5	**B is the correct answer** A is incorrect because the CW moment of the force could balancethe ACW moment of the weight C is incorrect because the CW moment of the force could balance theACW moment of the weight D is incorrect because the CW moment of the force could balance the ACW moment of the weight	1

5	C **Gain in gravitational potential energy: same for P and Q** **Power developed: greater for P than Q** Incorrect Answers: A – incorrect gain in GPE but correct power developed B – incorrect gain in GPE and incorrect power developed D – correct gain in GPE but incorrect power developed	1

2	**C is the correct answer as 1 kWh = 1000 W × 3600 s = 3.6× 10^6 J** A is not the correct answer as 0.28 J= $\frac{1000\ \text{W}}{3600\ \text{J}}$ B is not the correct answer as 0.28 W= $\frac{1000\ \text{W}}{3600\ \text{J}}$ and the unit should be J and not W D is not the correct answer as the unit should be J and not W.	**(1)**

8	**B is the correct answer** A is incorrect because the factor 9.81 = g / (N kg^{-1}) is not needed since it is already included in the weight, $\Delta E_{grav} = mg\Delta h = W\Delta h$ C is incorrect because dividing by 9.81 removes g from the calculation D is incorrect because dividing by 9.81 removes g and the factor 25 = Δh / m is missing from the calculation	1

8	**B to the left of O** Incorrect Answers: the centre of mass has moved to the left of O. The right-hand half has double the density but half the diameter so the weight is $(2 \times \frac{1}{(2)^2} =) \frac{1}{2}$ the original weight. The pivot needs to be placed under the centre of gravity for the rod to balance. A – O is no longer the position of the centre of gravity C – The centre of gravity is to the left of O and not the right D – There is a balance point but, so that there is equal weight either side of the centre of gravity, its position has moved to the left	1

5	The only correct answer is **B** A is not correct because Q has the same change in E_{grav}. C is not correct because R is lifted a smaller distance. D is not correct because R has the smallest change in E_{grav}.	1

2	**The only correct answer is B (Useful power output is constant; total energy output increases.)** A is not correct because total energy output would increase with time C is not correct because useful power output is constant D is not correct because useful power output is constant and total energy output would increase with time	1

1	**The correct answer is A** $\left(\frac{180}{240}\right)$ B is incorrect because 60 kW is the wasted energy C is incorrect because 60 kW is the wasted energy and 180 kW is the useful energy D is incorrect because 300 kW is the sum of the wasted and input energy	1

3	**The only correct answer is D 0.59 J** *A is not correct because* $0.045\ J = ½ \times 0.040\ kg \times (1.5\ m)^2$ *B is not correct because* $0.060\ J = 0.040\ kg \times 1.5\ m$ *C is not correct because* $0.39J = 0.040\ kg \times 9.81\ N\ kg^{-1}$	1

6	**D is the correct answer** A is not the correct answer as spurious factor of 100 and 0.68 multiplies B is not the correct answer as this gives a lower input than output C is not the correct answer as there is a spurious factor of 100	**(1)**

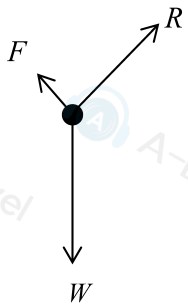
3	**A** Fd Incorrect Answers: (all due to incorrect variables selected from information given) B – Ft is the impulse on the block due to the applied force F C – Fv is the power developed by the block D – mgd would be the work done had the block moved a distance d due to the gravitational force and not the applied force F	1

10	**The only correct answer is D** ($90g$) A is not correct because by conserving energy, the expression for speed in metres per second should be $\sqrt{2 \times g \times (75 - 30)}$ B is not correct because by conserving energy, the expression for speed in metres per second should be $\sqrt{2 \times g \times (75 - 30)}$ C is not correct because by conserving energy, the expression for speed in metres per second should be $\sqrt{2 \times g \times (75 - 30)}$	1

8	**D is the correct answer** A is not the correct answer as it gives units of J^{-1} which is not a unit for energy. B is not the correct answer for the same reason that A is not. C is not the correct answer as $68 \neq 68\%$.	**(1)**

4	**C is the correct answer as efficiency** $= \frac{\text{useful energy output}}{\text{total energy input}} = \frac{200\ N \times 4\ m}{90\ N \times 10\ m}$ A is not the correct answer as this is the total energy input divided by the useful energy output B is not the correct answer as this is the useful energy output divided by the total of the energy output and the energy input D is not the correct answer as this is the total energy input divided by the total of the energy output and the energy input	**(1)**

