Work, Energy and Power *[43 marks]*

1. An object falls from rest from a height h close to the surface of the Moon. The Moon has no atmosphere. *[1 mark]*

   When the object has fallen to height $\frac{h}{4}$ above the surface, what is

   $$\frac{\text{kinetic energy of the object at } \frac{h}{4}}{\text{gravitational potential energy of the object at } h}?$$

   A. $\frac{3}{4}$

   B. $\frac{4}{3}$

   C. $\frac{9}{16}$

   D. $\frac{16}{9}$

Markscheme

A

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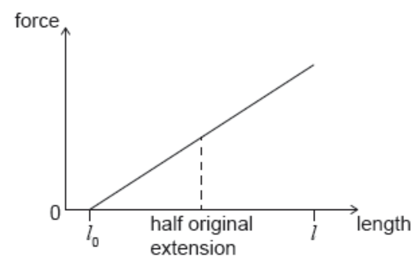
2. An increasing force acts on a metal wire and the wire extends from an initial length l_0 to a new length l. The graph shows the variation of force with length for the wire. The energy required to extend the wire from l_0 to l is E. *[1 mark]*



   The wire then contracts to half its original extension.

   What is the work done by the wire as it contracts?

   A. 0.25 E

   B. 0.50 E

   C. 0.75 E

   D. E

Markscheme

C

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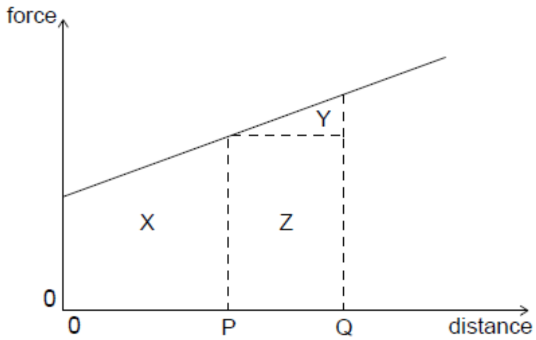
3. A graph shows the variation of force acting on an object moving in a straight line with *[1 mark]*

distance moved by the object. Which area represents the work done on the object during its motion from P to Q?



A. X
B. Y
C. Y + Z
D. X + Y + Z

Markscheme

C

4. The initial kinetic energy of a block moving on a horizontal floor is 48 J. A constant frictional force acts on the block bringing it to rest over a distance of 2 m. What is the frictional force on the block? *[1 mark]*

A. 24 N

B. 48 N

C. 96 N

D. 192 N

Markscheme

A

5. A stone is falling at a constant velocity vertically down a tube filled with oil. Which of the following statements about the energy changes of the stone during its motion are correct? *[1 mark]*

I. The gain in kinetic energy is less than the loss in gravitational potential energy.
II. The sum of kinetic and gravitational potential energy of the stone is constant.
III. The work done by the force of gravity has the same magnitude as the work done by friction.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

B

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6. An object of mass m is initially at rest. When an impulse I acts on the object its final kinetic energy is E_{K}. What is the final kinetic energy when an impulse of $2I$ acts on an object of mass $2m$ initially at rest? *[1 mark]*

A. $\frac{E_{\mathrm{K}}}{2}$

B. E_{K}

C. $2E_{\mathrm{K}}$

D. $4E_{\mathrm{K}}$

Markscheme

C

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7. An object of mass m_1 has a kinetic energy E_1. Another object has a mass m_2 and kinetic energy E_2. The objects have the same momentum. What is the ratio $\frac{E_1}{E_2}$? *[1 mark]*

A. 1

B. $\sqrt{\frac{m_2}{m_1}}$

C. $\frac{m_2}{m_1}$

D. $\left(\frac{m_2}{m_1}\right)^2$

Markscheme

C

8. In an inelastic collision *[1 mark]*

A. momentum and kinetic energy are both conserved.
B. momentum is conserved but kinetic energy is not.
C. kinetic energy is conserved but momentum is not.
D. neither momentum nor kinetic energy are conserved.

