Work, Energy and Power

Q1.

In the sport of curling, two teams of 'curlers' take turns sliding polished granite stones across an ice surface towards a circular target marked on the ice.

commons.wikimedia.org

A stone of mass 19.6 kg is accelerated uniformly for 1.25 s before being released by a curler. The stone then decelerates uniformly to rest, travelling 32.5 m in a time of 17.5 s.

Calculate the average useful power developed by the curler in accelerating the stone.

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Average power = ...

(Total for question = 4 marks)

Q2.

Read the passage and answer the question below.

© Reuters

The Solar Impulse 2 is a solar-powered plane that completed a round the world trip in 2016 without using fossil fuels.

The wings are covered in thin solar panels, keeping the total mass of the plane and pilot at 1600 kg. The need to reduce the weight limits the efficiency of the solar panels to 23%. However, in daylight, these panels generate enough energy to run the four 7.5 kW electric motors that keep the plane airborne and to fully charge the batteries that power the plane during the night. The batteries take about 6 hours to fully charge.

In daylight the plane flies at a height of 8500 m to harness the most sunlight, and at night descends to 1500 m. This descent makes use of the gravitational potential energy gained during the day to help the plane get through the night.
(Source: www.solarimpulse.com)

The plane flies at the greater height during the day. At night it glides down to the lower height over a period of 4 hours, with the motors switched off.

Calculate the change in gravitational potential energy as the plane glides down.

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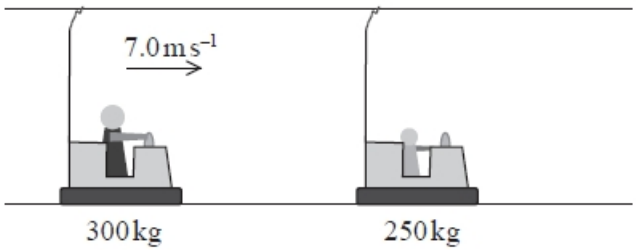
Change in gravitational potential energy = ...

(Total for question = 2 marks)

Q3.

A child in a bumper car travelling at velocity of 7.0ms^{-1} collides with a stationary bumper car directly ahead of him. The diagram shows the bumper cars before the collision.



(a) (i) Assume that the bumper cars move off together after the collision.
Calculate the velocity of the bumper cars after the collision.

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Velocity = ...

(ii) After travelling 1.3m the cars come to rest.
Calculate the magnitude of the frictional force between the cars and the floor.

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Frictional force = ...

(b) State **one** assumption made in order to carry out the calculation in (a)(i).

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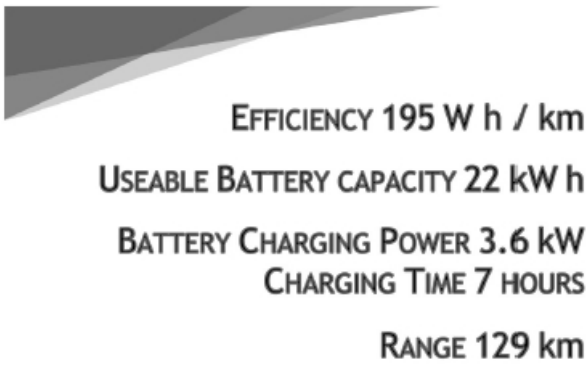
(Total for question = 7 marks)

Q4.

A website advertises an electric car with the following information.



The website provides the following additional information.

Maximum Engine Power 80 kW Maximum Performance 0 to 28 ms^{-1} in 11.5 s Mass of Car 1500 kg

Deduce whether the power of the engine is capable of producing this performance.

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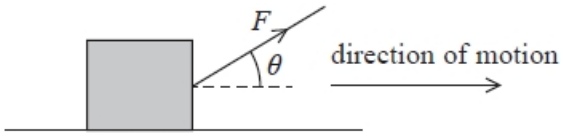
(Total for question = 3 marks)

Q5.

A rope is used to apply a force *F* to a box as shown. The box is pulled a distance *d* along a horizontal surface.



Which of the following could be used to determine the work done on the box?

☒ **A** $Fd \sin \theta$

☒ **B** $\frac{Fd}{\sin \theta}$

☒ **C** $Fd \cos \theta$

☒ **D** $\frac{Fd}{\cos \theta}$

(Total for question = 1 mark)

Q6.

A power station provides electrical power at a mean rate of 3500 MW.

Which of the following gives the best estimate of the energy provided to consumers over a period of a year?

1 year = 3.2×10^7s

☒ **A** 1×10^6 J

☒ **B** 1×10^{11} J

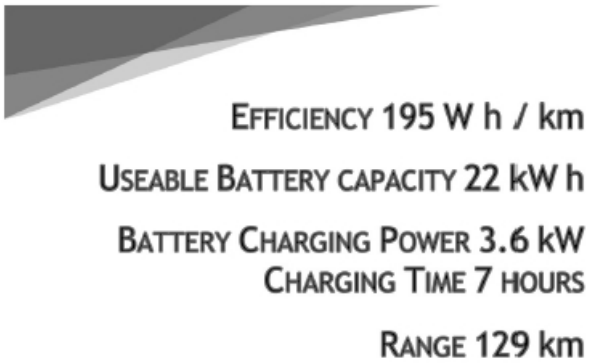
☒ **C** 1×10^{13} J

☒ **D** 1×10^{17} J

(Total for question = 1 mark)

Q7.

A website advertises an electric car with the following information.



Explain why the kilowatt-hour (kW h) is a unit of energy.

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(Total for question = 2 marks)

Q8.

One region of Australia decided to trial the removal of the speed limit on some roads.

The following statements were made in an online forum discussing this issue.

> Comment
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> *"If a car was going faster, it would have better fuel economy. A lot of modern cars have engines that are more efficent at 200 km h^{-1} than at 100 km h^{-1}."*
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> Reply
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> *"You confuse efficiency with fuel consumption. You cannot get better fuel economy at higher speeds."*

Justify the statement in the reply.

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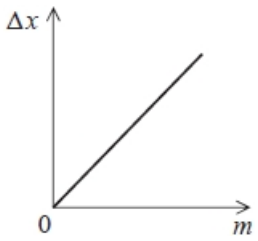
(Total for question = 3 marks)

Q9.