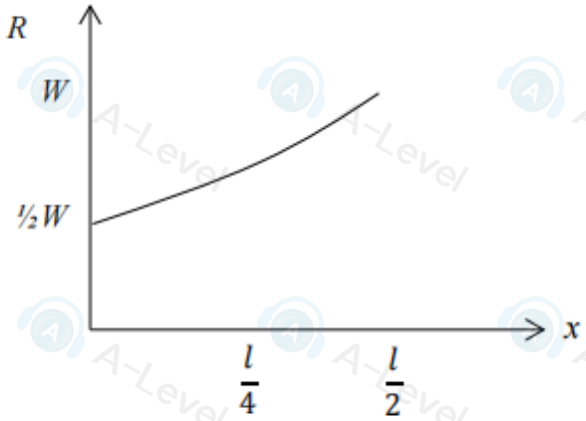
8	**C is the correct answer** This is because the power needed is equal to the gravitational energy supplied per second (mgh) plus the kinetic energy given to the water per second ($\frac{1}{2}mv^2$).	**(1)**

Question Number	Answer	Mark
18(a)	• Weight/W/mg labelled **(1)** • (Normal) reaction/contact force (accept R/N/C) **(1)** • Friction/F **(1)** • Lengths $R<W$ **and** $F<W$ **(1)** (-1 off total for each additional arrowed line and MP4 conditional on MP1, 2 **and** 3) (do not accept components of forces, even if both given and accept correct direction/size by eye) 	**4**
18(b)(i)	• Initially friction/drag negligible/small/less (as the velocity is low) **(1)** • See $mg\sin\theta$ **Or** $W\sin\theta$ **(1)** • $mg\sin\theta = ma$ and the masses cancel (so a independent of m) **(1)**	**3**
18(b)(ii)	• As velocity increases, air resistance increases **(1)** • Until frictional forces = component of weight down slope **(1)** • Resultant force = 0 **and** there is no more acceleration (at max velocity) **(1)** (MP2 allow frictional forces = $mg\sin\theta$)	**3**
18(b)(iii)	• A larger person would have a greater area/volume **(1)** • The air resistance would be greater **(1)** (accept drag)	**2**

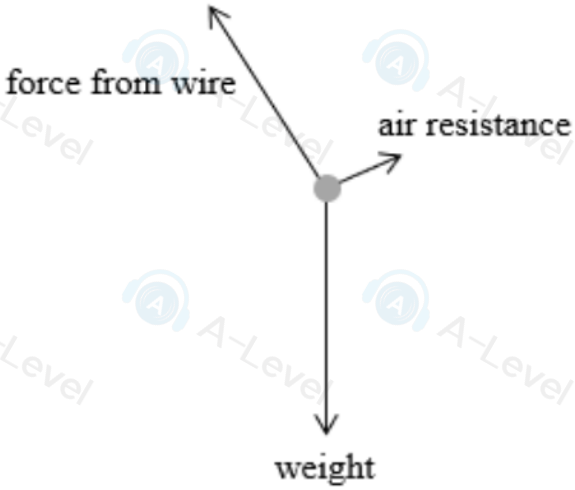
18(c)(i)	See $\theta = \tan^{-1} 0.2$ **and** $\theta = 11.3°$ **Or** see $\tan\theta = 0.2$ **and** $\theta = 11.3°$	**(1)**	**1**
18(c)(ii)	**Either** (Energy) Use of $E_k = ½ mv^2$ Use of trig to determine the component of weight along the slope or the vertical height in terms of L Use of $E_{grav} = mg\Delta h$ (to determine E_{grav}) **Or** use of $W = F\Delta s$ Use of of $E_k = E_{grav} + W$ (to determine $L = 120$ m **Or** (forces) Use of trig to determine the component of weight along the slope or the vertical height in terms of L Use of resultant force = $mg\sin 11.3° + 240$ N Use of $\Sigma F = ma$ to determine a Use of $v^2 = u^2 + 2as$ with their a (not 9.81) to determine s $L = 120$ m Example of calculation $E_k = ½ \times 95$ kg $\times$ (33 m s^{-1})^2 = 51728 J 51728 J = (95 kg $\times$ 9.81 N kg^{-1} $\times$ sin 11.3° $\times$ L) + (240 N $\times$ L) $L = 122$ m	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**5**
	Total for question 18		**18**

