WORK, ENERGY & POWER

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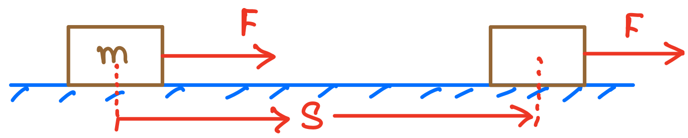
Work:-

Def. Product of force and displacement travelled in the direction of force.

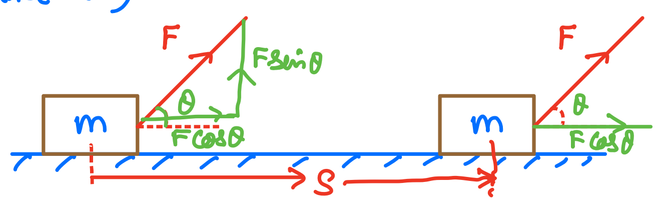
Symbol: W

Formula (i) $W = (F)(S)$



(ii) If Force F makes an angle 'θ' with displacement S

W = (Component of force along displacement)(Displacement)



$W = (F\cos\theta)(S)$

$$\boxed{W = FS\cos\theta}$$

P.S. Scalar

Units $Nm = (kg\,m\,s^{-2})(m) = kg\,m^2 s^{-2} = \text{Joule (J)}$

Note: $W = FS\cos\theta$

(i) If $\theta = 0^\circ$ ie $\cos 0 = 1 \Rightarrow W = (F)(S)$ i.e. work is done by the force.

(ii) If $\theta = 180^\circ$ ie $\cos 180 = -1 \Rightarrow W = (-F)(S)$ i.e work is done against a force

(iii) If $\theta = 90^\circ$ ie $\cos 90 = 0 \Rightarrow W = 0$

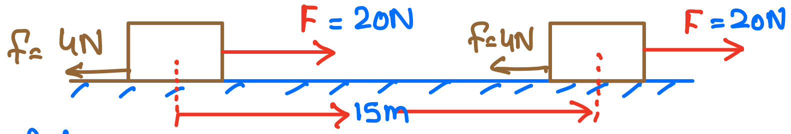
ie no work is done on an object as its weight and displacement are not parallel to each other.

Dependance :- $W = (F)(S)$

(i) Dependance on Force :-

Case 1: Work done by a Constant force :-

Ex.1 :



(a) Calculate

(i) work done by an applied force

$W = (F)(S) = (20)(15) = 300J$

(ii) work done against friction

$W = (f)(S) = (4)(15) = 60J$

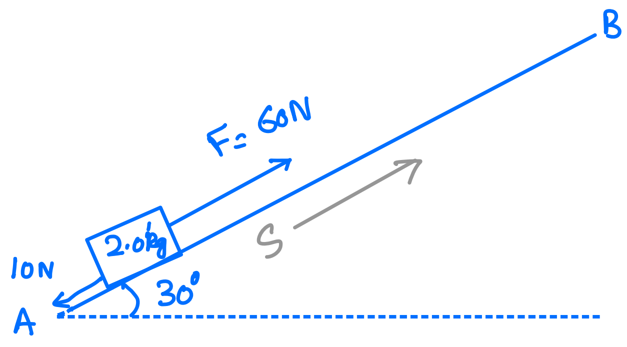
(iii) work done by a resultant force.

$W = (F-f)(S) = (20-4)(15) = 240J$

(b) What happen to the energy of block as a result of resultant work done on it.

Kinetic energy of block increases

Ex.2 :



Length of AB track = 80m

Calculate

(i) Work done by an applied.

