1. Motion, forces and energy

1.5 Forces

Paper 3 and 4

Answer Key

Paper 3

Q1.

Question	Answer	Marks
(a)	(30 – 10 =) 20 (N)	**B1**
	forwards OR in direction of 30 N force	**B1**
(b)(i)	(work done =) 2000 (J)	**A3**
	(work done =) 40 × 50	(C2)
	(work done =) force × distance (moved in direction of force) OR (W) = $F \times d$	(C1)
(b)(ii)	internal OR thermal energy (of surroundings / tyres)	**B1**
	kinetic energy	**B1**

Q2.

Question	Answer	Marks
(a)(i)	24 (N m)	**A3**
	26 × 0.94	(C2)
	(moment =) force × (perpendicular) distance (from pivot)	(C1)
(a)(ii)	increase distance between pivot and force owtte	**B1**

Q3.

Question	Answer	Marks
(a)(i)	(200 – 80 =) 120 (N)	**B1**
	forwards **OR** to the right **OR** in same direction as 200 (N force)	**B1**
(a)(ii)	friction **OR** air / water / wind resistance **OR** drag (from water)	**B1**
(a)(iii)	constant / steady / uniform velocity	**B1**
(b)	3000 **OR** 30	**A3**
	60 × 50 **OR** 60 × 0.5(0)	(C2)
	moment = force × distance from pivot	(C1)
	N cm **OR** N m	**B1**

Q4.

Question	Answer	Mark
(a)	cone	**M0**
	(because it has) lower centre of mass/gravity	**A1**
(b)	(weight =) 2.5 (N)	**A2**
	(weight =) mass × *g* **OR** 0.25 × 9.8	(C1)
(c)(i)	(moment =) 66 (N cm)	**A3**
	(moment =) 3(.0) × 22	(C2)
	moment = force × (perpendicular) distance (from pivot)	(C1)
(c)(ii)	(moment of weight =) answer to **(c)(i) OR** 66 (N cm)	**B1**

Q5.

(b)	friction OR drag OR (air) resistance	**B1**
	3.9 (N)	**B1**
(c)	(weight = 97.5 ÷ 42) = 2.3 (N)	**A4**
	W × 42 = 3.9 × 25 {OR 97.5} OR (*W* =) 3.9 × 25 / 42	(C3)
	(moment of cylinder =) 3.9 × 25 OR 97.5	(C1)
	clockwise moment = anticlockwise moment **OR** moment of cylinder = moment of block	(C1)

Q6.

Question	Answer	Marks
(a)	2000 (N m)	**A3**
	1100 × 1.8	(C2)
	(moment =) force × (perpendicular) distance	(C1)
(b)(i)	190 (N)	**A3**
	(*W* =) {62 × 1.2} ÷ 0.4 OR 74.4 ÷ 0.4	(C2)
	(moment of spring =) 62 × 1.2 OR 74.4	(C1)
(b)(ii)	(length of spring =) 17 (cm)	**A2**
	(extension =) 1.0 (cm)	(C1)

Q7.

Question	Answer	Marks
(a)	(pressure =) 0.8(0) (N / cm^2)	**A4**
	(pressure =) 1540 ÷ 1920 **OR** 1540 ÷ (160 × 12)	(C3)
	(pressure =) force ÷ area	(C1)
	(area in contact with ground =) 12 × 160 = 1920 (cm^2)	(C1)
(b)	(moment =) 120 000 (N cm) **OR** 1.2 × 10^5 (N cm)	**A3**
	(moment =) 1030 × 120	(C2)
	(moment =) force × (perpendicular) distance from pivot	(C1)
(c)	move (lifting) force further from pivot owtte	**B1**
(d)	centre of gravity / mass is high(er) **OR** idea that area of base is small(er)	**B1**

Q8.

(c)(i)	60 (N)	**B1**
(c)(ii)	accelerates **OR** increases speed	**B1**

Q9.

Question	Answer	Marks
(a)	300 (N)	**A2**
	(resultant force =) force to right – force to left **OR** 1200 – 900	C1
	to the right **OR** in forward direction	**B1**

Q10.