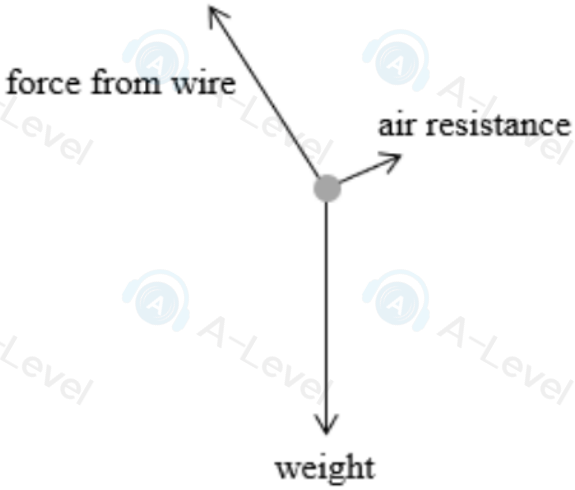
Question Number	Answer	Mark
13(a)	• Use of $\Sigma F = 0$, seen or implied (1) • $F = 11$ N (1) • Use of moment of force = Fx (with any corresponding force and known distance from an end, A or midpoint) (1) • Use of the principle of moments (1) • $x = 0.86$ m (1) Example of calculation $F_A + F_B = 8.5$ N + 14 N = 22.5 N $F_A = F_B$ $2F = 22.5$ N $F = 11.25$ N if moments taken from the left end (11.25 N × 0.15 m) + (11.25 N × x) = (8.5 N × 0.35 m) + (14 N × 0.60 m) $x = 0.861$ m if moments taken from midpoint (11.25 N × 0.45 m) = (11.25 N × x) + (8.5 N × 0.25 m) $x = 0.261$ m so distance = 0.261 m + 0.6 m = 0.861 m if moments taken from A (8.5 N × 0.20 m) + (14 N × 0.45 m) = (11.25 N × x) $x = 0.711$ m so distance = 0.711 + 0.15 m = 0.861 m	**5**
13(b)	The moment (of B) must be the same (1) For a smaller distance (from the left end of the shelf), the (normal contact) force must increase (1)	**2**
	Total for question 13	**7**

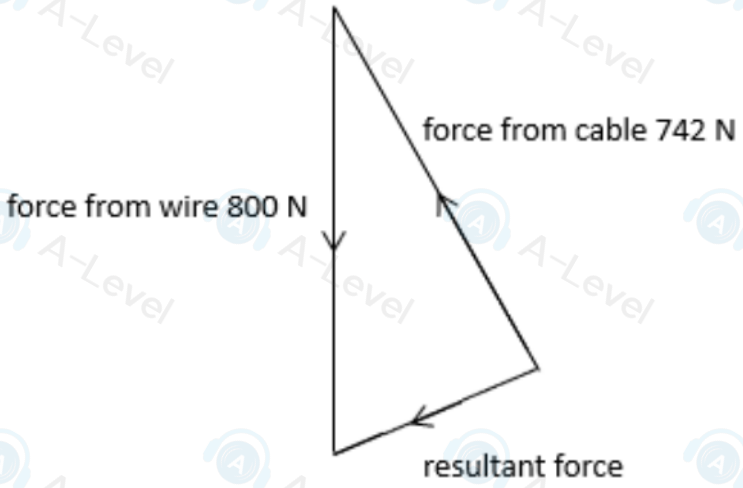
Question Number	Answer		Mark
14(a)(i)	• Use of $\rho = \frac{m}{V}$ • Use of $A = \pi r^2$ • Use of volume in 1 second = cross section area × speed • Speed = 37.1 (m s^{-1}) Example of calculation $\frac{V}{t} = \frac{300 \text{ kg s}^{-1}}{1030 \text{ kg m}^{-3}} = 0.291 \text{ m}^3\text{s}^{-1}$ $A = \pi \times 0.05^2 = 7.85 \times 10^{-3}$ m^2 Speed = 0.291 m^3 s^{-1}/ 7.85×10^{-3} m^2 = 37.1 m s^{-1}	(1) (1) (1) (1)	4
14(a)(ii)	• Use of $p = mv$ • Rate of change of momentum = 1.1×10^4 kg m s^{-2} (ecf from (a)(i)) Example of calculation mass × speed = 300 kg ×37.1 m s^{-1} = 1.11×10^4 kg m s^{-2}	(1) (1)	2
14(b)	• Pump applies a (forward) force to the water. • By Newton 3, water applies an (equal and) opposite/backward force to the pump **Or** By Newton 3, water applies a force to the pump in the opposite direction to the (flow of) water.	(1) (1)	2
14(c)	• Initially (speed is constant because) drag force = forward force • Turning on pump gives resultant force backwards, so boat slows. • Drag force becomes less (as boat slows) until forces balance again.	(1) (1) (1)	3
	Total for question 14		**11**