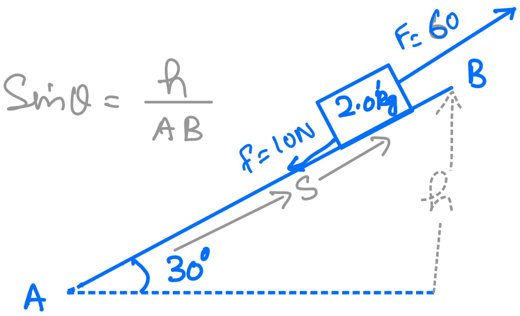
$W = (F)(S) = (60)(80) = 4800 J$

(ii) Work done against frictional force

$$W = (f)(s) = (10)(80) = 800J$$

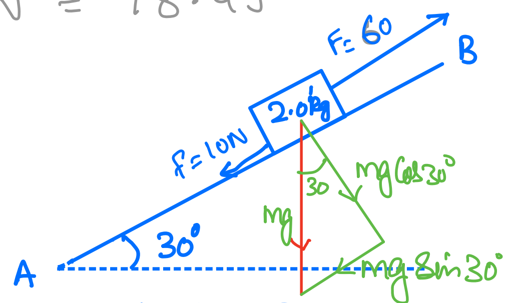
(iii) Work done against Gravitational pull of Earth

$\sin\theta = \frac{h}{AB}$



$$W = \text{Gain of G.P.E}$$
$$= mgh$$
$$= mg(s \sin\theta)$$
$$W = (2.0)(9.81)(80 \sin 30)$$
$$W = 78.4J$$

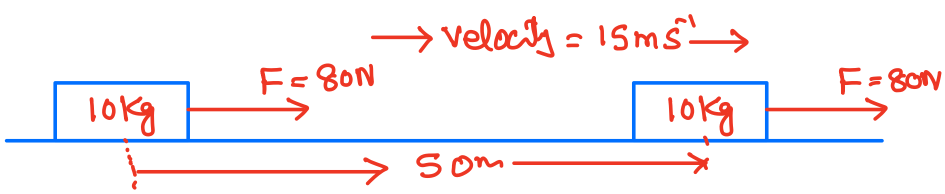
$$W = (mg\sin\theta)(s)$$
$$= (2.0)(9.8)(\sin 30)(80)$$
$$= 78.4J$$



(iv) Work done by a resultant force.

$$W = [F - (f + mg\sin 30)][s]$$
$$= [60 - (10 + (2.0)(9.81)(0.5))][80]$$
$$= 3922J$$

Q)

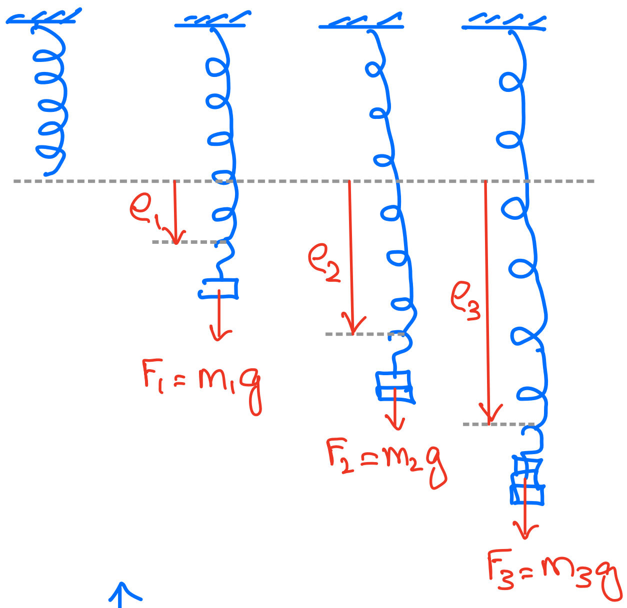


What is the resultant work done?

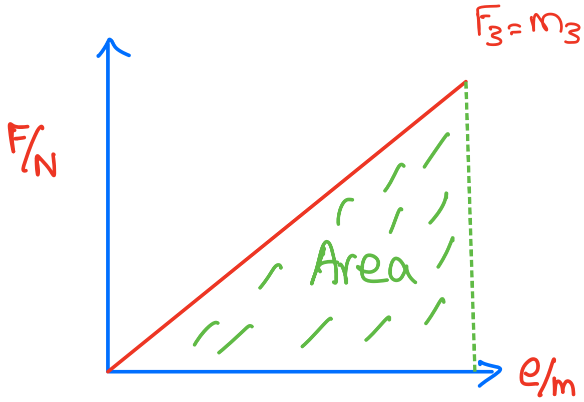
Zero because resultant force is zero due to constant momentum ie constant mass and constant velocity.