Question	Answer	Marks
(a)	6000 (N cm)	**A3**
	(moment of force =) 200 × 30	C2
	(moment of force =) force × (perpendicular) distance (of force from pivot)	C1
(b)(i)	any **two** from: • chemical energy to (gravitational) potential energy (of sail) • chemical energy to kinetic energy • kinetic energy (of winch) to kinetic energy (of rope / sail) • kinetic energy (of rope / sail) to (gravitational) potential energy (of sail).	**B2**
(b)(ii)	chemical energy **OR** kinetic energy to thermal **OR** sound (energy)	**B1**

Q11.

(b)(i)	friction / air resistance / drag	**B1**
(b)(ii)	number greater than 0 AND smaller than 750 (N)	**B1**
(b)(iii)	750 (N)	**B1**
(c)	75 (kg)	**A3**
	750 ÷ 10	(C2)
	W = mg OR (m =) W ÷ g OR W ÷ 10 in any form	(C1)

Q12.

(b)	50 (N cm)	**A3**
	2.5 × 20	**(C2)**
	(moment of force =) force × (perpendicular) distance (of force from pivot)	**(C1)**

Q13.

Question	Answer	Marks
(a)(i)	4000 (N)	**A2**
	(resultant force =) force to R – force to L OR 12000 – 8000	**(C1)**
	(to the) left or forwards	**B1**
(a)(ii)	air resistance	**B1**
(a)(iii)	constant/steady speed	**B1**
(b)	1200 (N cm)	**A3**
	(moment of force =) 60 × 20	**(C2)**
	(moment of force =) force × (perpendicular) distance of force from pivot	**(C1)**

Q14.

Question	Answer	Marks
(a)	any **three** from: line drawn alongside cotton thread / string hang triangle from a different corner (B or C) repeat marking of string (position on the card) centre of mass is where lines intersect	**B3**
(b)	(moment of weight =) weight × distance (of direction of force from pivot)	**C1**
	(moment =) 1.4 × 20	**C1**
	28 (N cm)	**A1**

Q15.

Question	Answer	Marks
(a)	70 – 15	**C1**
	55 (N)	**A1**
(b)	streamline / friction / drag / air resistance	**M1**
	reduce (owtte) friction / drag / air resistance	**A1**

Q16.

Question	Answer	Marks
(a)	moment = force × distance (of direction of force from pivot)	C1
	404 × 1.2	C1
	484.8 (N m) (which is about 480 N m)	A1
(b)	c.w. moment = a.c.w moment **OR** moment of weight = moment of force/F	C1
	404 × 1.2 = F × 1.6 **OR** (F =) 484.8 ÷ 1.6	C1
	(F =) 300 (N)	A1

Q17.

Question	Answer	Marks
(a)(i)	8 (N)	B1
	forwards	B1
(a)(ii)	same non-zero values for pulling and friction force	B1
(b)	(area = 2 × 0.60) = 1.2 (cm^2)	B1
	(P =) F ÷ A	C1
	150 ÷ 1.2 OR 150 ÷ 0.60	C1
	125 (N / cm^2)	A1

Q18.

Question	Answer	Marks
(a)	(moment of weight =) weight × (perpendicular) distance (of weight from pivot)	C1
	(moment of weight =) 150 × 1.8	C1
	270	A1
	N m	B1
(b)	barrier no longer balanced OR cannot be lowered (easily)	B1
	(more) force needed to lower barrier	B1
	(because) moment of heavy weight (has) increased	B1

Q19.

Question	Answer	Marks
(a)(i)	900 – (300 + 250)	C1
	350 (N)	A1
	(direction of resultant force =) forwards	B1
(a)(ii)	any **two** from: • friction (in the brakes) • (transfers 100 kJ OR kinetic energy) into thermal energy (store) OR internal energy (store) • of brakes / car / surroundings OR is dissipated OR (transferred) into surroundings / environment	B2
(b)	(moment =) force × (perpendicular) distance (from pivot)	C1
	(moment =) 35 × 20	C1
	(moment =) 700	A1
	Ncm	B1

Q20.

