolley and bag.

Horizontal force applied by golfer = 277Cos24.53° ≈ 252 N **(3)**
Vertical force applied by golfer = 277Sin24.53° ≈ 115 N **(3)**
Net force ≈ 0 N **(3)**

What does the net force tell you about the golfer's motion?

constant speed **(3)**

Use Newton's second law of motion to derive an equation relating force, mass and acceleration.

F proportional to (mv – mu)/t **(2)**
F proportional to ma **(2)**
F = kma **(2)**
k = 1 (by definition of the newton) **(2)**
F = ma **(1)**

A force of 5.3 kN is applied to a golf ball by a club. The mass of the ball is 45 g and the ball and club are in contact for 0.54 ms.

Calculate the speed of the ball as it leaves the club.

F = ma // I = Ft // F = (mv – mu)/t **(3)**
correct substitution **(3)**
$v = 63.6\ m\ s^{-1}$ *(–1 for omission of or incorrect units)* **(3)**

The ball leaves the club head at an angle of 15° to the horizontal. Calculate the maximum height reached by the ball. You may ignore the effect of air resistance.

$u_y = 16.46\ m\ s^{-1}$ **(3)**
$v^2 = u^2 + 2as$ // $½mv^2 = mgh$ **(3)**
height = 13.82 m *(–1 for omission of or incorrect units)* **(3)**

Question 3

11. (*a*) **Seismic waves can be longitudinal or transverse. What is the main difference between them?**

direction of vibration parallel to direction of propagation of wave .. (longitudinal)
direction of vibration perpendicular to direction of propagation of wave .. (transverse) 4 + 3

(award 7 marks for "only transverse waves can be polarised")

(*b*) **An earthquake generates a seismic wave that takes 27 seconds to reach a recording station. If the wave travels at 5 km s^{-1} along the earth's surface, how far is the station from the centre of the earthquake?**

$s = vt$ 4
$s = 5000 \times 27 = 135000$ m $= 135$ km *(–1 for omission of or incorrect units)* 3

(*c*) **Draw a diagram to show the forces acting on the suspended mass when the seismometer is at rest.**

weight acting downwards
tension acting upwards 4 + 3

(–1 if vectors unequal; –3 for incorrect additional forces)

(*d*) **At rest, the tension in the spring is 49 N. What is the value, in kilograms, of the suspended mass?**

$W = mg$ 4
$m = 5$ kg 3

(*e*) **What type of motion does the frame have when it moves relative to the mass?**

simple harmonic motion 7

(award 4 marks for "wave motion" or "periodic motion" or "up-down motion")

(*f*) **During an earthquake the ground was observed at the recording station to move up and down as the seismic wave generated by the earthquake passed. Give an equation for the acceleration of the ground in terms of the periodic time of the wave motion and the displacement of the ground.**

$a = \frac{4\pi^2 s}{T^2}$ 7

(*g*) **If the period of the ground motion was recorded as 17 seconds and its amplitude was recorded as 0.8 cm, calculate the maximum ground acceleration at the recording station.**

$a_{max} = \frac{4\pi^2(0.008)}{17^2}$ 4
$a_{max} = 0.0011$ m s^{-2} *(–1 for omission of or incorrect units)* 3

(*h*) **In some modern seismometers a magnet is attached to the mass and a coil of wire is attached to the frame. During an earthquake, there is relative motion between the magnet and the coil. Explain why an emf is generated in the coil.**

magnetic field passing through the coil // coil cuts 4
is changing // (magnetic) flux 3

('due to Faraday's law', 4 marks ; 'due to Faraday's law of e.m.i.', 4 + 3)

(acceleration due to gravity, $g = 9.8$ m s^{-2})

Question 4

Draw a labelled diagram of the apparatus used in the experiment.

track/means of coalescing, two trolleys, labeled means of measuring time/velocity (e.g. motion sensor)

3 marks per component 3×3

What adjustments did the student make to the apparatus so that body A would move at constant velocity?

adjust gradient of track, lubricate trolley wheels, polish/brush track, clear holes (air track), etc. any *two* 2×3

How did the student know that body A was moving at constant velocity?

dots on the ticker tape were equally spaced / same time interval shown by both light gates / horizontal line on v vs. t graph (datalogging method) 6

Describe how the student measured the velocity *v* of the bodies after the collision.