A spring is hung vertically and masses are added to the lower end.
The graph shows how the extension Δ*x* of the spring varies with the mass *m* added.



The work done in extending the spring can be expressed as

(1)

☒ **A** $mg\Delta x$

☒ **B** $\frac{mg}{\Delta x}$

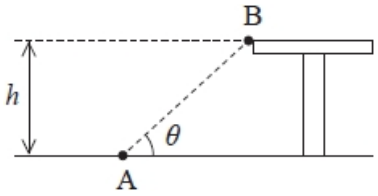
☒ **C** $\frac{1}{2}mg\Delta x$

☒ **D** $\frac{mg}{2\Delta x}$

(Total for question = 1 mark)

Q10.

An object of mass *m* is moved from point A on the ground, to point B on a bench of height *h* as shown in the diagram.



Which of the following is a correct expression for the work done on the object?

(1)

☒ **A** $\frac{mgh}{\sin\theta}$

☒ **B** $\frac{mgh}{\cos\theta}$

☒ **C** mgh

☒ **D** $mgh\sin\theta$

(Total for question = 1 mark)

Q11.

An object of weight 7 N is raised from a height of 2 m to a height of 8 m.
The change in gravitational potential energy is

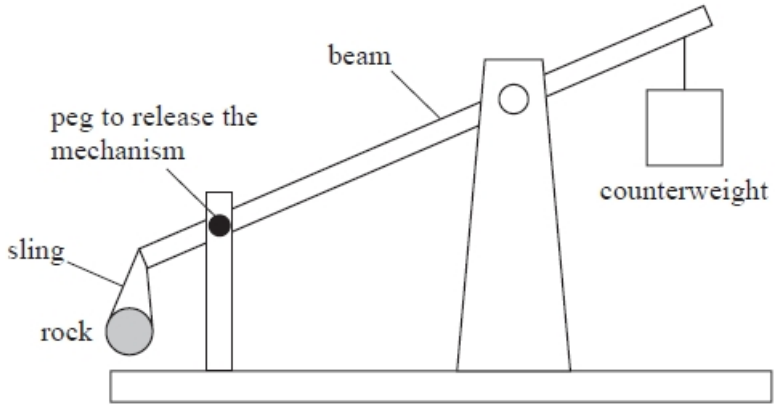
- ☒ **A** 42 J
- ☒ **B** 56 J
- ☒ **C** 412 J
- ☒ **D** 549 J

(Total for question = 1 marks)

Q12.

A trebuchet is a medieval catapult designed to project a rock over large distances.

A simplified diagram of a trebuchet is shown.



The rock is held in a sling. When the peg is removed the counterweight falls and the rock is projected through the air.

A student assumes that all the gravitational potential energy transferred from the counterweight is transferred to the kinetic energy of the rock.

Give two reasons why this is not correct.

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(Total for question = 2 marks)

Q13.

Read the extract and answer the question that follows.

Gravitricity is developing a new technology to capture and store the excess power generated by renewable energy resources. A large load is suspended by cables in a disused mineshaft. During periods of low power demand, excess generated power is used to winch the load upwards. During periods of high demand, the load is lowered down the shaft, causing electricity to be generated. The system can produce electricity at low power for several hours, or a short burst of electricity at high power.

(Source based on: https://gravitricity.com/)

One such system is planned to use a load of mass 2500 tonnes. The load will be at the top of a shaft. The load will be lowered down the shaft at a steady speed. A useful power output of 15 MW will be generated. The system will have an efficiency of 80%.

Calculate the speed of the load.

1 tonne = 1000 kg

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Speed = ...

(Total for question = 3 marks)

Q14.

Read the extract and answer the question that follows.

Gravitricity is developing a new technology to capture and store the excess power generated by renewable energy resources. A large load is suspended by cables in a disused mineshaft. During periods of low power demand, excess generated power is used to winch the load upwards. During periods of high demand, the load is lowered down the shaft, causing electricity to be generated. The system can produce electricity at low power for several hours, or a short burst of electricity at high power.

(Source based on: https://gravitricity.com/)

One such system is planned to use a load of mass 2500 tonnes. The load will be at the top of a shaft. The load will be lowered down the shaft at a steady speed. A useful power output of 15MW will be generated. The system will have an efficiency of 80%.

The system can generate "a short burst of electricity at high power".

Explain why high power can be generated for only a short time.

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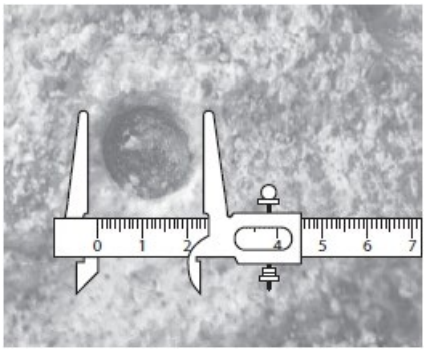
(Total for question = 2 marks)

Q15.

Impact craters are formed when meteorites strike the surface of a planet. A student investigated some factors that might influence the formation of impact craters. He did this by dropping spheres of modelling clay into a tray of sand.

The diameter of the crater produced by each sphere was measured using vernier calipers as shown.



This process was repeated for spheres of different diameters.

In one test, the spheres were dropped from the same height.

Determine the factor by which the kinetic energy of the sphere just before impact increases when the sphere diameter is increased from 2.0 cm to 4.0 cm.

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Factor = ...

(Total for question = 3 marks)

Q16.

Two ice skaters are gliding across the horizontal ice surface at an ice rink.

(Source: © ITAR-TASS News Agency/Alamy Stock Photo)

When the male skater pushes the female skater forwards, the total kinetic energy of the skaters increases.

Explain why kinetic energy is not conserved in this interaction.

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(Total for question = 2 marks)

Q17.

A car of mass 1.5×10^3 kg is travelling at a speed of 25 m s^{-1}. The driver applies the brakes and the car comes to rest.

Which of the following gives the decrease in kinetic energy, in joules, as the car is brought to rest?

☒ **A** $750 \times (25)^2$

☒ **B** $750 \times \left(\frac{25}{2}\right)^2$

☒ **C** $1500 \times (25)^2$

☒ **D** $1500 \times \left(\frac{25}{2}\right)^2$

(Total for question = 1 mark)

Q18.