Question	Answer	Marks
(a)(i)	20.0 – (2.5 + 16.0)	C1
	1.5 (N)	A1
	(vertically) down	B1
(a)(ii)	(upwards force) increases	B1
	increases air resistance	B1
(b)(i)	6.5 (s)	B1
(b)(ii)	(resultant force is) zero	B1
	(because the) speed (of parachute) is constant / steady / uniform	B1
(b)(iii)	(dist. travelled =) area under line (of speed-time graph)	C1
	45 x 10	C1
	450 (m)	A1

Q21.

Question	Answer	Marks
(a)	(Moment) = $F \times d$	C1
	200 × 50	C1
	10 000 (Ncm)	A1
(b)	use a longer spanner / move force to end of spanner owtte	B1
	(to) increase the distance (from force to wheel nut or pivot) OR distance (from force to wheel nut or pivot) is greater than 50 cm	B1

Q22.

Question	Answer	Marks
(a)(i)	6.0 (cm)	B1
(a)(ii)	13.0 (cm)	B1
(a)(iii)	(ii) – (i)	B1
(b)	shape	B1
	size	B1

Q23.

Question	Answer	Marks
(a)	(moment =) force × distance (from pivot)	B1
	(moment =) 5.0 × 40	B1
(b)	(sum of) clockwise moments = (sum of) anticlockwise moments	C1
	200 = (2.0 × 10) + (F × 60)	C1
	F = (200 – 20) ÷ 60 OR 180 ÷ 60	C1
	(F =) 3.0 (N)	A1

Q24.

Question	Answer	Marks
(a)	measure without any load / weights AND measure with load / weights	B1
	measure length OR ruler stated or seen	B1
	(extension =) difference in two values	B1
(b)(i)	30 (cm)	B1
(b)(ii)	2.5 (N)	B1
(c)	W = m × g OR W = m × 10 OR (m =) W ÷ g in any form	C1
	6.0 ÷ 10	C1
	0.6(0) (kg)	A1

Q25.

Question	Answer	Marks
(a)(i)	stop the tractor tipping up/keep tractor level owtte	B1
(a)(ii)	moment = force × (perp.) distance from pivot in any form	C1
	6000 × 2.1	C1
	12 600	A1
	Nm	B1

Q26.

Question	Answer	Marks
(a)(i)	10 (N) AND forwards/to the right	B1
(a)(ii)	friction (between swimmer and water)	B1
(a)(iii)	(now) moving at steady/constant speed	B1
	forces (now)balanced / in equilibrium **OR** forward force = backward force OR no resultant force	B1
(b)	moment = force × (perp.) distance (from pivot)	C1
	700 × 3.5	C1
	2450 (Nm)	A1

Q27.

Question	Answer	Marks
(a)	below	B1
(b)	B A D C	B3

Q28.

Question	Answer	Marks
(a)	moment	B1
(b)(i)	(sum of) clockwise moment(s) = (sum of) anticlockwise moment(s)	C1
	1.2 × 400 = 0.3 × F	C1
	1600 (N)	A1
(b)(ii)	use a longer lever **OR** pivot closer to log / force F	B1

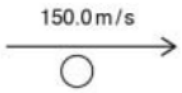
Q29.

Question	Answer	Marks
(a)(i)	weight	B1
(a)(ii)	W = m × g	C1
	m = 20 000 ÷ 10	C1
	2000 (kg)	A1
(b)	400 (N)	B1
	forwards / to the right	B1

Q30.

Question	Answer	Marks
(a)	Force × distance (from pivot) OR 80 000 × 5.0	C1
	400 000	A1
	Nm	B1
(b)	c.w. moment = a.c.w moment **OR** moment of load = moment of counterweight **OR** 5.0 × 80 000 = load × 8.0	C1
	400 000 ÷ 8.0 = load	C1
	50 000 (N)	A1

Q31.

Question	Answer	Marks
(a)	43.0 + 2.4 = 45.4 (N)	1
	(74.2 – 45.4 =) 28.8 (N)	1
	upwards	1
(b)		1

Q32.

Question	Answer	Marks
(a)(i)	(moment =) force × distance	1
	150 × 0.5	1
	75	1
	N m	1
(a)(ii)	accept any example involving turning forces	1
(b)	increase distance (of force from pivot point)	1

Paper 4

Q33.

