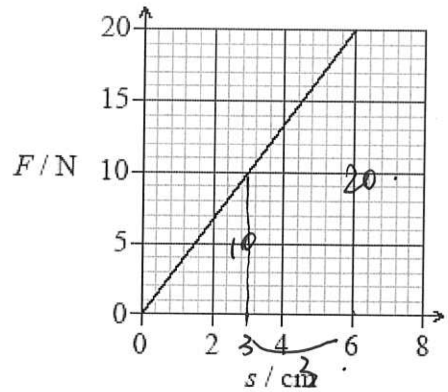
1. The graph shows the variation with force F of the extension s of a spring.



The work done in changing the extension of the spring from 3.0 cm to 6.0 cm is

A. 15 N cm.

B. 30 N cm.

C. 45 N cm.

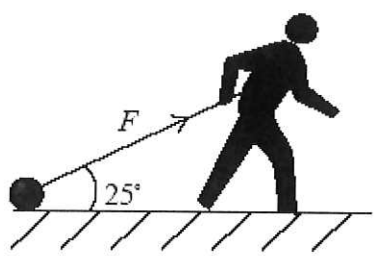
D. 60 N cm.

$\frac{30 \times 3}{2} = 15 \times 3$

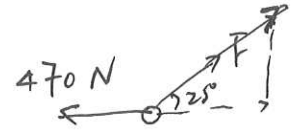
(Total 1 mark)

2. This question is about forces.

An athlete trains by dragging a heavy load across a rough horizontal surface.



The athlete exerts a force of magnitude F on the load at an angle of 25° to the horizontal.



$\cos 25^\circ = \frac{470}{F}$.

=

(a) Once the load is moving at a steady speed, the average horizontal frictional force acting on the load is 470 N.

Calculate the average value of F that will enable the load to move at constant speed.

520 .

$F = \frac{470N}{\cos 25^\circ} = 519$ (3 s.f.)

(b) The load is moved a horizontal distance of 2.5 km in 1.2 hours.

Calculate

(i) the work done on the load by the force F.

$W = F \cdot s = 470N \times 2.5 \times 10^3\ m = 1.175 \times 10^6\ J.$

(ii) the minimum average power required to move the load.

$P = \frac{W}{t} = \frac{1.175 \times 10^6\ J}{1.2 \times 60 \times 60\ s} = 272W$

(c) The athlete pulls the load uphill at the same speed as in part (a).

Explain, in terms of energy changes, why the minimum average power required is greater than in (b)(ii).

(b)(ii) is only friction, Gravity done no work.
uphill : gravity ↓. work done to overcome it.

3. This question is about momentum, energy and power.

(a) In his *Principia Mathematica* Newton expressed his third law of motion as "to every action there is always opposed an equal reaction". State what Newton meant by this law.

When A exerts a force on B, B exerts an equal and opposite force on A, know as normal reaction T.

(b) A book is released from rest and falls towards the surface of Earth. Discuss how the conservation of momentum applies to the Earth-book system.

Consider earth as stationary. w/ mass M. $\vec{v}_e = 0$.

book w/ mass m, $\vec{v}_b$

total $\vec{v}_b m + \vec{v}_e M = \vec{v}_b' m + \vec{v}_e' M$.

initial $\vec{P} = 0$. $\vec{v}_b m = \vec{v}_b m + \vec{v}_e' M$.

$\vec{P}$ book ↑.

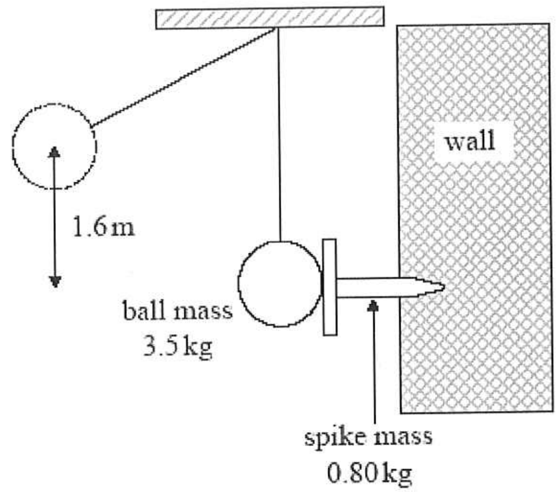
$\vec{v}_b m = \vec{v}_e' (m + M)$ as they stick together after collision.