Seat belts are being tested by a car manufacturer. In the test, a car moving at a steady speed of 28 m s^{-1} collides with a wall and stops.

A crash-test dummy in the driving seat is wearing a seat belt made from polyester webbing. The seat belt has a cross-sectional area of 0.85 cm^2 and a total length of 2.0 m. A student suggests that in the collision the seat belt absorbs all the kinetic energy of the dummy.

Show that the energy per unit volume that would have to be absorbed by the seat belt is about 2×10^8 J m^{-3}.

mass of dummy = 75 kg

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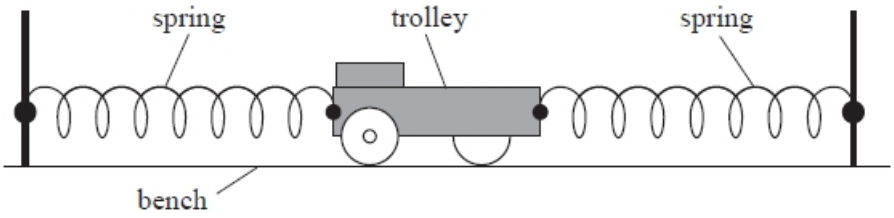
(Total for question = 3 marks)

Q19.

A trolley is attached to the ends of two springs as shown. When displaced from its equilibrium position, the trolley moves with simple harmonic motion.



The student displaces the trolley a greater distance from the equilibrium position, so the amplitude of oscillation is doubled. The trolley still moves with simple harmonic motion.

Explain how the maximum kinetic energy of the trolley will change.

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(Total for question = 3 marks)

Q20.

A cyclist travels up a slope through a vertical height *h* in a time *t*. The mass of the cyclist and his bike is *m*.

The average power of the cyclist is

☒ **A** $\frac{mg}{t}$

☒ **B** $\frac{t}{mg}$

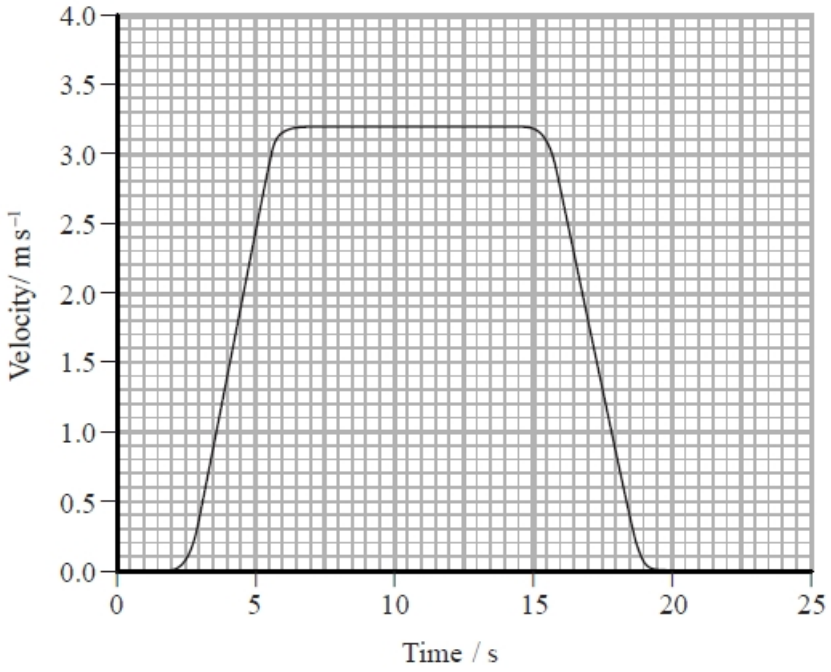
☒ **C** $\frac{mgh}{t}$

☒ **D** $\frac{t}{mgh}$

(Total for question = 1 mark)

Q21.

A lift moves upwards from the ground to the tenth floor of a building. The velocity-time graph for the lift is shown.



The power developed by the lift when travelling upwards with different loads is shown in the table.

Number of passengers	Load / kg	Power developed when accelerating / kW	Power developed when at constant velocity / kW
0	0	34	25
1	75	39	28
2	150	44	31
3	225	49	34

(i) By considering the forces acting on the lift as it rises, discuss the difference in values for the power developed by the lift.

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(ii) Lifts use a significant proportion of all total energy consumption of a building.
When designing the lift systems, engineers compare the predicted daily energy consumption of different lift motors by

- estimating the time for typical lift journey based on the number of floors in the building and the speed of the lift
- estimating the number of lift journeys per day
  using daily energy consumption = maximum power output of motor × number of journeys × time per journey

Discuss the advantages and disadvantages of using this method to compare the predicted energy consumption of different lift motors.

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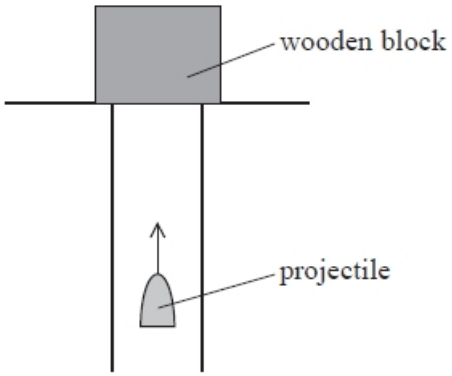
Q22.

A projectile of mass 65 g is fired vertically upwards into a stationary wooden block of mass 2.400 kg, as shown.



The projectile becomes embedded in the block. They both move vertically upwards through a vertical displacement of 55 cm before momentarily coming to rest.

Explain how the principle of conservation of energy applies to this collision.

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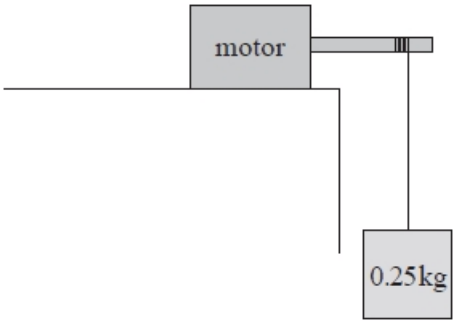
(Total for question = 2 marks)

Q23.

A motor is used to lift an object as shown. The object is raised through a vertical height of 75 cm at a constant speed of 0.40 m s^{-1}.