Question	Answer	Marks
(a)(i)	43 cm **AND** 63 cm	**B1**
(a)(ii)	20 cm	**B1**
(b)	0.28 N / cm	**A2**
	$k = F / x$ **OR** (k =) F / x **OR** 5.6 / 20	C1
(c)(i)	4.9 N	**B1**
(c)(ii)	3.2(0) m / s^2	**A3**
	$F = ma$ **OR** (a =) F / m **OR** (6.5 – 4.9) / 0.50	C1
	(resultant force =) 6.5 – 4.9 **OR** 1.6	C1

Q34.

Question	Answer	Marks
(a)	force × perpendicular distance (from pivot)	**A2**
	Any one from: • force × distance from pivot • reference to perpendicular distance (from pivot) • reference to perpendicular force	C1
	(it measures the) turning effect (of a force)	**B1**
(b)(i)	point where (all) the weight (of an object) seems to act	**B1**
(b)(ii)	2.2 × 10^7 N m	**A2**
	1.7 (m) **OR** 3.4 / 2 **seen**	C1
(c)	resultant force = 0 **OR** (all) forces cancel out owtte	**B1**
	resultant moment = 0 **OR** moments balance owtte	**B1**

Q35.

Question	Answer	Marks
(a)	0.077 kg **OR** 77 g	**A2**
	$g = W / m$ **OR** (m =) W / g **OR** 0.75 / 9.8	C1
(b)	2 vectors at right angles **OR** use of Pythagoras' theorem e.g. $a^2 + b^2 = c^2$ **OR** (force =) $\sqrt{(1.2^2 + 0.75^2)}$	**B1**
	1.4 (N)	**B1**
	58(°)	**A2**
	resultant force including correct direction of arrow **OR** use of trigonometry to find angle e.g. $\tan\theta = 1.2 / 0.75$	C1
(c)	any **two** from: • velocity • speed • direction • acceleration / deceleration • moment	**B2**

Q36.

Question	Answer	Marks
(a)(i)	(point / place / position) where (all) the weight (seems to) acts	**B1**
(a)(ii)	a small tilt / rotation makes G no longer vertically above the base **OR** small tilt / rotation produces moment (that topples transmitter)	**B1**
(b)(i)	arrow(head) marked along wire W towards ground	**B1**
(b)(ii)	moment = $F \times d$ **AND** correct indication of F and d on Fig. 4.1.	**A3**
	(moment is) force × (perpendicular) distance (from base / pivot)	C1
	(moment is) force × perpendicular distance (from base / pivot)	C1
(c)	a use of radio waves, e.g. RFID / astronomy / Bluetooth / RADAR / wifi	**B1**

Q37.

Question	Answer	Marks
(a)(i)	(speed =) 38 m / s	**A2**
	$a = \Delta v / \Delta t$ **OR** (Δv =) $a\Delta t$ **OR** (Δv =) 7.2 × 5.3	C1
(a)(ii)	(resultant force =) 1 700 N	**A2**
	$F = ma$ **OR** (F =) ma **OR** (F =) 240 × 7.2	C1
(b)(i)	(vector) has direction (as well as magnitude) **OR** scalar does not have direction	**B1**

Question	Answer	Marks
(b)(ii)	(velocity) changes (as direction of motion changes) **OR** direction (of velocity) changes	**B1**
(b)(iii)	any **two** from: • because there is an acceleration / change in velocity / change in direction / change in momentum (which needs a resultant force) • motorcyclist accelerates / changes momentum (because velocity / direction changes) • (resultant) force is perpendicular to the motion (of the motorcycle) **OR** $a \propto F$	**B2**

Q38.

