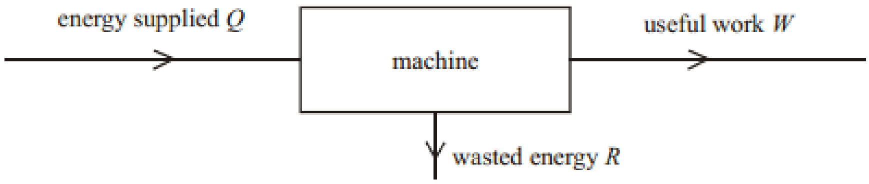
TOPPERZ @ WORK EDUCATION CENTRE

Class: IB Year 1 | Topic: Work, Power & Energy

Subject: Physics | Time: 90 Min

1. An amount Q of energy is supplied to a machine. The machine does useful work W and an amount R of energy is wasted, as illustrated below.



Which **one** of the following is a correct expression for the efficiency of the machine?

A. $\frac{W}{Q}$

B. $\frac{R}{Q}$

C. $\frac{W+R}{Q}$

D. $\frac{W-R}{Q}$

(1)

2. A force of magnitude F_1 accelerates a body of mass m from rest to a speed v. A force of magnitude F_2 accelerates a body of mass $2m$ from rest to a speed $2v$.

The ratio $\frac{\text{work done by } F_2}{\text{work done by } F_1}$ is

A. 2.

B. 4.

C. 8.

D. 16.

(1)

3. A machine lifts an object of weight W at constant speed through a vertical distance h. The efficiency of the machine is 25%. The total input energy to the machine is

A. $0.25Wh$.

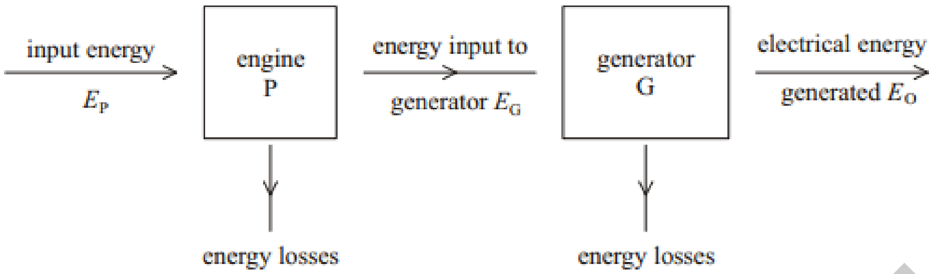
B. $0.75Wh$.

C. $2.5Wh$.

D. $4.0Wh$.

(1)

4. A petrol engine P is used to drive a generator G. The energy-flow diagram for this system is shown below.



What is the efficiency of this electrical energy generating system?

A. $\frac{E_G}{E_P}$

B. $\frac{E_O}{E_P}$

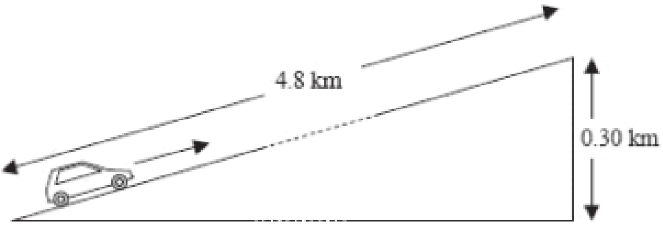
C. $\frac{E_O}{E_G}$

D. $\frac{(E_O + E_G)}{E_P}$

(1)

5. Mechanical power

(a) A car drives up a straight incline that is 4.8 km long. The total height of the incline is 0.30 km.



The car moves up the incline at a steady speed of 16 m s^{-1}. During the climb, the average friction force acting on the car is 5.0×10^2 N. The total weight of the car and the driver is 1.2×10^4 N.

(i) Determine the time it takes the car to travel from the bottom to the top of the incline.

(2)

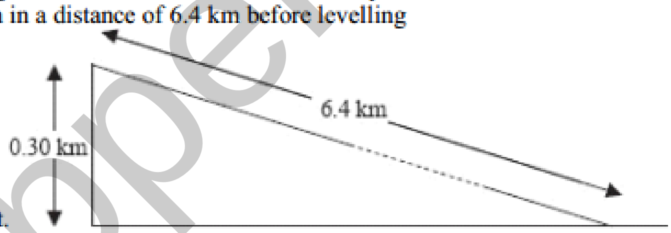
(ii) Detemine the work done against the gravitational force in travelling from the bottom to the top of the incline.