Which of the following gives the rate of increase of potential energy of the object in watts?

☒ **A** 0.25 × 9.81 × 0.40

☒ **B** 0.25 × 0.75

☒ **C** 0.25 × 9.81 × 0.75

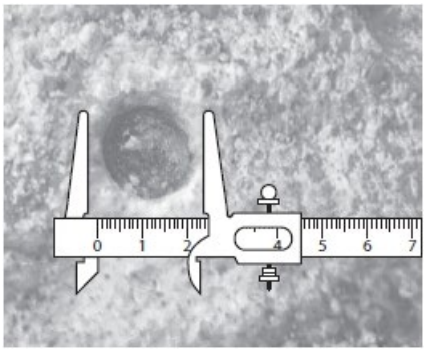
☒ **D** 0.5 × 0.25 × $(0.40)^2$

(Total for question = 1 mark)

Q24.

Impact craters are formed when meteorites strike the surface of a planet. A student investigated some factors that might influence the formation of impact craters. He did this by dropping spheres of modelling clay into a tray of sand.

The diameter of the crater produced by each sphere was measured using vernier calipers as shown.



This process was repeated for spheres of different diameters.

* The student also dropped the spheres from different heights. His results are shown in the table.

Drop height / m	Sphere diameter / cm	Crater diameter / cm
0.30	2.0	3.6
	4.0	7.0
	6.0	6.8
0.60	2.0	4.8
	4.0	7.5
	6.0	7.3
0.90	2.0	5.6
	4.0	8.0
	6.0	8.3

The student wrote the following conclusion:

"The greater the drop height, the greater the diameter of the crater formed when a sphere hits the sand. This is because the impact velocity increases as the drop height is increased. As the speed of the sphere increases the diameter of the crater formed also increases. Also, the bigger the sphere the bigger the crater."

Assess the validity of the student's conclusion.

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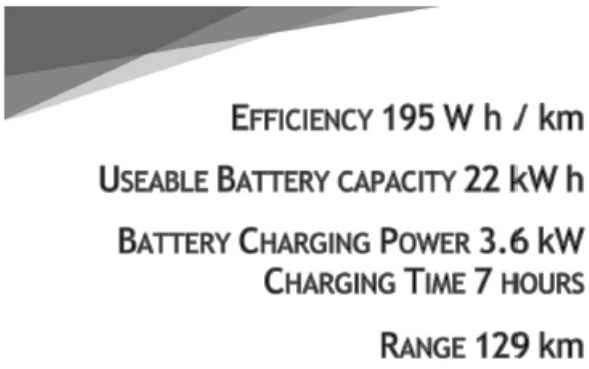
(Total for question = 6 marks)

Q25.

A website advertises an electric car with the following information.



State why the 'efficiency' given on the website cannot be a value of efficiency as defined in physics.

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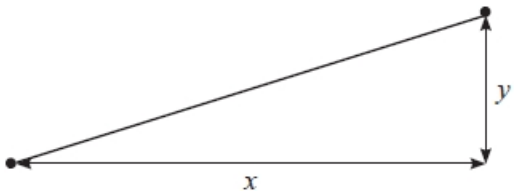
(Total for question = 1 mark)

Q26.

An object of mass *m* is moved from the bottom to the top of a slope. The vertical height of the slope is *y*.

The horizontal distance between the bottom and top of the slope is *x*.



Which of the following gives the gain of gravitational potential energy of the object as it moves from the bottom to the top of the slope?

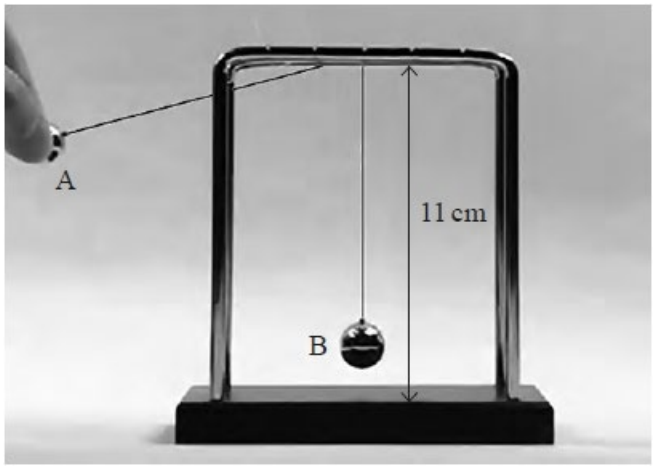
- ☒ **A** mgx
- ☒ **B** mgy
- ☒ **C** $mg(x + y)$
- ☒ **D** $mg\sqrt{(x^2 + y^2)}$

(Total for question = 1 mark)

Q27.

Two small identical solid metal spheres, A and B, are suspended by light inextensible threads from a frame.

The photograph shows sphere A just before it was released.



Determine the momentum of sphere A just before the collision. You should take measurements from the photograph.

height of frame = 11 cm
mass of sphere = 0.022 kg

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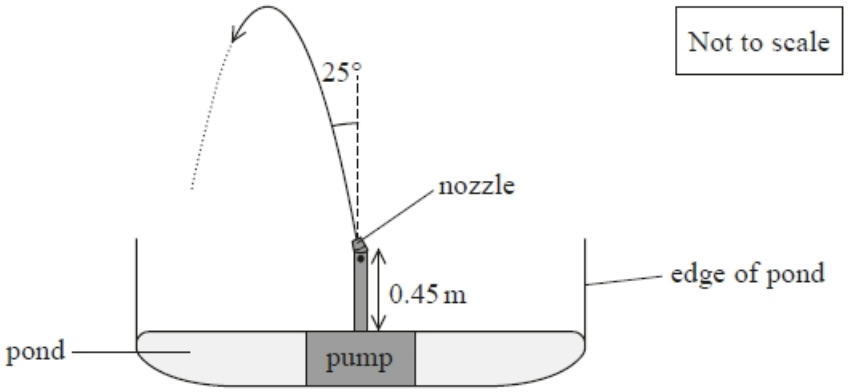
Momentum of sphere A = ...

(Total for question = 5 marks)

Q28.

A garden pond contains a water fountain. The fountain consists of a pump and nozzle and is used to create a jet of water which falls back into the pond as shown. The top of the edge of the pond is level with the nozzle.