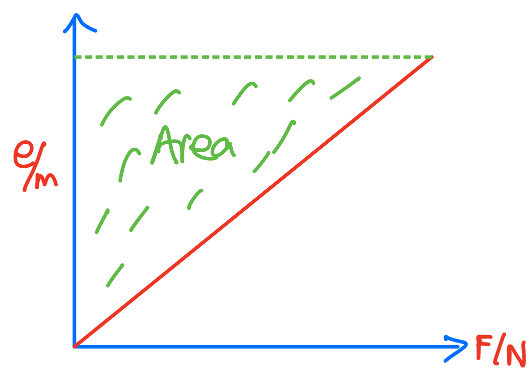
Case 2: Work done by a variable force:-

Ex. 1: Work done to stretch a spring / Gain of Elastic potential energy / strain energy:-



Since both force/weight and displacement/extension in the direction of force vary, so a graph is plotted in between them.





W = Area of F/N - e/m graph along with e/m axis

$$W = \frac{1}{2}(F)(e)$$

But $F = Ke$

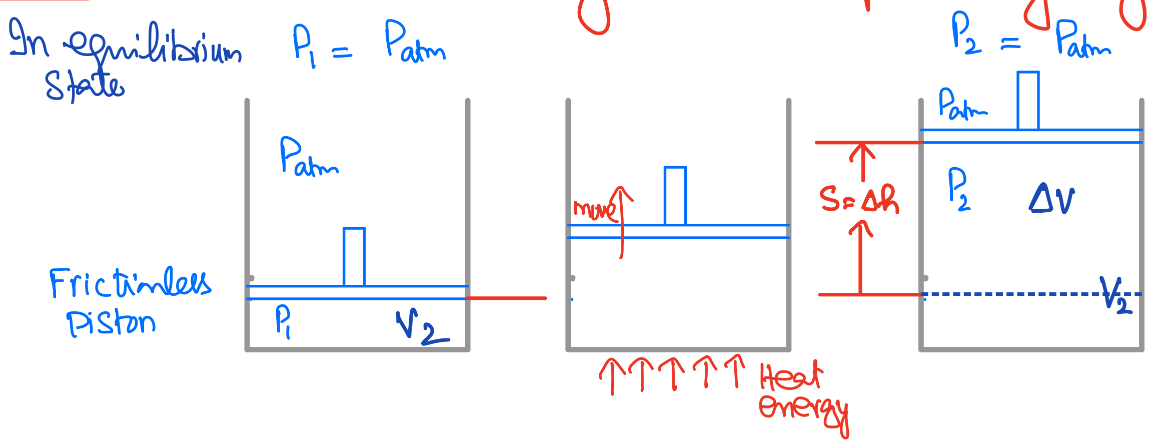
$$W = \frac{1}{2}(Ke)(e)$$

$$W = \frac{1}{2}(Ke^2)$$

$$W = \frac{1}{2}(F)\left(\frac{F}{K}\right)$$

$$W = \frac{F^2}{2K}$$

Ex.2: Work done by an escpanding gas :-



$P_1 = P_{atm} = P_2 \Rightarrow P_1 = P_2$

$\Delta P = P_1 - P_2 = 0$ ie no change of pressure

$$W = (F)(S)$$

$$= (PA)(\Delta h) = P(A\,\Delta h)$$

$$\boxed{W = P\,\Delta V}$$

Note:

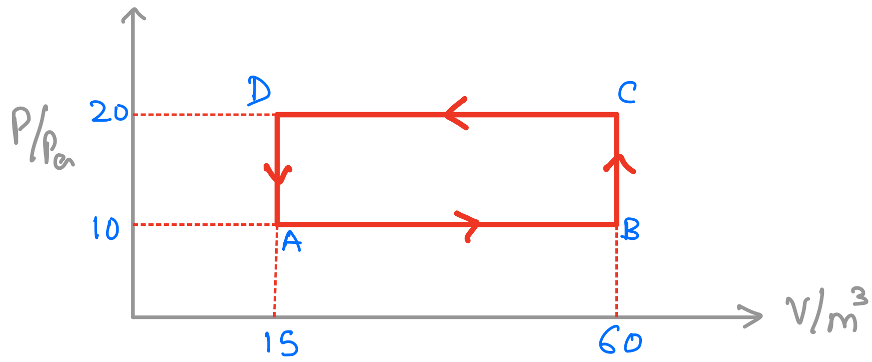
(1) Work done $= 0$ if volume is constant and pressure vary.

(2) If Volume of gas

(i) increases then work is done BY the gas and this decreases the internal energy or temperature of gas particles.

(ii) decreases then work is ON the gas and this increases internal energy or temperature of gas.

Q) A gas undergoes a cyclic process as shown.



(a) Calculate work done

(i) on the gas

$W_{ON} = P\Delta V$
$= (20)(60-15)$
$= 900J$

$W =$ Area under CD graph
$= (20)(60-15)$
$= 900J$

(ii) By the gas

$W_{BY} = P\Delta V$
$= (10)(60-15)$
$= 450J$

$W =$ Area under AB graph
$= (10)(60-15)$
$= 450J$

(b) Why no work is done in path BC and CD?

because volume is constant and pressure vary.

(c) Calculate resultant work done ON the gas

$W = W_{ON} - W_{BY}$
$= 900 - 450$
$= 450J$

$W =$ Area of ABCD
$= (20-10)(60-15)$
$= 450J$

(d) What happens to the temperature of gas as a resultant of net work done ON it?

temperature increases.

Energy:-

Def. Ability or capacity of an object to do work.

Symbol: E , Q , U

Units: $Nm = kg\,m^2 s^{-2} = \text{Joule (J)}$

P.S: Scalar

Types:

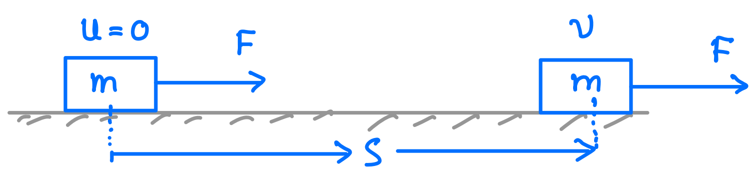
1 - Kinetic energy:-

Def. Ability of an object to do work due to its motion is kinetic energy.

Symbol: E_K (K.E.)

Formula $E_K = \frac{1}{2}mv^2$, m - mass of object, v - velocity " "

Proof:



Suppose an object of mass m initially at rest. A force F brings it in state of motion and it travel a displacement s with uniform acceleration a and final velocity becomes v.

$$W = (F)(S) \quad \text{------(1)}$$

But $F = ma$ ....(2)

Also $2as = v^2 - u^2$

$$2as = v^2 - (0)^2 \Rightarrow S = \frac{v^2}{2a} \quad \text{------(3)}$$

Therefore eq. (1) becomes as

$$W = (m\cancel{a})\left(\frac{v^2}{2\cancel{a}}\right)$$

$$W = \frac{1}{2} m v^2$$

This work done becomes the kinetic energy of the object by work-energy principle.

$$\boxed{E_K = \frac{1}{2} m v^2}$$

Potential energy :-

Potential → Position in a field of force

energy → Ability to do work

Def Ability of a body to do work due to change of its position in a field of force.

Symbol E_p (P.E.)