(1)

(iii) Using your answers to (a)(i) and (a)(ii), calculate a value for the minimum power output of the car engine needed to move the car from the bottom to the top of the incline.

(4)

(b) From the top of the incline, the road continues downwards in a straight line. At the point where the road starts to go downwards, the driver of the car in (a), stops the car to look at the view. In continuing his journey, the driver decides to save fuel. He switches off the engine and allows the car to move freely down the hill. The car descends a height of 0.30 km in a distance of 6.4 km before levelling



out.

The average resistive force acting on the car is 5.0×10^2 N.

Estimate

(i) the acceleration of the car down the incline.

(5)

(ii) the speed of the car at the bottom of the incline.

(2)

(c) In fact, for the last few hundred metres of its journey down the hill, the car travels at constant speed. State the value of the frictional force acting on the car whilst it is moving at constant speed.

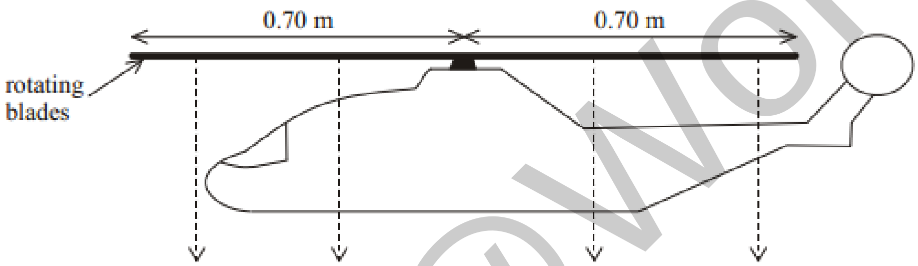
(1)
(Total 15 marks)

6. This question is about Newton's laws of motion, the dynamics of a model helicopter and the engine that powers it.

(a) Explain how Newton's third law leads to the concept of conservation of momentum in the collision between two objects in an isolated system.

(4)

(b) The diagram illustrates a model helicopter that is hovering in a stationary position.



The rotating blades of the helicopter force a column of air to move downwards. Explain how this may enable the helicopter to remain stationary.

(3)

(c) The length of each blade of the helicopter in (b) is 0.70 m. Deduce that the area that the blades sweep out as they rotate is 1.5 m^2. (Area of a circle = πr^2)

(1)

(d) For the hovering helicopter in (b), it is assumed that all the air beneath the blades is pushed vertically downwards with the same speed of 4.0 m s^{-1}. No other air is disturbed.

The density of the air is 1.2 kg m^{-3}.

Calculate, for the air moved downwards by the rotating blades,

(i) the mass per second;

(2)

(ii) the rate of change of momentum.

(1)

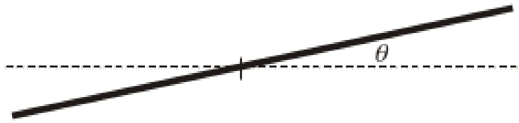
(e) State the magnitude of the force that the air beneath the blades exerts on the blades.

(1)

(f) Calculate the mass of the helicopter and its load.

(2)

(g) In order to move forward, the helicopter blades are made to incline at an angle θ to the horizontal as shown schematically below.



While moving forward, the helicopter does not move vertically up or down. In the space provided below draw a free body force diagram that shows the forces acting on the helicopter blades at the moment that the helicopter starts to move forward. On your diagram, label the angle θ.

(4)

(h) Use your diagram in (g) to explain why a forward force F now acts on the helicopter and deduce that the initial acceleration a of the helicopter is given by

$$a = g\tan\theta$$

where g is the acceleration of free fall.

(5)

(i) The helicopter is driven by an engine that has a useful power output of 9.0×10^2 W. The engine makes 300 revolutions per second. Deduce that the work done in one cycle is 3.0 J.

(1)

7. This question is about momentum and energy.

(a) Define *impulse of a force* and state the relation between impulse and momentum.