The water is lifted through a height of 0.45 m before it leaves the nozzle at an angle of 25° to the vertical.

The efficiency of the pump is 76 %.

Show that the water leaves the nozzle at a speed of about 8 m s^{-1}.

mass of water leaving the pump each second = 3.5 kg s^{-1}

power of pump = 160 W

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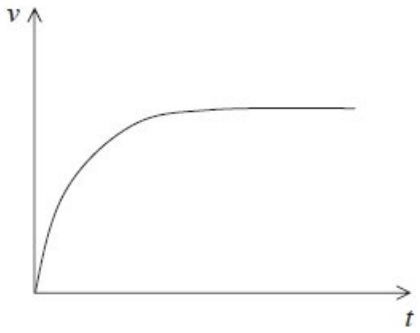
(Total for question = 5 marks)

Q29.

A sports class is studying cycling. They produce a video of a cyclist on a horizontal lawn.
The cyclist starts from rest.
They produce a sketch graph of the velocity *v* of the cyclist against time *t*.



A student makes the following statement.

The work done by the cyclist is converted into the kinetic energy of the cyclist and bicycle.

Criticise this statement.

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(Total for question = 3 marks)

Q30.

A car of mass 1.2×10^3 kg is travelling at a speed of 18 m s^{-1}. The driver applies the brakes and the car comes to rest.

What is the work done by the brakes in stopping the car?

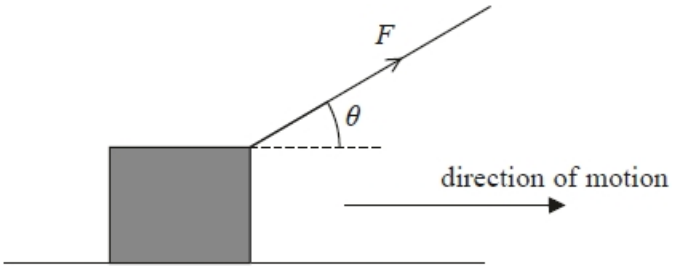
- ☒ **A** 11 kJ
- ☒ **B** 22 kJ
- ☒ **C** 190 kJ
- ☒ **D** 390 kJ

(Total for question = 1 mark)

Q31.

A rope is used to pull a box a distance *d* along a horizontal surface at a constant speed.

A force *F* is applied to the rope and the rope is at an angle θ to the horizontal.



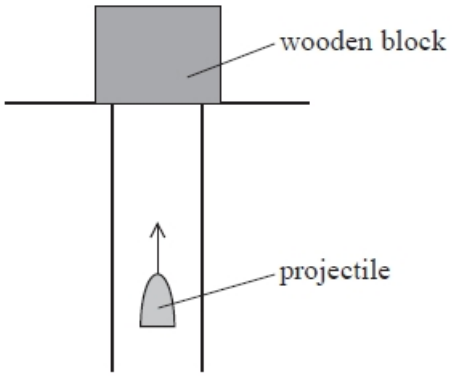
Which of the following could be used to determine the work done on the box?

- ☒ **A** $\frac{Fd}{\cos\theta}$
- ☒ **B** $Fd\cos\theta$
- ☒ **C** $\frac{Fd}{\sin\theta}$
- ☒ **D** $Fd\sin\theta$

(Total for question = 1 mark)

Q32.

A projectile of mass 65 g is fired vertically upwards into a stationary wooden block of mass 2.400 kg, as shown.



The projectile becomes embedded in the block. They both move vertically upwards through a vertical displacement of 55 cm before momentarily coming to rest.

Calculate the energy dissipated as the projectile hits the block.

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Energy dissipated = ...

(Total for question = 6 marks)

Q33.

The velocity v of a non-relativistic particle can be expressed in terms of combinations of the following quantities: kinetic energy E_k, momentum p and mass m.

Which of the following expressions is correct?

☒ **A** $v = \frac{p^2}{m}$

☒ **B** $v = \sqrt{\frac{2E_k}{m}}$

☒ **C** $v = \frac{E_k}{2p}$

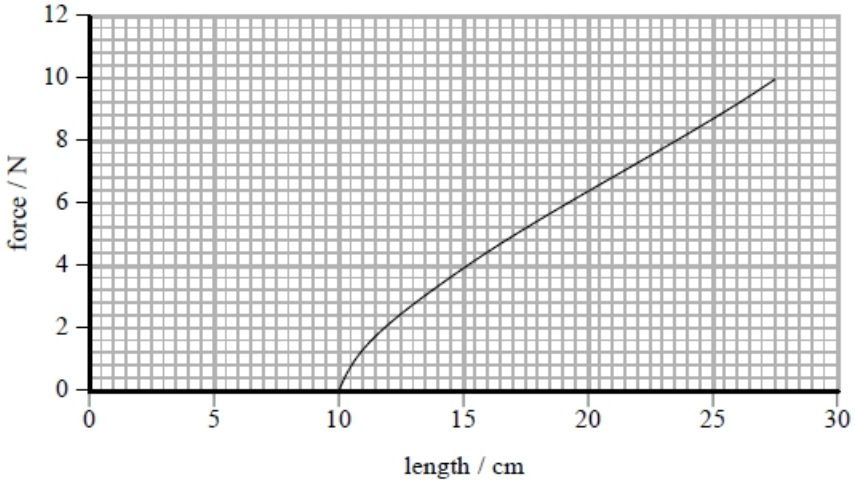
☒ **D** $v = \frac{2E_k}{pm}$

(Total for question = 1 mark)

Q34.

The photograph shows a toy that fires rubber bands.

A student investigates the properties of one of the rubber bands and obtains the following graph.



(a) The student wants to determine the mass of one of the rubber bands. He places five rubber bands on a balance and obtains a reading of 2 g. He divides the reading on the balance by five to determine the mass of one rubber band.

Explain how he could improve his result.

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(b) The rubber band is stretched by 17.4 cm when it is placed on the toy.

Show that the work done on the rubber band is about 1 J.

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(c) Calculate the maximum possible value for the initial velocity of the rubber band as it is fired from the toy.

Assume the mass of a rubber band is 0.4 g.

(2)

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Maximum initial velocity = ...

(d) The student thinks the calculated value of maximum velocity is too high because the band does not travel as far as expected.