Types :
- → Gravitational E_p
- → Electric potential energy
- → Strain / elastic potential energy

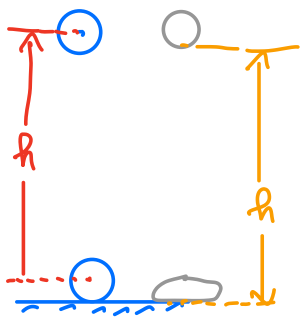
Gravitational potential energy:-

Def. Ability of a mass to do work due to change of its position in an attractive field of a planet/ Earth.

Symbol : E_p or $G\,E_p$ (GPE)

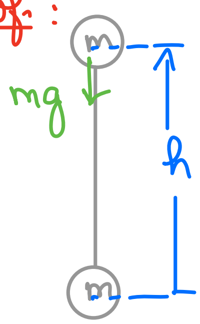
Formula : $E_p = mgh$

Here
- m – mass of object
- g – Gravitational field strength
- h – Height from surface of planet



Note: height h is taken from surface of Earth to the
(i) Centre of object for rigid object
(ii) Lower surface of object because it C.G. changes due to contact on hitting the ground.

Proof:



Suppose an object of mass m is raised to a height h.

Work done = (F)(d)

Here F = mg and d = h

So

$$W = (mg)(h) \Rightarrow W = mgh$$

This work done becoms the potential energy of object by work-energy principle.

$$\boxed{E_p = mgh}$$

Electric potential energy:- Ability of a charged particle to do work
- in the electric field of another charged object
- due to change of position

Formula:-

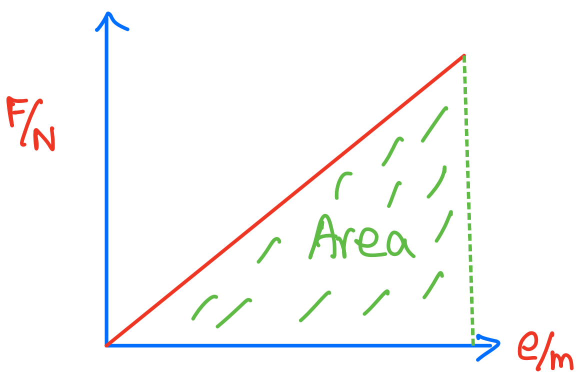
$$V = \frac{W}{q} \Rightarrow \boxed{W = E_p = Vq}$$

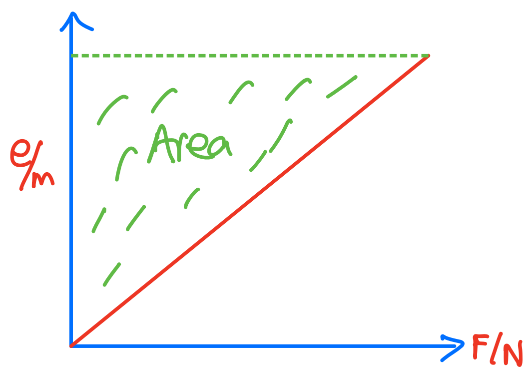
Here V - p.d., q - charge on object

Elastic potential energy:- (Strain energy)

Ability of a solid to do work due to change of its position from its normal/original position.

Formula. E_p = Area under F/N - e/m graph





W = Area of F/N - e/m graph along with e/m axis

$$W = \frac{1}{2}(F)(e)$$

But $F = Ke$

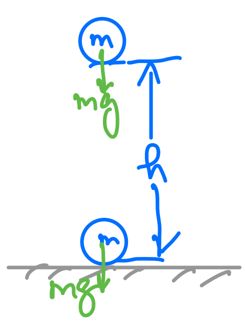
$$W = \frac{1}{2}(Ke)(e)$$

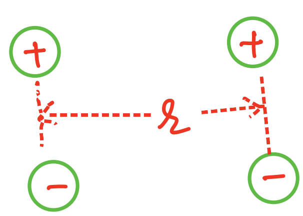
$$W = \frac{1}{2}(Ke^2)$$

$$W = \frac{1}{2}(F)\left(\frac{F}{K}\right)$$

$$W = \frac{F^2}{2K}$$

Note :- (P.E) ↑ if work is done against a force:





Principle of Conservation of energy:-

Statement: Energy can neither be created nor be destroyed but can change its forms but the total energy of the system remain conserved.