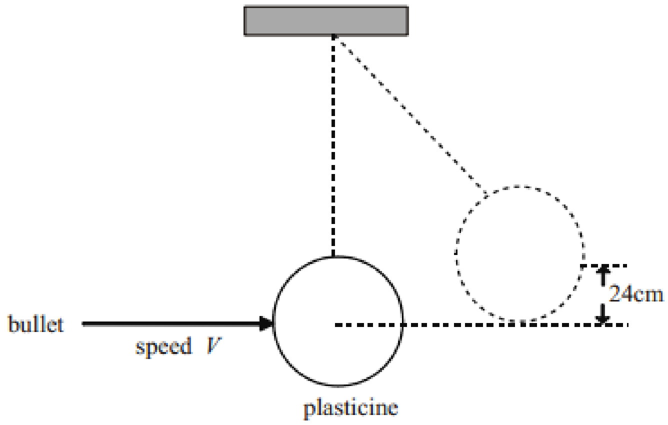
definition

relation

(b) By applying Newton's laws of motion to the collision of two particles, deduce that momentum is conserved in the collision.

(5)

(c) In an experiment to measure the speed of a bullet, the bullet is fired into a piece of plasticine suspended from a rigid support by a light thread.



The speed of the bullet on impact with the plasticine is V. As a result of the impact, the bullet embeds itself in the plasticine and the plasticine is displaced vertically through a height of 24 cm. The mass of the bullet is 5.2×10^{-3} kg and the mass of the plasticine is 0.38 kg.

(i) Ignoring the mass of the bullet, calculate the speed of the plasticine immediately after the impact.

(2)

(ii) Deduce that the speed V with which the bullet strikes the plasticine is about 160 m s^{-1}.

(2)

(iii) Estimate the kinetic energy lost in the impact.

(3)

(d) Another bullet is fired from a different gun into a large block of wood. The block remains stationary after impact and the bullet melts completely. The temperature rise of the block is negligible. Use the data to estimate the minimum impact speed of the bullet.

mass of bullet	= 5.3×10^{-3} kg
specific heat capacity of the material of the bullet	= 130 J kg^{-1} K^{-1}
latent heat of fusion of the material of the bullet	= 870 J kg^{-1}
melting point of the material of the bullet	= 330°C
initial temperature of bullet	= 30°C

(5)
(Total 19 marks)

WORK ENERGY POWER HL MARKSCHEME

1. A [1]

2. C [1]

3. D [1]

4. B [1]

5. Mechanical power

(a) (i) $t=\frac{d}{v}$;

$=\frac{4800}{16}=300\text{s}$; 2

(ii) $W = mgh = 1.2 \times 10^4 \times 300 = 3.6 \times 10^6$ J; 1

(iii) work done against friction $= 4.8 \times 10^3 \times 5.0 \times 10^2$;
total work done $= 2.4 \times 10^6 + 3.6 \times 10^6$;
total work done $= P \times t = 6.0 \times 10^6$;
to give $P=\frac{6.0\times10^6}{300}=20\text{kW}$; 4

(d) (i) $\sin\theta = \frac{0.30}{6.4}=0.047$;

weight down the plane $= W\sin\theta = 1.2 \times 10^4 \times 0.047 = 5.6 \times 10^2$N;
net force on car $F = 5.6 \times 10^2 - 5.0 \times 10^2 = 60$N;

$a=\frac{F}{m}$;

$\frac{60}{1.2\times10^3}=5.0\times10^{-2}\text{ ms}^{-2}$; 5

(ii) $v^2 = 2as = 2 \times 5.0 \times 10^{-2} \times 6.4 \times 10^3$;

to give $v = 25\text{ms}^{-1}$; 2

(e) 5.6×10^2 N; 1

[15]

6. (a) before and after collision there are no forces acting on the objects;
from Newton 3 when the two bodies are in contact the forces that they exert on each other are equal and opposite / *OWTTE*;
therefore, the net force on the two balls is always zero;
therefore, there is no change in momentum (of the objects) / momentum is conserved;

or

Accept an argument based on change in momentum of each individual object.
eg
from Newton 3 $F_{12} = -F_{21}$; *(accept statement in words)*

$F_{12} = \frac{\Delta p_1}{\Delta t}$ and $F_{21} = \frac{\Delta p_2}{\Delta t}$;