Δt between dots = 0.02 s = $\frac{1}{50}$ s	measure length l of card	select number of points on (s vs. t) graph	3
measure distance for n intervals	read Δt from light gate	(use) slope (tool)	3
velocity = $\frac{\Delta s}{\Delta t}$ or in words	velocity = $\frac{\Delta l}{\Delta t}$ or in words	slope = ($\frac{\Delta s}{\Delta t}$) = velocity	3

Using the recorded data, show how the experiment verifies the principle of conservation of momentum.

momentum	= mass × velocity / $\vec{p}=m\times\vec{v}$ / $p=m\times v$	2
initial momt	= (0.230)(0.53) / 0.1219 (kg m s^{-1})	2
final momt	= (0.390)(0.32) / 0.1248 (kg m s^{-1})	2
principle verified since	0.1219 kg m s^{-1} $\approx$ 0.1248 kg m s^{-1} or equivalent	2

(–1 for omission of or incorrect unit)

How could the accuracy of the experiment be improved?

use digital balance / select more dots / select greater distance/displacement /avoid parallax error 2

Question 5

(*a*) **Define the moment of a force.**

($T =$) force × (perp) distance / $F \times d$ 6

When the toy is knocked over, it always returns to the upright position. Explain why this happens.

(toy non-vertical) c.g. has a (turning) moment about <u>fulcrum</u> / <u>point of support/contact</u> /
(c.g. has) zero turning moment when toy is in vertical position 6

(any valid reference, e.g. 'low c.g.', 'equilibrium', 'turning moment', … 3 marks)

(*b*) **State the conditions necessary for the equilibrium of a body under a set of co-planar forces.**

<u>(vector</u>/<u>algebraic)</u> sum of the forces = zero // forces up = forces down // $\Sigma F = 0$ 6+3

sum of the (turning) moments (about any point) = zero // CTM = ACTM // $\Sigma T = 0$

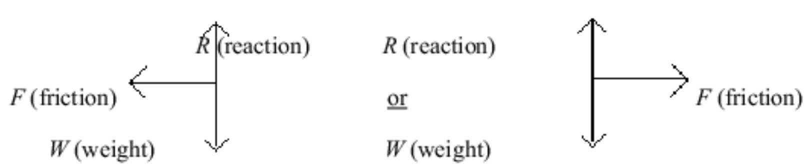
Three children position themselves on a uniform see-saw so that it is horizontal and in equilibrium. The fulcrum of the see-saw is at its centre of gravity. A child of mass 30 kg sits 1.8 m to the left of the fulcrum and another child of mass 40 kg sits 0.8 m to the right of the fulcrum. Where should the third child of mass 45 kg sit, in order to balance the see-saw?

$30g(1.8)$ / $40g(0.8)$ / $45g(x)$ 6

$30g(1.8) = 40g(0.8) + 45g(x)$ 3

$x =$ 0.488 m / 0.49 m / 49 cm **(–1 for omission of or incorrect unit)** 3

(*c*) **A simple merry-go-round consists of a flat disc that is rotated horizontally. A child of mass 32 kg stands at the edge of the merry-go-round, 2.2 metres from its centre. The force of friction acting on the child is 50 N. Draw a diagram showing the forces acting on the child as the merry-go-round rotates.**



(–1 per each unlabelled force; 3 marks per each correct force) 3×3

What is the maximum angular velocity of the merry-go-round so that the child will not fall from it, as it rotates?