Note:

(1) $E_p \uparrow$ if work is done against a force.

(2) $E_K \downarrow$ if work is done against motion and this energy is converted into heat / internal energy.

Power:

Def. Work done or energy transferred per unit time is Power.

Symbol: P

Formula: (i) $P = \frac{W}{t}$

(ii) $P = F\left(\frac{S}{t}\right) \Rightarrow \boxed{P = Fv}$ Here F - Forward or Drag force. v - Uniform velocity

(iii) $P = \frac{mgh}{t}$

(iv) $P = \frac{\frac{1}{2}mv^2}{t}$

Units: Watt (W) $1\text{ Watt} = \frac{1\text{ Joule}}{1\text{ second}}$

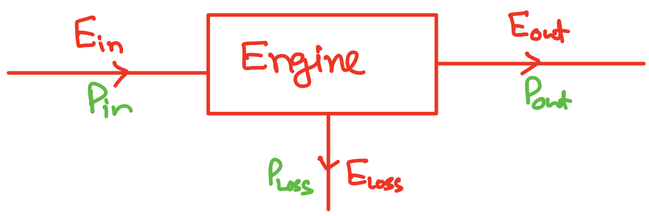
P.S. Scalar

Efficiency:

Def: Ratio of useful energy output (Power output) to total energy input (Power input) is efficiency.

Symbol: η (eata)

Formula:



$$\eta = \frac{E_{out}}{E_{in}} \times 100$$

or $$\eta = \frac{P_{out}}{P_{in}} \times 100$$

Units:- No units because it is the ratio between two similar quantities but normally it is represented interms of percentage.

P.S. Scalar

WORK, ENERGY & POWER (Page 1)

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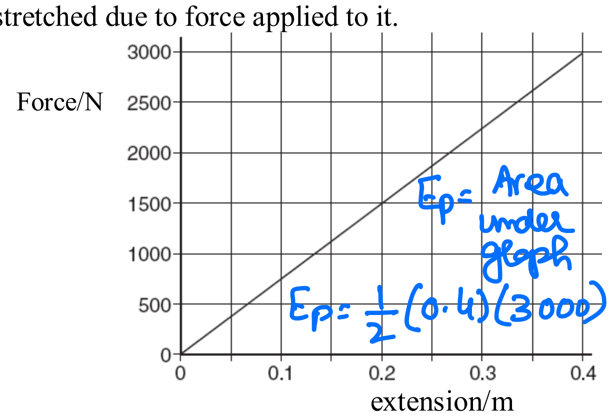
1. A mass is raised vertically. In time t, the increase in its gravitational potential energy is E_p and the increase in its kinetic energy is E_k.
What is the average power input to the mass?
A $(E_p - E_k)t$ **B** $(E_p + E_k)t$
C $(E_p + E_k)/t$ **D** $(E_p - E_k)/t$

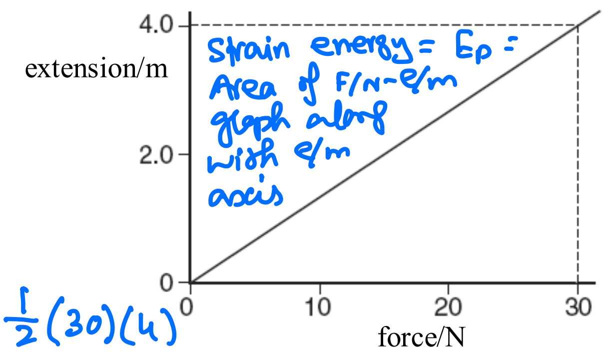
2. A boat moving at constant speed v through still water experiences a total frictional drag F.
What is the power developed by the boat?
A $(1/2)Fv$ **B** Fv **C** $(1/2)Fv^2$ **D** Fv^2