Markscheme

B

9. A motor of input power 160 W raises a mass of 8.0 kg vertically at a constant speed of 0.50 m s^{-1}. *[1 mark]*

What is the efficiency of the system?

A. 0.63%

B. 25%

C. 50%

D. 100%

Markscheme

B

10. A car travelling at a constant velocity covers a distance of 100 m in 5.0 s. The thrust of the engine is 1.5 kN. What is the power of the car? *[1 mark]*

A. 0.75 kW
B. 3.0 kW
C. 7.5 kW
D. 30 kW

Markscheme

D

11. The efficiency of an electric motor is 20 %. When lifting a body 500 J of energy are wasted. What is the useful work done by the motor? *[1 mark]*

A. 100 J

B. 125 J

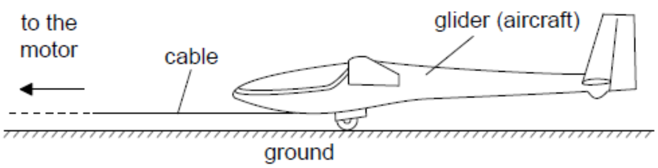
C. 250 J

D. 400 J

Markscheme

B

A glider is an aircraft with no engine. To be launched, a glider is uniformly accelerated from rest by a cable pulled by a motor that exerts a horizontal force on the glider throughout the launch.



12a. The glider reaches its launch speed of 27.0 m s $^{-1}$ after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground. *[2 marks]*

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Markscheme

correct use of kinematic equation/equations

148.5 ***or*** 149 ***or*** 150 «m»

Substitution(s) must be correct.

12b. The glider and pilot have a total mass of 492 kg. During the acceleration the glider is subject to an average resistive force of 160 N. Determine the average tension in the cable as the glider accelerates. *[3 marks]*

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Markscheme

$a = \frac{27}{11}$ ***or*** 2.45 «m s^{-2}»

$F - 160 = 492 \times 2.45$

1370 «N»

Could be seen in part (a).
*Award **[0]** for solution that uses $a = 9.81$ m s^{-2}*

12c. The cable is pulled by an electric motor. The motor has an overall efficiency of 23 %. Determine the average power input to the motor. *[3 marks]*

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Markscheme

ALTERNATIVE 1

«work done to launch glider» = 1370 x 149 «= 204 kJ»

«work done by motor» $= \frac{204 \times 100}{23}$

«power input to motor» $= \frac{204 \times 100}{23} \times \frac{1}{11} = 80$ ***or*** 80.4 ***or*** 81 k«W»

ALTERNATIVE 2

use of average speed 13.5 m s^{-1}

«useful power output» = force x average speed «= 1370 x 13.5»

power input = «$1370 \times 13.5 \times \frac{100}{23}$ =» 80 ***or*** 80.4 ***or*** 81 k«W»

ALTERNATIVE 3

work required from motor = KE + work done against friction « $= 0.5 \times 492 \times 27^2 + (160 \times 148.5)$» = 204 «kJ»

«energy input» $= \frac{\text{work required from motor} \times 100}{23}$

power input $= \frac{883000}{11} = 80.3$ k«W»

*Award **[2 max]** for an answer of 160 k«W».*

12d. The cable is wound onto a cylinder of diameter 1.2 m. Calculate the angular velocity of the cylinder at the instant when the glider has a speed of 27 m s^{-1}. Include an appropriate unit for your answer. *[2 marks]*