$F = m\omega^2 r$ 3

$50 = (32)(\omega)^2(2.2)$ 3

$\omega = 0.842 \text{ rad s}^{-1}$ **(–1 for omission of or incorrect unit)** 3

If there was no force of friction between the child and the merry-go-round, in what direction would the child move as the merry-go-round starts to rotate?

child remains stationary / any appropriate answer, e.g. '*it depends on the frame of reference*' 5

Question 6

(i) **Calculate the acceleration due to gravity at a height of 31 km above the surface of the earth.**

equation: $\frac{g_1}{g} = \frac{d^2}{d_1^2}$ // $g_1 = \frac{GM}{d_1^2}$ 6

substitution: $\frac{(9.81)(6.36\times10^6)^2}{(6.391\times10^6)^2}$ // $g_1 = \frac{(6.6742\times10^{-11})(5.97\times10^{24})}{(6.391\times10^6)^2}$ 3

answer: $g_1 = 9.7(15)$ m s-2 // $g_1 = 9.96$ m s-2 **(–1 for omission of or incorrect units)** 3

(ii) **What downward force was exerted on Kittinger and equipment at 31km, taking their total mass as 180 kg?**

$(W = F =)\ mg$ 3

$F = 180(9.715)$ / 1748.7 N **(–1 for omission of or incorrect units)** 3

(iii) **Estimate how far he fell during the first 13 seconds.**

equation $s = ut + \frac{1}{2}at^2$ 3

substitution $\frac{1}{2}(9.715)(13)^2$ 3

answer $s = 820.(92)$ m **(–1 for omission of or incorrect units)** 3

What assumptions did you take in this calculation?

u taken as zero / g_1 constant / no atmospheric resistance / no buoyancy due to atmosphere any *two* 2+1

(iv) **What was his average speed during the next 4 minutes and 36 seconds?**

average speed = distance ÷ time 3

distance = 31000 – 820.(92) –5000 / ≈ 25180 3

average speed = 25180 ÷ 276 / ≈ 91.23 m s^{-1} **(–1 for omission of or incorrect units)** 3

(v) **How much was the force on a hemispherical parachute of diameter 8.5 m greater than that on a similar parachute of diameter 1.8 m?**

pressure = force ÷ area 3

$\frac{F}{F'} = \frac{(PA)}{(PA)'}$ / $\frac{2\pi R^2}{2\pi r^2}$ 3

$\frac{F}{F'} = \frac{(4.25)^2}{(0.9)^2}$ / $\frac{(8.5)^2}{(1.8)^2}$ / 22.3 3

(vi) **Calculate the upthrust that acted on Kittinger when he reached constant velocity in the last stage of his descent (assume g = 9.81 m s^{-2} during this stage).**

upthrust $(U) = mg$ 3

= (180)(9.81) 3

≈ 1766 N **(–1 for omission of or incorrect units)** 2

Question 7

(*b*) **State the law of conservation of momentum.**

momentum before = momentum after 4

in a closed system / provided no external forces act 3

Question 8

State Newton's law of universal gravitation.

force proportional to product of masses // $F = \frac{Gm_1m_2}{d^2}$ / $F \propto \frac{m_1m_2}{d^2}$ 3

(F) inversely/indirectly proportional to square of the distance // correct notation 3

Use this law to calculate the acceleration due to gravity at a height above the surface of the earth, which is twice the radius of the earth.

$2d$ above surface results in a distance = $3d$ from earth's centre (state/imply) 3

[for mass m on earth's surface:] $mg = \frac{GMm}{d^2}$ / $g = \frac{GM}{d^2}$ / $g \propto \frac{1}{d^2}$ 3

[for a distance of $3d$ from centre of earth] $mg_1 = \frac{GMm}{(3d)^2}$ / $g_1 = \frac{GM}{9d^2}$ / $g_1 \propto \frac{1}{(3d)^2}$ 3

[for mass m on at distance ($3d$) from earth's centre] $\therefore g_1 = \frac{g}{9}$ / $1.09\ \text{m s}^{-2}$ 3

(–1 for omission of or incorrect units) 18

A spacecraft carrying astronauts is on a straight line flight from the earth to the moon and after a while its engines are turned off.