Explain how the student could determine the initial velocity with the use of a video camera and why light gates would not be suitable.

(4)

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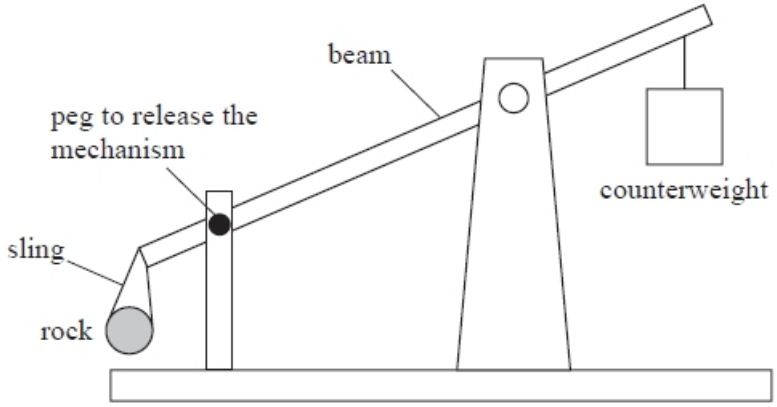
(Total for question = 12 marks)

Q35.

A trebuchet is a medieval catapult designed to project a rock over large distances.

A simplified diagram of a trebuchet is shown.



The rock is held in a sling. When the peg is removed the counterweight falls and the rock is projected through the air.

The mass of the counterweight was reduced. The trebuchet was then used to project the rock again.

Explain why the horizontal distance travelled by the rock decreases.

(5)

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(Total for question = 5 marks)

Mark Scheme- Work, Energy and Power

Q1.

Question Number	Acceptable Answer		Additional Guidance	
	• Use of $s = \frac{(u+v)}{2}.t$ • Use of $E_k = \frac{1}{2}mv^2$ • Use of $P = \frac{\Delta W}{\Delta t}$ • $P = 110$ W	(1) (1) (1) (1)	Example of calculation: $32.5\text{ m} = \frac{(u+0)}{2} \times 17.5\text{ s}$ $\therefore u = \frac{32.5\text{ m} \times 2}{17.5\text{ s}} = 3.71\text{ m s}^{-1}$ $P = \frac{\Delta E_k}{\Delta t} = \frac{\frac{1}{2} \times 19.6\text{ kg} \times (3.7\text{ m s}^{-2})^2}{1.25\text{ s}} = 107\text{ W}$	4

Q2.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Use of $E = mg\Delta h$ • $E = 1.1 \times 10^8$ J	(1) (1)	Example of Calculation $E = mg\Delta h = 1600\ kg \times 9.81 ms^{-1} \times (8500 - 1500) m$ $E = 1.1 \times 10^8$ J	2

Q3.

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)(i)	• use of $p = mv$ • use of conservation of momentum • $v = 3.8$ m s^{-1}	(1) (1) (1)	Example of calculation $p = 300$ kg $\times$ 7 m s^{-1} $p = 2100$ kg m s^{-1} 2100 kg m s^{-1} = (300 kg + 250 kg) v $v = 3.8$ m s^{-1}	**(3)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)(ii)	• use of $E_k = ½ mv^2$ • use of $W = Fd$ • $F =$ 3100 N	(1) (1) (1)	Example of calculation $E_k = ½ \times 550$ kg $\times$ (3.8 m s^{-1})^2 $E_k = 3970$ J 3970 J = $F \times 1.3$ m $F = 3050$ N Allow error carried forward for velocity from (a)(i)	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	no external forces acted on the cars/system		**(1)**

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
	• use of $E_k = ½ mv^2$	(1)	Example of calculation	
	• use of $P = E/t$	(1)	$E_k = \frac{1}{2}1500 \text{ kg } 28^2 \text{ (ms}^{-1})^2 = 5.88\times10^5 \text{ J}$	
	• power required is 51 kW, less than engine power so it does have enough power	(1)	$P = 5.88\times10^5 \text{ J} / 11.5 \text{ s} = 51.1 \text{ kW}$	3

Q5.

Question Number	Answer	Additional Guidance	Mark
	C is the only correct answer	A is incorrect because the wrong trigonometric function has been used B is incorrect because the wrong trigonometric function has been used D is incorrect because the wrong algebraic equation has been used	**1**

Q6.

Question Number	Answer	Mark
	D 1×10^{17} J	**1**
	A – this answer is incorrect B – this answer is incorrect C – this answer is incorrect	

Q7.

Question Number	Acceptable answers		Additional guidance	Mark
	• Quote $P = E/t$	(1)		
	• (k)W is unit of P and h unit of t so equivalent to E	(1)		2

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• As the speed increases, drag increases (1) • There is greater fuel consumption to maintain a higher constant speed **Or** the fuel economy reduces at higher speeds to maintain a constant speed (1) • Statement linking fuel economy to engine efficiency (1)	MP1: accept 'air resistance' for 'drag' MP3 e.g. The efficiency of the engine may increase (with speed) but the fuel economy decreases **Or** you can't compare efficiency which is a ratio with fuel consumption/economy which is a volume	3

Q9.

Question Number	Answer	Mark
	C $\frac{1}{2}mg\Delta x$	1
	Incorrect Answers: A – no factor of $\frac{1}{2}$ B – incorrect equation and no factor of $\frac{1}{2}$ D – incorrect equation	

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	C	*mgh*	1
	A uses the distance AB rather than height B uses a component of height D uses a component of height		

Q11.

Question Number	Answer	Mark
	A	1

Q12.

Question Number	Acceptable Answer	Additional guidance	Mark
	Max 2 • Beam/sling/counterweight also gain kinetic energy **(1)** • Beam/sling/rock also gain gravitational potential energy **(1)** • Work done against friction so some energy transferred to surroundings **(1)**		**2**

Q13.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\Delta E_{grav} = mg\Delta h$ **and** $P = \frac{E}{t}$ (1) • Use of Efficiency $= \frac{\text{useful energy/power output}}{\text{total energy/power input}}$ (1) • $0.76\ \text{m s}^{-1}$ (1)	Example of calculation Useful energy output in 1 s = 15 MJ Total energy in 1 s $= \frac{1.5 \times 10^7}{0.8} =$ 1.875×10^7 J $mg\Delta h$ per second $= 1.875 \times 10^7$ J Δh per second $= v = \frac{1.875 \times 10^7\ \text{J}}{2500000\ \text{kg} \times 9.81\ \text{N kg}^{-1}}$ $v = 0.76\ \text{m s}^{-1}$	**3**

Q14.