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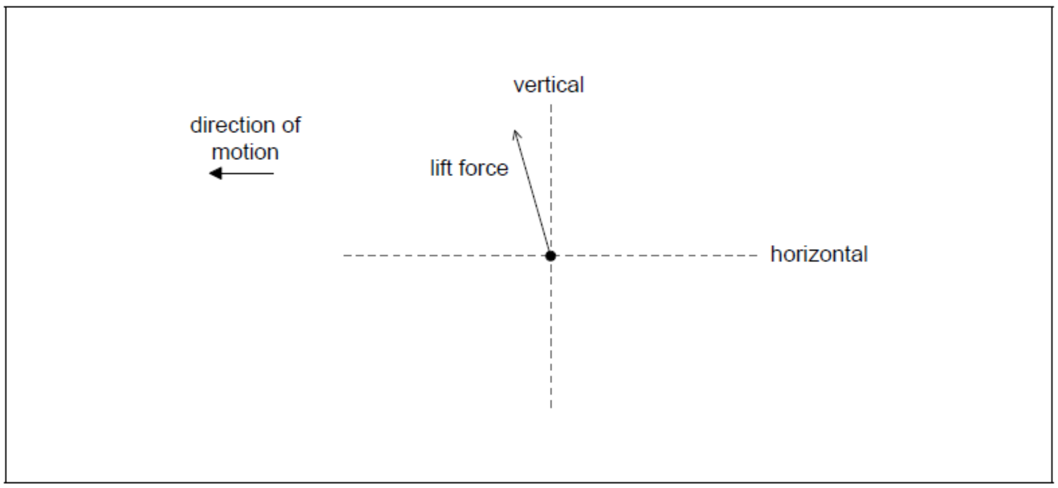
Markscheme

$\omega = «\frac{v}{r} =» \frac{27}{0.6} = 45$

rad s^{-1}

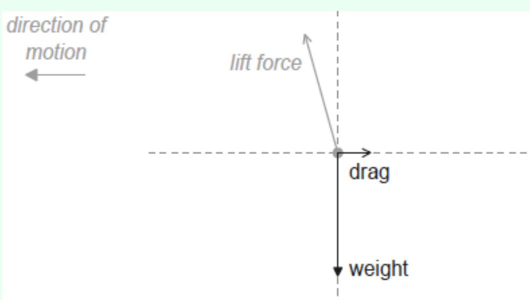
Do not accept Hz.
*Award **[1 max]** if unit is missing.*

12e. After takeoff the cable is released and the unpowered glider moves horizontally at constant speed. The wings of the glider provide a lift force. The diagram shows the lift force acting on the glider and the direction of motion of the glider. *[2 marks]*



Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions.

Markscheme



drag correctly labelled and in correct direction

weight correctly labelled and in correct direction ***AND*** no other incorrect force shown

*Award **[1 max]** if forces do not touch the dot, but are otherwise OK.*

12f. Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight. *[2 marks]*

Markscheme

name Newton's first law

vertical/all forces are in equilibrium/balanced/add to zero
OR
vertical component of lift mentioned

as equal to weight

12g. At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is 12.5 m s^{-1}. Calculate the **velocity** of the glider. Give your answer to an appropriate number of significant figures. *[3 marks]*

Markscheme

any speed and any direction quoted together as the answer

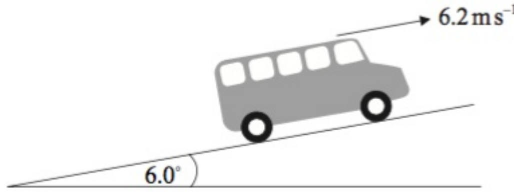
quotes their answer(s) to 3 significant figures

speed = 12.7 m s^{-1} ***or*** direction = 9.46° ***or*** 0.165 rad «below the horizontal» ***or*** gradient of $-\frac{1}{6}$