$\vec{P}$ earth equal and opposite so

$\vec{v}_e' = \frac{\vec{v}_b m}{m+M}$ as $m \ll M$.

$\Rightarrow \frac{m}{m+M} \approx 0$. $\Rightarrow \vec{v}_e' \approx 0$.

(c) A large swinging ball is used to drive a horizontal iron spike into a vertical wall. The centre of the ball falls through a vertical height of 1.6 m before striking the spike in the position shown.



The mass of the ball is 3.5 kg and the mass of the spike is 0.80 kg. Immediately after striking the spike, the ball and spike move together. Show that the

(i) speed of the ball on striking the spike is 5.6 m s^{-1}.

$\Delta E_p + \Delta E_K = 0$. $-3.5\times10\times1.6 + \frac{1}{2}\cdot3.5\times v^2 = 0$.

$v^2 = 32$

(ii) energy dissipated as a result of the collision is about 10 J.

$\Delta \vec{P}$: $3.5\times5.6 = v\times4.3 \Rightarrow v = 4.56$ kgms^{-1} $v = 5.6$.

$\Delta \vec{E}$: ~~$\frac{1}{2}\,3.5\times5.6^2$~~

$\frac{1}{2}\times4.3\times4.56^2 - \frac{1}{2}3.5\times5.6^2 \approx \boxed{-10}$

(d) As a result of the ball striking the spike, the spike is driven a distance 7.3×10^{-2} m into the wall. Calculate, assuming it to be constant, the friction force F between the spike and wall.

$\Delta E_K = \frac{1}{2}4.3\times4.56^2 = W = 7.3\times10^{-2}\times F$.

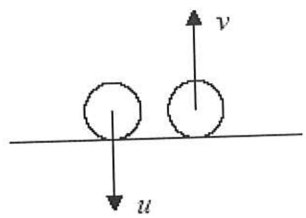
$F = 612$.

(e) The machine that is used to raise the ball has a useful power output of 18 W. Calculate how long it takes for the machine to raise the ball through a height of 1.6 m.

$t = \frac{W}{P} = \frac{3.5\times1.6}{18}$

$= 0.311$ s

4. A ball falls vertically and bounces off the ground. Immediately before impact with the ground the speed of the ball is u. Immediately after leaving the ground the speed is v.



Which of the following expressions is the ratio of $\dfrac{\text{kinetic energy lost on collision}}{\text{kinetic energy immediately before collision}}$?

A. $\dfrac{v}{u}$

B. $1-\dfrac{v}{u}$

C. $\left(\dfrac{v}{u}\right)^2$

D. $1-\left(\dfrac{v}{u}\right)^2$

$$\frac{\frac{1}{2}mv^2 - \frac{1}{2}mu^2}{\frac{1}{2}mu^2}$$

$$\frac{v^2-u^2}{u^2}$$

$$\frac{v^2}{u^2}-1$$

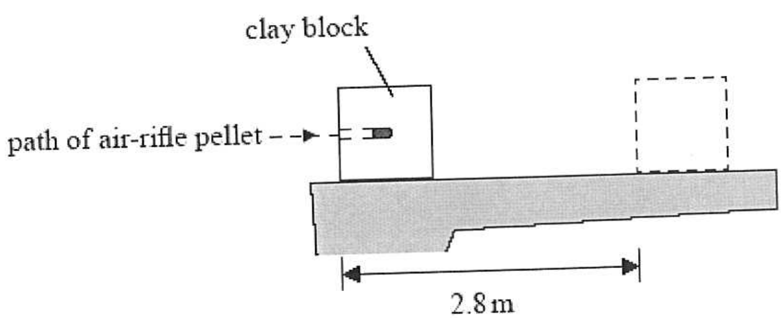
(Total 1 mark)

5. This question is about collisions.

(a) State the principle of conservation of momentum.