(i) Explain why the spacecraft continues on its journey to the moon, even though the engines are turned off.

reference to Newton's 1st law of motion / 'because of its momentum/inertia' 6

(ii) Describe the variation in the weight of the astronauts as they travel to the moon.

weight decreases (to zero) as the astronaut moves away from the earth 3

gains (a lesser than normal) weight as she/he approaches the moon 3

12

(iii) At what height above the earth's surface will the astronauts experience weightlessness?

gravitational pull of earth = gravitational pull of moon 3

$$\frac{GM_E m}{R_1^2} = \frac{GM_m m}{R_2^2}$$ 3

$$\frac{M_E}{M_m} (=81) = \frac{R_1^2}{R_2^2}$$ 3

$$9 = \frac{R_1}{R_2}$$

(–1 for incomplete answer) / height above earth = 3.39×10^8 m 3

(–1 for omission of or incorrect units) 12

(iv) The moon orbits the earth every 27.3 days. What is its velocity, expressed in metres per second?

formula: (for one orbit:) $v = \frac{2\pi r}{T}$ 3

substitution: $v = \frac{2\pi(3.84 \times 10^8)}{27.3 \times 24 \times 60 \times 60}$ 3

answer: $v = 1022.9\ \text{m s}^{-1}$ $(\approx 1.02 \times 10^3\ \text{m s}^{-1})$ 3

(–1 for omission of or incorrect units) 9

(v) Why is there no atmosphere on the moon?

gravitational force too weak (to sustain atmosphere) 5

5

Question 9

Question 12 (a)

***(a)* What is friction?**

a force	3
that opposes motion / tries to prevent one surface sliding over another	3

A car of mass 750 kg is travelling east on a level road. Its engine exerts a constant force of 2.0 kN causing the car to accelerate at 1.2 m s^{-2} until it reaches a speed of 25 m s^{-1}.
Calculate

(i) the net force,

$F_{net} = m\,a$		3
$F_{net} =$ (750)(1.2) **or** 900 N, (east)	**(no penalty for units)**	3

(ii) the force of friction, acting on the car.

$F_{net} = F_{car} - F_{friction}$		3
$900 = 2000 - F_{friction}$ **or** $F_{friction} = 1100$ N, (west)	**(no penalty for units)**	3

If the engine is then turned off, calculate how far the car will travel before coming to rest.

(Friction causes deceleration:) $a = F \div m$ (re-arrangement only)		3
$a = (-1100) \div 750$ **or** -1.47 m s^{-2}		2
$v^2 = u^2 + 2as$		3
$0 = 25^2 + 2(-1.47)\,s$ **or** $s = 213.07$ m ≈ 213 m	**(-1 for omission of or incorrect units)**	2

Question 10

(a) **State Newton's third law of motion.** (7)

action and reaction are equal	// when body A exerts a force on body B, B exerts a force equal in magnitude	4
(and) opposite	// (but) opposite in direction (on A)	3

Question 6

State Newton's laws of motion.

- body <u>at rest</u>/<u>moves with constant velocity</u> unless external force acts 3
- force proportional to // $F \propto$ 3

  rate of change of momentum // $\frac{\Delta p}{\Delta t}$ 3

  ($F = m\,a$ .... 3 marks)
- action and reaction are equal and opposite 3

12

Show that $F = m\,a$ is a special case of Newton's second law.

$$F \propto \frac{mv - mu}{t}$$ 3

$$F \propto ma$$ 3

$$F = kma$$ 3

$$k = 1$$ 1

10

A skateboarder with a total mass of 70 kg starts from rest at the top of a ramp and accelerates down it. The ramp is 25 m long and is at an angle of 20° to the horizontal. The skateboarder has a velocity of 12.2 m s^{-1} at the bottom of the ramp.