Question Number	Answer	Mark
13(a)	• Point at which weight is taken to act. (1)	**(1)**
13(b)	• Gradient everywhere positive (1) • Stops at R = weight/W/mg at $l/2$ (1) • Starts at R = ½ weight/0.5W/0.5mg etc. (1) 	**(3)**
13(c)	• Centre of gravity/mass is not above the shelf. **Or** Line of action of weight does not pass through the shelf. (1) • There is a net moment clockwise. **Or** No anticlockwise moment to balance moment of weight. (1)	**(2)**
	Total for question 13	**6**

Question Number	Answer	Additional Guidance	Mark
20(a)	In equilibrium, total clockwise moment = total anticlockwise moment **Or** In equilibrium, sum of all moments (about any point) = 0 **Or** In equilibrium, resultant moment (about any point) = 0 **(1)**	Clockwise moment = anticlockwise moment is insufficient.	**1**
20(b)(i)	The weight causes a clockwise moment (about the pivot) **(1)** So the direction (of the moment provided by the motor) is anticlockwise (dependent on MP1) **(1)**		**2**
20(b)(ii)	The motor needs to provide a smaller moment **(1)** So a smaller force is needed (which moves through the same distance) **(1)** So the work done decreases (dependent on MP1 or MP2) **(1)**		**3**
20(b)(iii)	Determines distance from pivot to centre of gravity of section **(1)** Use of Moment of force $= Fx$ **(1)** Use of principle of moments **(1)** Moment produced by motor = 8.4×10^7 Nm **(1)**	<u>Example calculation</u> Distance from pivot to centre of gravity of section $= 33\text{ m} - \frac{33\text{ m} + 12\text{ m}}{2}$ $= 10.5\text{ m}$ $4.0 \times 10^6\text{ N} \times 11\text{ m} +$ moment produced by motor $= 1.2 \times 10^7\text{N} \times 10.5\text{ m} + 71 \times 10^3\text{ N} \times 28\text{ m}$ Moment produced by motor = 8.40×10^7 Nm	**4**
	Total for question 20		**10**

19(a)	Arrow to the left and upwards labelled force from wire / harness Arrow vertically downwards labelled weight / W / mg Arrow to right (and slightly upward) labelled (viscous) drag / D or labelled air resistance Example diagram  	**(1)** **(1)** **(1)**	**3**
19(b)(i)	Appropriate trigonometry used 742 (N) Example of calculation $R = 2 \times 1\,200\ \text{N} \times \cos(72°) = 741.6\ \text{N}$	**(1)** **(1)**	**2**

19(a)	Arrow to the left and upwards labelled force from wire / harness Arrow vertically downwards labelled weight / W / mg Arrow to right (and slightly upward) labelled (viscous) drag / D or labelled air resistance Example diagram  	**(1)** **(1)** **(1)**	**3**
19(b)(i)	Appropriate trigonometry used 742 (N) Example of calculation $R = 2 \times 1\,200\ \text{N} \times \cos(72°) = 741.6\ \text{N}$	**(1)** **(1)**	**2**

19(b)(ii)	Straight line at least 8 cm long representing force from wire (800 N), with label	**(1)**	
	Vector triangle drawn with at least two sides labelled, and resultant force on shortest side	**(1)**	
	All 3 arrows in correct relative directions (dependent on MP2)	**(1)**	
	Resultant force = 400 N (Range from 390 to 410)	**(1)**	**4**
	Example diagram 		
19(c)	(most) E_{grav} transferred to E_k and mass is in both equations	**(1)**	
	(So final) speed does not depend on mass of person **Or** (So final) speed only depends on change in height **Or** (So final) speed = $\sqrt{2g\Delta h}$ (and g is constant)	**(1)**	
	(assuming) work done against resistive forces is negligible	**(1)**	**3**
	Total for question 19		**12**