Question	Answer	Marks
(a)(i)	no resultant / net force	**B1**
	no resultant/net moment	**B1**
(a)(ii)	4.7×10^7 J or 47 MJ	**A2**
	(Δ)$E_p = mg(\Delta)h$ **OR** (ΔE_p =) $mg(\Delta)h$ **OR** (ΔE_p =) 3200 × 9.8 × 1500	C1
(b)(i)	point, labelled 1, on either of the horizontal sections of the graph (to the left of A or to the left of B)	**B1**
	point, labelled 2, on the graph between A and the start of the horizontal section of the graph to the left of B	**B1**
	point, labelled 3, on the graph between the start of the curved section to the right of the origin and the start of the horizontal section of the graph to the left of A	**B1**
(b)(ii)	(initially there is acceleration due to) weight **OR** gravitational force **OR** unbalanced force / resultant force / downward force	**B1**
	(then) air resistance increases as speed or velocity increases	**B1**
	(as air resistance increases) resultant force downwards decreases **OR** acceleration decreases	**B1**
	constant speed when air resistance = weight / gravitational force	**B1**

Q39.

Question	Answer	Marks
(b)	24 N	**A2**
	$Ft = \Delta mv$ **OR** $F = ma$ **OR** (F =) (0.16 × 18) / 0.12	C1
(c)	longer time (of impact / contact) **AND** smaller force (on them) **OR** longer time (of impact / contact) **AND** does not hurt as much	**B1**

Q40.

Question	Answer	Marks
(a)(i)		**B2**
	magnitude **or** size	B1
	direction	B1
(a)(ii)		**B2**
	any **two** from: acceleration / deceleration, gravitational field strength, impulse, momentum, velocity, weight	B2
(b)(i)	0.12 m	**B1**
(b)(ii)		**B2**
	beyond where the extension is not directly proportional to the load **or** (point) where extension stops being directly proportional to the load **or** point up to which extension is directly proportional to the load	B1
	10.4 N $\leqslant$ weight $\leqslant$ 10.9 N	B1
(b)(iii)	22 N / m $\leqslant k \leqslant$ 25 N / m	**A3**
	clear subtraction of 0.12 from a length that is in Hooke's law region e.g. 0.54 – 0.12	C1
	$k = F / x$ in any form **or** $k = W / x$ in any form **or** k = 1 / gradient	C1

Q41.

Question	Answer	Marks
(a)	620 N	**B1**
(b)		**B2**
	no resultant force (on object in equilibrium)	B1
	no resultant moment (on object in equilibrium)	B1
(c)(i)	560 N m	**A2**
	(Γ =) $Fx_{\perp F}$ **or** 620 × 0.90	C1
(c)(ii)	540 N	**A3**
	use of any moment	C1
	$T \times 1.2 \sin 60°$ (= 560) **or** (T =) 560 / (1.2 × sin 60°)	C1

Q42.

Question	Answer	Marks
(a)	(F = 2.0 × 4.0 =) 8.0 N	**A2**
	(F =) ma in any form	C1

Question	Answer	Marks
(b)	(F = 30 – 12 =) 18 N	**A3**
	resultant force on 3 kg mass (3 × 4 =) 12 (N)	C1
	(weight of 3 kg mass = 3 × 10) = 30 (N)	C1
(c)(i)	(Δv =) 4.0 × 0.80 (= 3.2 m / s)	**A2**
	(Δ)v = at in any form	C1
(c)(ii)	(t = 0.020 / 3.2 =) 0.0063 s OR 6.3 × 10^{-3} s	**A2**
	(t =) d / v in any form	C1

Q43.

Question	Answer	Marks
(a)	scale at least 2 cm : 1 m / s stated	**B1**
	2.5 m / s AND 4.0 m / s vectors correctly drawn by eye **AND** correct resultant	**M1**
	magnitude of resultant velocity = 2.3 – 2.8 m / s inclusive	**A1**
	direction 35° – 40° inclusive (downstream)	**A1**
(b)	(E = ½ × 65 × 2.5^2 =) 200 J	**A2**
	(E =) ½ mv^2 in any form	C1

Q44.

Question	Answer	Marks
(a)	extension is (directly) proportional to load (if elastic limit is not exceeded)	**B1**
(b)(i)	0 to 20.5 + / – 0.5 N	**B1**
(b)(ii)	(k =) F / x OR (k =) 1 / gradient	**C1**
	140 N / m OR 0.14 N / mm	**A1**
(b)(iii)	60 OR 61 OR 62 OR 63 (mm) seen	**C1**
	180 mm OR 0.18 m	**A1**
(c)	W = mg in any form OR (m =) W / g OR (m) = 4 / 8.7	**C1**
	0.46 kg	**A1**

Q45.