$\Delta\vec{P} = 0$ when external force $= 0N$.

(b) In an experiment, an air-rifle pellet is fired into a block of modelling clay that rests on a table.



(not to scale)

The air-rifle pellet remains inside the clay block after the impact.

2.8m →

As a result of the collision, the clay block slides along the table in a straight line and comes to rest. Further data relating to the experiment are given below.

Mass of air-rifle pellet	= 2.0 g
Mass of clay block	= 56 g
Velocity of impact of air-rifle pellet	= 140 m s^{-1}
Stopping distance of clay block	= 2.8 m

(i) Show that the initial speed of the clay block after the air-rifle pellet strikes it is 4.8 m s^{-1}.

$2\times\cancel{10^{-3}} \times 140\,ms^{-1} = 58\times\cancel{10^{-3}}\times \vec{v}$

$\vec{v} = 4.83$

(ii) Calculate the average frictional force that the surface of the table exerts on the clay block whilst the clay block is moving.

$E_K = \frac{1}{2}(58\times10^{-3})(4.83)^2 = W = f\times 2.8 \Rightarrow f = 0.24\,N$

(c) Discuss the energy transformations that occur in the clay block and the air-rifle pellet from the moment the air-rifle pellet strikes the block until the clay block comes to rest.

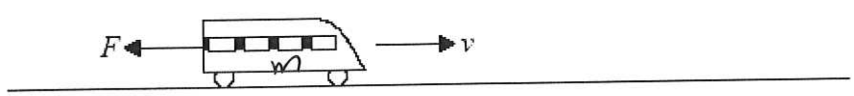
Ek pellet → E for pellet to go into the block + Ek ~~block~~ and pellet.
→ E ~~W~~ to overcome W done by friction.

(d) The clay block is dropped from rest from the edge of the table and falls vertically to the ground. The table is 0.85 m above the ground. Calculate the speed with which the clay block strikes the ground.

$u=0$
$s=0.85$
$a=10$
$v=?$

$v = \sqrt{2gh} = \sqrt{2\times10\times0.85} = 4.1\,m/s$ ↓

6. A railway engine of mass m moves along a horizontal track with uniform speed v. The total resistive force acting on the engine is F.



Which of the following is the power of the engine?