Question Number	Acceptable Answers	Additional guidance	Mark
	Either • A high power requires the mass to be lowered at a high speed (1) • But the length of time is limited by the depth of the mineshaft (1) **Or** • Total output energy is determined by the depth of the shaft (1) • $E=Pt$ so for a high power time must be small (since E is constant) (1)		**2**

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Speed of impact is the same for both spheres (1) • mass of sphere ∝ (diameter)^3 (1) • $E_k = \frac{1}{2}mv^2$ so factor = 8 (1) **OR** • Final $E_k = \Delta E_{grav}$ (1) • mass of sphere ∝ (diameter)^3 (1) • $\Delta E_{grav} = mg\Delta h$, so factor = 8 (1)	For MP2 accept radius instead of diameter A bald correct answer scores MP3 only Example of calculation: $\frac{m_2}{m_1} = \left(\frac{4\text{ cm}}{2\text{ cm}}\right)^3 = 8$ $\frac{E_{k2}}{E_{k1}} = \frac{m_2}{m_1} = 8$	3

Q16.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Male skater does work as he pushes female skater (1) **Or** Energy transfers from the male skater as he pushes female skater • So there is an increase in kinetic energy (1) [MP2 dependent on MP1]		2

Q17.

Question Number	Answer	Additional Guidance	Mark
	A is the only correct answer	B is incorrect because speed has been divided by 2 C is incorrect because $E_K = 0.5\ mv^2$ D is incorrect because $E_K = 0.5\ mv^2$	1

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Cross sectional area × length used to calculate volume (1) • Use of $E_k = \frac{1}{2}mv^2$ (1) • Energy per unit volume $= 1.7 \times 10^8$ (J m^{-3}) (1)	Example of calculation: Volume of seatbelt, $V = 0.85 \times 10^{-4}$ m^2 × 2 m $V = 1.7 \times 10{-}4$ m^3 $E_k = \frac{1}{2} \times 75$ kg $\times (28$ m s$^{-1})^2 = 2.9 \times 10^4$ J $\therefore \frac{E}{V} = \frac{2.9 \times 10^4 \text{ J}}{1.7 \times 10^{-4} \text{ m}^3} = 1.73 \times 10^8$ J m^{-3}:	3

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • $v_{max} = \omega A$ and ω constant (1) • If A doubles, then v_{max} doubles (1) • Hence max E_k will quadruple, since $E_k = \frac{1}{2}mv^2$ [dependent upon MP2] (1) OR • $\Delta E_{el} = \frac{1}{2}F\Delta x$ **and** $\Delta F = k\Delta x$ (1) • $\Delta E_{el} \propto (\Delta x)^2$ since k is constant (1) • Hence max E_k will quadruple, since max E_k = max ΔE_{el} (dependent upon MP2) (1)		3

Q20.

Question Number	Acceptable Answer	Additional guidance	Mark
	C	$\frac{mgh}{t}$	**(1)**

Q21.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• as the lift accelerates the accelerating force is equal to $T-mg$ **Or** $T - mg = ma$ **Or** $T = mg + ma$	(1)	Accept force provided by motor for the tension in the lift cable (T)	
	• greater power when accelerating because there is a resultant/accelerating force.	(1)	Accept **correct** references to frictional force (not air resistance) e.g. for MP1 $T - mg -$ frictional force $= ma$	
	• lower power when at constant velocity as just need to overcome weight (of lift and passengers)	(1)		
	• greater power as the number of passengers increases because **weight** (of lift + passengers) increases (as well as the accelerating force)	(1)		**(4)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to **four** of the following: <u>Disadvantages</u> because it doesn't take into account: • mass of passengers **Or** variations in load (1) • additional power needed to accelerate lift (1) • assumes full power used all the time (1) • efficiency of the motor (1) • suitable reference to other energy consumption such as lighting or opening/closing doors (1) • lift usage would decrease/change if there is more than one lift (1)	To award all 4 marks at least one mark must be awarded for the discussion of an advantage Allow credit for a correct equivalent point provided it has a physics basis	**(4)**
	<u>Advantages</u> because: • can give a basic comparison between motors (1) • energy estimate will take into account the height of the building (1) • gives a value for operational energy use (1)		

Q22.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Total energy is constant, but kinetic energy decreases **Or** reference to an inelastic collision **(1)** • Projectile does work on block **Or** internal energy of block increases **(1)**		**2**

Q23.

Question Number	Answer	Additional Guidance	Mark
	A is the only correct answer	B is incorrect because $P = mgh/t = mgv$ C is incorrect because $P = mgh/t = mgv$ D is incorrect because $P = mgh/t = mgv$	**1**

Q24.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The table shows how the marks should be awarded for indicative content and lines of reasoning.
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
Indicative content:

The table shows that increasing the drop height does increase the crater diameter
Increasing the drop height increases the impact velocity/E_k
Because there is a greater acceleration time
Or because there is a greater transfer of GPE to KE
The table does not show that increasing the sphere diameter (always) increases the crater diameter
For smaller spheres (from 2 to 4 cm), increasing sphere diameter does increase crater diameter **Or** for bigger spheres (from 4 to 6 cm), increasing the sphere diameter has little effect on crater diameter
More data is needed for firmer conclusions

</td>
<td>
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between its points and is unstructured</td><td>0</td></tr>
</table>
For IC3 accept reference to an appropriate equation

For IC5 accept "no effect" or "inconsistent effect" for "little effect"
</td>
<td>6</td>
</tr>
</table>

Q25.

Question Number	Acceptable answers	Additional guidance	Mark
	• Efficiency shouldn't have any units **Or** efficiency should be a ratio of energies **Or** efficiency should be a ratio of powers **Or** number < 1		**1**

Q26.

Question Number	Answer	Mark
	B - mgy, $E_P = mg\Delta h$, correct distance (vertical)	**1**
	Incorrect Answers: **A** – incorrect distance (horizontal) **C** – incorrect distance (horizontal + vertical) **D** – incorrect distance (length of slope)	

Q27.