Calculate :

(i) the average acceleration of the skateboarder on the ramp.

$v^2 = u^2 + 2as$ // $(12.2)^2 = 0 + 2a(25)$ 3

$a = 2.977$ m s^{-2} ($\approx$2.98 m s^{-2}) **(–1 for omission of or incorrect unit)** 3

(ii) the component of the skateboarder's weight that is parallel to the ramp.

$(W =)$ $mg\sin\theta$ / $mg\cos\theta$ / $mg\sin 20$ / $mg\cos 70$ 3

$(W =)$ 234.63 N **(–1 for omission of *g*)** 3

(–1 for omission of or incorrect unit)

(iii) the force of friction acting on the skateboarder on the ramp.

$F_r = 234.63 - 70(2.977)$ // $F_r = 234.63 - 208.38$ N 3

$F_r = 26.25$ N

18

The skateboarder then maintains a speed of 10.5 m s^{-1} until he enters a circular ramp of radius 10 m. What is the initial centripetal force acting on him?

$F = \frac{mv^2}{r}$ // $F = \frac{70(10.5)^2}{10}$ 3

$F = 771.75$ N **[–1 for omission of or incorrect unit if not already penalised in (ii)]** 3

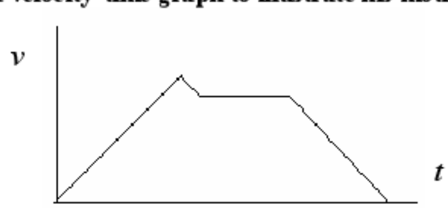
What is the maximum height that the skateboarder can reach?

$v^2 = u^2 + 2as$ // $u^2 = 2gs$ // $E_k = E_p$ // $\frac{1}{2}mv^2 = mgh$ // $h = \frac{u^2}{2g}$ 3

$0 = (10.5)^2 + 2(-9.8)h$ // $h = \frac{(10.5)^2}{2(9.8)}$ // $h = 5.63$ m **(–1 for omission of or incorrect unit)** 3

12

Sketch a velocity-time graph to illustrate his motion.



any line/curve from origin 3

correct graph shape 1

(–1 if no spike)

4

Question 12

Draw a diagram of the apparatus used in the experiment. (9)

air track // (smooth) runway 3

two riders // two trolleys 3

cork-pin or velcro etc. for coalescing 3

Describe how the time interval of 0.2 s was measured. (6)

use ticker tape timer / 0.2 s is time taken for a 10 dot interval // two light gates and card (on trolley) 3

time interval between dots = 0.02 s (= 1/50 sec) // read time(s) 3

Calculate the velocity of the body A (i) before, (ii) after, the collision. (6)

velocity before: ($v = s/t = 0.101/0.2$)

v (= 0.505 m s^{-1}) ≈ 0.51 m s^{-1} 3

velocity after: ($v = 0.051/0.2$)

v (= 0.255 m s^{-1}) ≈ 0.26 m s^{-1} 3

(-1 for omission of or incorrect unit)

Show how the experiment verifies the principle of conservation of momentum. (12)

momentum before

$p = mv$ or $p = (0.5201)(0.505)$ 3

p (= 0.263) ≈ 0.26 kg m s^{-1} 3

momentum after

[p = (0.5201 + 0.4900)(0.255)]

p = 0.258 ≈ 0.26 kg m s^{-1} 3

momentum before ≈ momentum after 3

(-1 for omission of or incorrect unit)

How were the effects of friction and gravity minimised in the experiment? (7)

air (cushion) to separate surfaces // sloped runway // oil wheels or clean track 4

horizontal (track) // frictional force equal and opposite to gravitational force // tilt track so that trolley moves with constant velocity 3