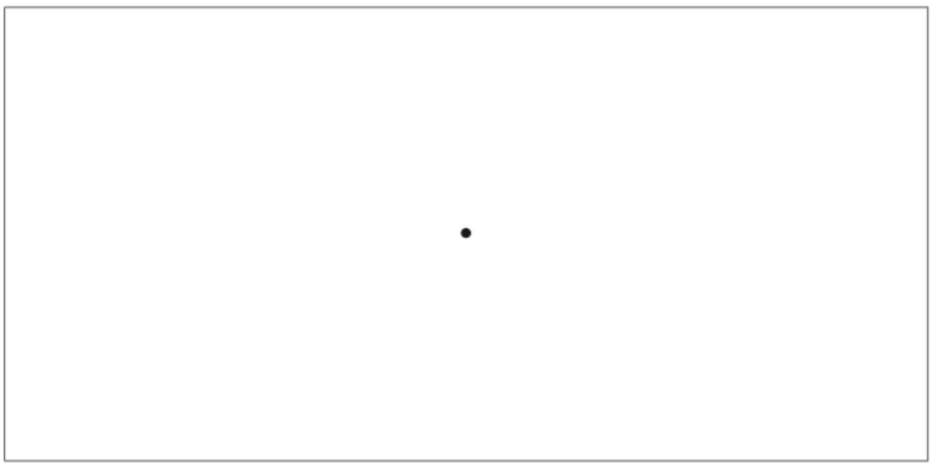
This question is in **two** parts. **Part 1** is about power and efficiency. **Part 2** is about electrical resistance.

Part 1 Power and efficiency

A bus is travelling at a constant speed of 6.2 m s $^{-1}$ along a section of road that is inclined at an angle of 6.0° to the horizontal.



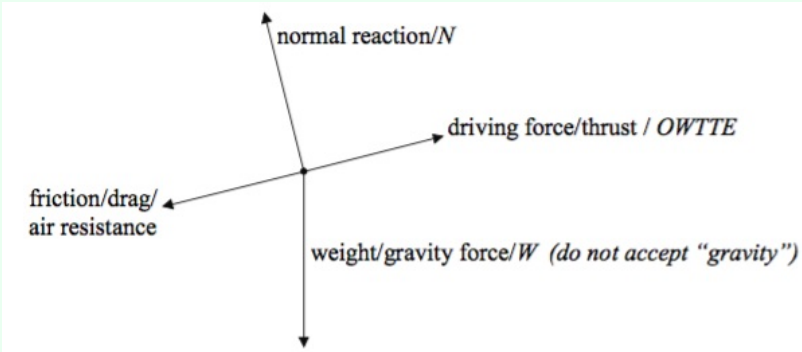
13a. (i) The bus is represented by the black dot shown below. Draw a labelled sketch to represent the forces acting on the bus. *[5 marks]*



(ii) State the value of the rate of change of momentum of the bus.

Markscheme

(i)



identification of normal reaction/ N and weight/ W;
identification of friction and driving force;
correct directions of all four forces;
correct relative lengths; { (*friction ≅ driving force and N ≅ W but N must not be longer than W) (judge by eye)*

(ii) zero;

13b. The mass of the bus is 8.5×10^{3} kg. Determine the rate of increase of gravitational potential energy of the bus. *[3 marks]*

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Markscheme

height gained in 1s=(6.2 sin 6=) 0.648(m);
rate of change of PE=$8.5\times10^{3}\times9.81\times0.648$;
=5.4×10^{4}W;

13c. Using your answer to (c) and the data in (b), estimate the magnitude of the resistive forces acting on the bus. *[3 marks]*

Markscheme

power used to overcome friction=(7×10^4–5.4×10^4=)1.6×10^4(W); {(*allow ECF from (c)*)

$F=\left(\frac{p}{v}=\right)\frac{1.6\times10^4}{6.2}$;

=2.6kN;

13d. The engine of the bus suddenly stops working. *[4 marks]*

(i) Determine the magnitude of the net force opposing the motion of the bus at the instant at which the engine stops.

(ii) Discuss, with reference to the air resistance, the change in the net force as the bus slows down.

Markscheme

(i) component of weight down slope = $8.5\times10^3\times9.81\sin6$;

net force=$2.6\times10^3+8.5\times10^3\times9.81\sin6$

=11kN;

Watch for ECF from (d).

(ii) air resistance decreases as speed drops;

so net force decreases;