3. The graph shows how a spring is gradually stretched due to force applied to it.



What is the potential energy stored in the spring?
A 1.2 kJ **B** 15 kJ **C** 0.6 kJ **D** 0.24kJ

4. The graph shows how the extension of a spring varies with the force used to stretch it.



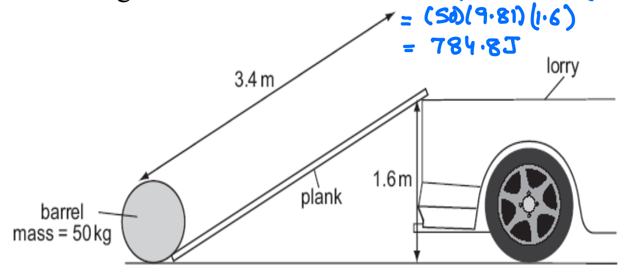
What is the strain energy stored in the spring when the extension is 4.0 cm?
A 60 J **B** 120 J **C** 600 J **D** 1200 J

5. What is the expression used to define power?
A input energy / output energy
B energy x time taken
C force x velocity
D taken time / done work

6. A ball is thrown vertically upwards. Neglecting air resistance, which statement is correct?
A The kinetic energy of the ball is greatest at the greatest height attained.
B By the principle of conservation of energy, the total energy of the ball is constant throughout its motion.
C By the principle of conservation of momentum, the momentum of the ball is constant throughout its motion.
D The potential energy of the ball increases uniformly with time during the ascent.

7. Car X is travelling at half the speed of car Y. Car X has twice the mass of car Y.
Which statement is correct?
A Car X has half the kinetic energy of car Y.
B Car X has one quarter of the kinetic energy of car Y.
C Car X has twice the kinetic energy of car Y.
D The two cars have the same kinetic energy.

8. A barrel of mass 50 kg is loaded onto the back of a lorry 1.6 m high by pushing it up a smooth plank 3.4 m long.



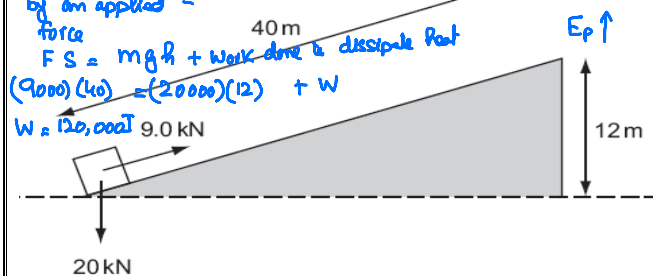
What is the minimum work done?
A 80 J **B** 170 J **C** 780 J **D** 1700 J

9. The kinetic energy of a particle is increased by a factor of 4.
By what factor does its speed increase?
A 2 **B** 4 **C** 8 **D** 16

10 A horizontal force of 90 N is used to push a box across a horizontal floor. The frictional force on the box is 50 N.
What is the gain in kinetic energy of the box when it is moved through a distance of 6.0 m?
A 240 J **B** 300 J **C** 540 J **D** 840 J

11 A cyclist is capable of generating an average power of 3.0 kW during a 4.0 km speed trial. His aerodynamic suit and position on the cycle reduce resistive forces to 180 N.
What is the approximate time achieved in the speed trial?
A 140 s **B** 240 s **C** 1300 s **D** 2200 s

12 A constant force of 9.0 kN, parallel to an inclined plane, moves a body of weight 20 kN through a distance of 40 m along the plane at constant speed. The body gains 12 m in height, as shown.