Question	Answer	Marks
(a)(i)	any value from 35 to 43 m / s²	A2
	(a =) (v – u) / t in any form **or** gradient (of line) **or** (58 – 50) / 0.20 **or** equivalent values from the graph	C1
(a)(ii)	3800 N	A3
	(F =) ma in any form **or** Δp / Δt in any form **or** 76 × candidate's **1(a)(i)** **or** 760 seen	C1
	76 × candidate's **1(a)(i)** evaluated **or** 76 × (candidate's **1(a)(i)** + 10) **or** 76 × (candidate's **1(a)(i)**)+ 760	C1
(b)	(deceleration because) upward force greater than weight **or** upward resultant force	B1
	air resistance decreases (with decreasing speed / with time) **or** deceleration decreases **or** resultant (upward) force decreases	B1
	(until / finally) weight equals air resistance **or** forces balance **or** at terminal / constant velocity / speed	B1
(c)	at zero speed there is no air resistance	B1
	weight / downwards force is (still) acting **or** there is (now) a resultant force (downwards at zero speed)	B1
	OR forces balance at a speed greater than zero	(B1)
	speed cannot decrease / no deceleration once forces balance	(B1)

Q46.

Question	Answer	Marks
(a)	force × perpendicular distance from pivot / point	B1
(b)	($F_1d_1 = F_2d_2$ =) 500 × 20 = F × 12 numbers substituted in any form	C1
	(F = 10 000 / 12 =) 830 N	A1

Question	Answer	Marks
(c)	clear diagram or description (of object) with pivot and vertical forces / weights / masses / cord tension causing moments in each direction	B1
	indicate / measure forces and perpendicular distances	B1
	calculates a moment or shows / describes how to AND confirms equality of total moment (in each direction) AND statement of equilibrium / balance	B1

Q47.

Question	Answer	Marks
(a)	(PE loss =) mgh AND (KE gain =) ½ mv^2	B1
	PE (loss) = KE (gain)	B1
	alternative route 1 for 1st two m.p.s	
	$v^2 = u^2 + 2as$	(B1)
	u = 0	(B1)
	alternative route 2 for 1st two m.p.s	
	$s = ut + 0.5at^2$ OR $h = 0.5gt^2$	(B1)
	u = 0 AND $t = \sqrt{3}$ OR 1.73	(B1)
	v^2 (= 2gh) = $2 \times 10 \times 15$ OR $v^2 = 300$ OR $v = 10\sqrt{3}$ OR $v = 10 \times 1.73$	B1
	{$v = 17$ m / s AND $v^2 = 300$ or $v = 10\sqrt{3}$} OR v = 17.3(2) m / s	B1

Question	Answer	Marks
(b)	(F =) change of *p* / (change of) time OR rate of change of momentum	C1
	(F =) 30×17.32	C1
	(F =) 520 N	A1

Q48.

Question	Answer	Marks
(a)	force × perpendicular distance (from point)	B1
(b)(i)	0.80 N	B1
(b)(ii)	(moment = force × distance =) 0.8×0.25	C1
	(moment =) 0.20 N m	A1
(b)(iii)	same value as (ii) with correct unit	B1
(b)(iv)	$F \times 0.75 = 0.20$ in any form OR (*F* =) 0.2 / 0.75	C1
	(*F* = 0.2 / 0.75 =) 0.27 N	A1
(c)	(perpendicular) distance (from pivot) of F decreases / is less (than 0.75 m) OR (perpendicular) distance (from pivot) of W increases / is more (than 0.75 m)	M1
	(so) increased / greater (force *F*) (needed for greater moment)	A1

Q49.

(b)	Ft = impulse OR Δp in any form OR (F =) (impulse OR Δp) / t	**C1**
	(F = 3.2 x 10^7 / 80 =) 3.9 $\times 10^5$ N	**A1**
(c)	reduces drag / air resistance (experienced by the train) / more streamlined	**B1**
(d)	less drag / air resistance (at slower speeds)	**B1**
(e)	(maximum) friction (force) between rails and train reduced / train may slide	**B1**