Question Number	Additional guidance		Mark
	• Measurement of change in height of Sphere A	**(1)**	Initial decrease in height from photo = 2.9 ± 0.1 cm Height of frame in photo = 4.8 ± 0.1 cm MP2-4 award even if measurement for the height is out of range MP3 use of equation of motion scores 0 Example of calculation $h_A = \frac{2.9\text{ cm} \times 11\text{ cm}}{4.8\text{ cm}} = 6.6\text{ cm}$ $½ \times 0.022\text{ kg} \times v_A^2 = 0.022\text{ kg} \times 9.81\text{ N kg}^{-1} \times 6.6 \times 10^{-2}\text{ m}$ $v_A = 1.14\text{ m s}^{-1}$ $p_A = 0.022\text{ kg} \times 1.14\text{ m s}^{-1} = 0.025\text{ kg m s}^{-1}$ Accept p_A in range 0.024 – 0.026 kg m s^{-1}	**5**
	• actual height = $\frac{\text{image height} \times 11}{4.8}$	**(1)**		
	• Use of E_k gained = E_{grav} lost to determine v	**(1)**		
	• Use of $p = mv$	**(1)**		
	• $p_A = 0.025$ kg m s^{-1}			

Q28.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of efficiency = $\frac{\text{useful power output}}{\text{total power input}}$ **(1)** • Use of $\Delta E_{grav} = mg\Delta h$ **(1)** • Use of $E_k = ½ mv^2$ **(1)** • Use of (output) power = $\frac{\Delta E_{grav}}{1\text{ s}} + \frac{E_k}{1\text{ s}}$ **(1)** • $v = 7.8$ (m s^{-1}) **(1)**	Example of calculation Output power = 0.76 × 160 W = 121.6 W 121.6 W = (3.5 kg s^{-1})(9.81 N kg^{-1})(0.45 m) + ½(3.5 kg s^{-1})v^2 v = 7.78 m s^{-1}	5

Q29.

Question Number	Acceptable answers	Additional guidance	Mark
	• Work done (by cyclist) results in a transfer of energy **(1)** • initially there is an increase in E_k of (cyclist and bicycle) **Or** work done is transferred/converted to other forms of energy **(1)** • when the velocity of the cyclist is constant, all the energy is being transferred to other forms **(1)**		3

Q30.

Question Number	Answer	Mark
	C 190 kJ	1
	Incorrect Answers: A – The velocity was not squared when using the formula $E_k = ½ mv^2$ e.g. ½ (1.2 × 10^3)(18) = 11 kJ B – The velocity was not squared and the ½ was omitted when using the formula $E_k = ½ mv^2$ e.g. (1.2 × 10^3)(18) = 22 kJ D – The ½ was omitted when using the formula $E_k = ½ mv^2$ e.g. (1.2 × 10^3)(18)^2 = 390 kJ	

Q31.

Question Number	Acceptable answers	Additional guidance	Mark
	B		**1**

Q32.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $E_{grav} = mg\Delta h$ **(1)** • Use of $E_K = \frac{1}{2}mv^2$ for block and projectile **(1)** • Use of $p = mv$ **(1)** • Use of conservation of momentum **(1)** • Use of $E_K = \frac{1}{2}mu^2$ for projectile **(1)** • $\Delta E = 490$ J **(1)**	MP1: Use of suvat equation to calculate u MP2: Use of $E_K = \frac{1}{2}mv^2$ for block and projectile **Or** use of $E_{grav} = mg\Delta h$ Example of calculation $E_{grav} = (2.4 + 0.065)\text{kg} \times 9.81\ \text{m s}^{-2} \times 0.55\ \text{m} = 13.3\ \text{J}$ (of block and projectile) $13.3\ \text{J} = \frac{1}{2} \times (2.4 + 0.065)\text{kg} \times v^2$ $\therefore v = \sqrt{\frac{13.3\ \text{J}}{0.5 \times 2.465\ \text{kg}}} = 3.28\ \text{m s}^{-1}$ $0.065\ \text{kg} \times u = 2.465\ \text{kg} \times 3.28\ \text{m s}^{-1}$ $\therefore u = \frac{8.10\ \text{kg m s}^{-1}}{0.065\ \text{kg}} = 124.6\ \text{m s}^{-1}$ $E_K = \frac{1}{2} \times 0.065\ \text{kg} \times (125\ \text{m s}^{-1})^2 = 504\ \text{J}$ $\therefore \Delta E = (504 - 13.3)\ \text{J} = 491\ \text{J}$	**6**

Q33.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B *A is not correct because this is not dimensionally correct* *C is not correct because* $E_k/_{2p} = v/_4$ *D is not correct because this is not dimensionally correct*		**1**

Q34.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An explanation that makes reference to: • balance measures to 1 g **(1)** • more rubber bands should have been placed on the balance to obtain a reading of at least 10 g **(1)** • so that a more precise reading is obtained **(1)**		3
(b)	• use of area under graph to represent work done **(1)** • uses area accurately between line and distance axis to determine work done **(1)** • 0.97 J (range from printed graph) **(1)**	Do not award first mark for use of E=1/2Fx	3
(c)	• use of ke = ½ mv^2 **(1)** • v = 70 m s^{-1} **(1)**	Example of calculation: 0.97 J = ½ mv^2 = ½ 0.0004 kg × v^2 v = 70 m s^{-1}	2
(d)	An explanation that makes reference to: • video the band over a short distance so it determines the initial speed **(1) OR** because its speed will rapidly reduce because of air resistance **(1)** • include a scale or object of known length in the area filmed **(1)** • analyse the video to determine the time taken to travel the known distance **AND** calculate the speed using the measured time in speed = distance/time **(1)** • (light gates would not be suitable because) the band is not sufficient in size to interrupt the light gate beam **(1)**		4

Q35.

Question Number	Acceptable Answer	Additional guidance	Mark
	• Counterweight transfers less gravitational potential energy **(1)** • So transfer of kinetic energy to rock is reduced **(1)** • (When released) rock has smaller vertical (component of) velocity **(1)** • Time of flight will be reduced **(1)** • (And) horizontal (component) of velocity will be smaller **(1)**	Additional Guidance. Accept references to force and acceleration for MP1 and MP2 eg: Force on rock is decreased (so) acceleration of rock in sling is decreased	5