A. $\frac{F}{mv}$

B. Fv

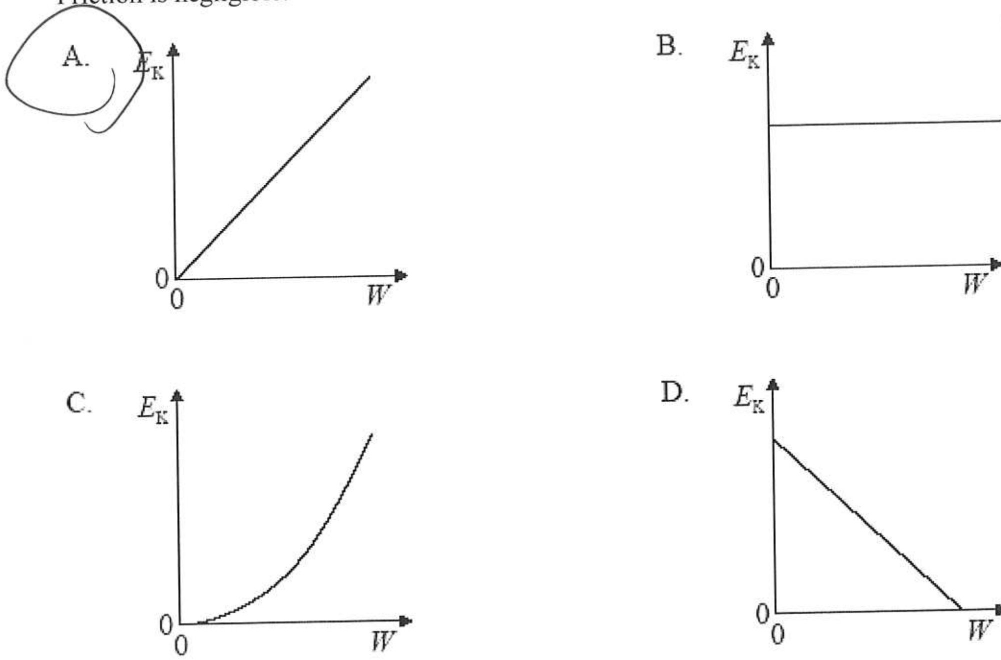
C. $\frac{mv}{F}$

D. $\frac{v}{F}$

$P = Fv.$

(Total 1 mark

7. A constant force acts on a mass that is initially at rest. Which of the following graphs best shows how the kinetic energy E_K of the mass changes with the work W done on the mass? Friction is negligible.



(Total 1 mark)

Mechanical power

8.

(a) Define *power*.

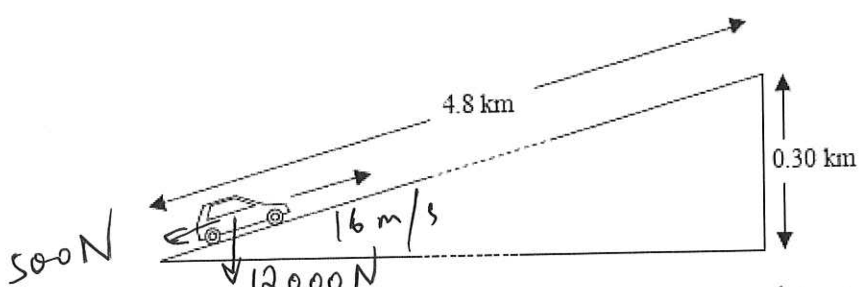
$P = \frac{W}{t}$ rate of work is done.

(b) A car is travelling with constant speed v along a horizontal straight road. There is a total resistive force F acting on the car.

Deduce that the power P to overcome the force F is $P = Fv$.

$F' = F. \Rightarrow P = \frac{W}{t} = \frac{F' \cdot s}{t} = F' \cdot v = F v.$

(c) 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.

$t = \frac{s}{v} = \frac{4.8 \times 10^3 \text{ m}}{16} = 300 \text{ s}.$

(2)

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

$W = \Delta E_p = 12000 \text{ N} \times 0.3 \times 10^3 \text{ m}$

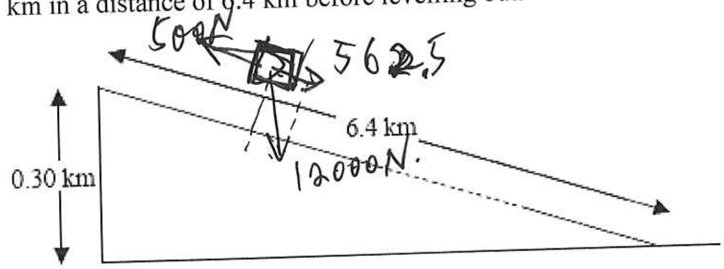
$= 3.6 \times 10^6 \text{ J}$

(1)

(iii) Using your answers to (c)(i) and (c)(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.

$P = \frac{W}{t} = \frac{3.6 \times 10^6 \text{ J}}{300 \text{ s}} = 1.2 \times 10^4 \text{ W}.$

(d) 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 (c), 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.

$a = \frac{F}{m} = \frac{62.5\ N}{1200\ kg}$

$= 0.052\ N kg^{-1}$

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

$\Delta E_K = \Delta E_P$

$\frac{1}{2}(1200)(v^2) = 12000 \times 0.3 \times 10^{-3}$ **(2)**

$v^2 = 3 \times 10^{-3} \times 2.$

$= 6 \times 10^{-3}.$

$v = 0.077$

(e) 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 18 marks)