$\frac{\Delta p_1}{\Delta t} = -\frac{\Delta p_2}{\Delta t}$;

therefore, $\Delta p_1 + \Delta p_2 = 0$; 4

(b) the blades exert a force on the air and by Newton's third law the air exerts an equal and opposite force on the blades / air has change in momentum downwards giving rise to a force and from Newton 3 there will a force upwards;
if this force equals the weight of the helicopter;
the net vertical force on the helicopter will be zero / *OWTTE*; 3

(c) area $= \pi 0.7^2$;
$= 1.5\ m^2$ 1

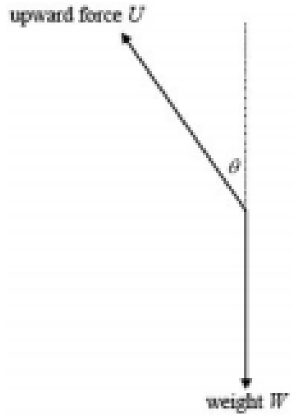
(d) (i) volume of air per second $= 1.5 \times 4.0 (m^3 s^{-1})$;
mass = volume × density $= (1.2 \times 1.5 \times 4.0) = 7.2 kgs^{-1}$; 2
No unit error for 7.2 kg.

(ii) momentum per second $= (7.2 \times 4.0) = 29N$; 1

(e) 29 N; 1

(f) recognise that the force on the blades $= Mg$;
to give3.0kg; 2

(g)



correct relative directions of forces;
upward force length greater than weight by eye;
appropriate labelling of forces;
angle θ as shown above; 4
Award [2 max] if extra force(s) drawn.

(h) the forward force is the horizontal component of U;
resolve vertically $U\cos\theta = W$;
horizontal component $F = U\sin\theta$;
divide to get $= \frac{F}{W} = \tan\theta$;
$F = (W\tan\theta) = Mg\tan\theta = Ma$;
to give $a = g\tan\theta$ 5

Award [5 max] for a correctly labelled force diagram incorporating mass with a justifying statement. Award [1 max] for triangle mixing accelerations and force.

(i) work done in one cycle $= \frac{900}{300}$;
$= 3.0\text{J}$ 1

(j) (i) isochoric / isovolumetric; 1

(ii) B → C absorbed;
D → A ejected; 2
Accept parallel arrows.

(iii) $Q_1 - Q_2 = 3.0$;

$1 - \frac{Q_2}{Q_1} = 0.6$;

$Q_1 = 5.0\text{J}$ and $Q_2 = 2.0\text{J}$; 3

7. (a) (impulse =) force × time for which force acts;
impulse ($F\Delta t$) = change in momentum (Δp); 2

(b) *The following points are needed for maximum marks.*
from Newton 3;
when objects are in contact, the forces exerted by the objects on each other are equal and opposite;
from Newton 2 / collision time is the same;
impulses are equal and opposite;
therefore changes in momentum are equal and opposite / total change in momentum is zero;

or

Accept algebraic solution.
from Newton 3;
$F_{AB} = -F_{BA}$
from Newton 2;
$F_{AB}\Delta t = m_A \Delta v_A$;
$= -m_B \Delta v_B$; 5

(c) (i) $v = \sqrt{2gh}$;
to give $v = 2.2$ ms^{-1}; 2
Award full marks for bald correct answer.

(ii) from conservation of momentum / $V \times 5.2 \times 10^{-3} = 0.38 \times 2.2$
$V = \frac{0.38 \times 2.2}{5.2 \times 10^{-3}}$
to give $V = 160$ m s^{-1} 2

(iii) KE before = $\left(\frac{1}{2} \times 5.2 \times 10^{-3} \times 1.6^2 \times 10^4\right) = 67$ J;

KE after = $\left(\frac{1}{2} \times 0.38 \times 4.8\right) = 0.91$ J / (0.38 × 9.8 × 0.24) = 0.91 J;
lost energy = 66 J 3

(d) energy to increase from 20 °C to 330 °C = (5.2 × 10^{-3} × 130 × 300) = 200 (J)
energy to melt pellet = (5.2 × 10^{-3} × 870) = 4.5 (J);
total KE = 210 J;
$\frac{1}{2}mv^2 = 210$;
to give $v = 280$ m s^{-1} 5

[19]