How much of the work done is dissipated as heat?
A 120 kJ **B** 240 kJ **C** 360 kJ **D** 600 kJ

13 A concrete cube of side 0.50 m and uniform density 2.0×10^3 kg m^{-3} is lifted 3.0 m vertically by a crane.
What is the change in potential energy of the cube?
A 0.75 kJ **B** 7.4 kJ **C** 29 kJ **D** 470 kJ

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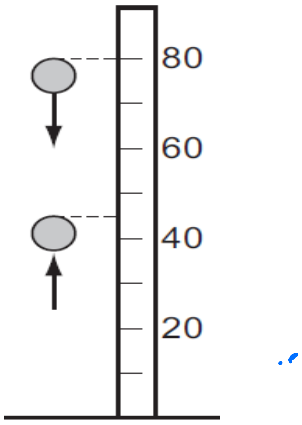
14. A solid rubber ball has a diameter of 8.0 cm. It is released from rest with the top of the ball 80 cm above a horizontal surface. It falls vertically and then bounces back up so that the maximum height reached by the top of the ball is 45 cm, as shown.



If the kinetic energy of the ball is 0.75 J just before it strikes the surface, what is its kinetic energy just after it leaves the surface?

A 0.36 J **B** 0.39 J **C** 0.40 J **D** 0.42 J

B{Q. 17/June 2013/11}

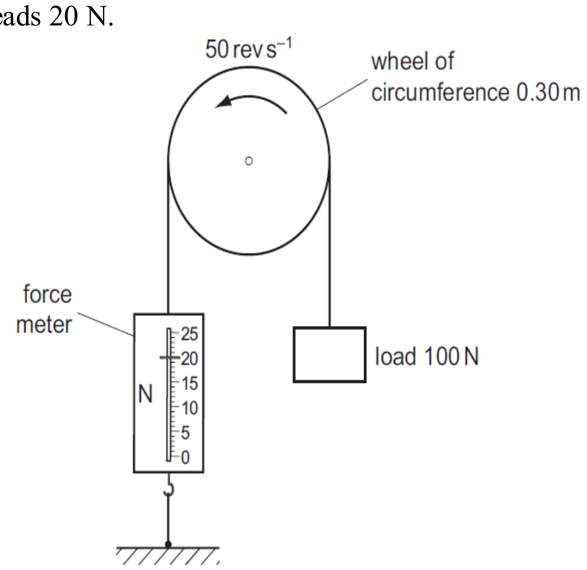
15. A wind turbine has blades that sweep an area of 2000 m^2. It converts the power available in the wind to electrical power with an efficiency of 50%. What is the electrical power generated if the wind speed is 10 m s^{-1}? (The density of air is 1.3 kg m^{-3}.)

A 130 kW **B** 650 kW **C** 1300 kW **D** 2600 kW

B{Q. 18/June 2013/11}

16. The diagram shows a wheel of circumference 0.30 m. A rope is fastened at one end to a force meter. The rope passes over the wheel and supports a freely hanging load of 100 N. The wheel is driven by an electric motor at a constant rate of 50 revolutions per second.

When the wheel is turning at this rate, the force meter reads 20 N.



What is the output power of the motor?

A 0.3 kW **B** 1.2 kW **C** 1.8 kW **D** 3.8 kW

B{Q. 19/June 2013/11}

17. A ball is thrown vertically upwards.

Neglecting air resistance, which statement is correct?

A The kinetic energy of the ball is greatest at the greatest height attained.

B By the principle of conservation of energy, the total energy of the ball is constant throughout its motion.

C By the principle of conservation of momentum, the momentum of the ball is constant throughout its motion.

D The potential energy of the ball increases uniformly with time during its ascent.

B{Q. 15/June 2013/12}

18. A bow of mass 400 g shoots an arrow of mass 120 g vertically upwards. The potential energy stored in the bow just before release is 80 J. The system has an efficiency of 28%.

What is the height reached by the arrow when air resistance is neglected?

A 4 m **B** 19 m **C** 187 m **D** 243 m

B{Q. 16/June 2013/12}

19. A train on a mountain railway is carrying 200 people of average mass 70 kg up a slope at an angle of 30° to the horizontal and at a speed of 6.0 m s^{-1}. The train itself has a mass of 80 000 kg.

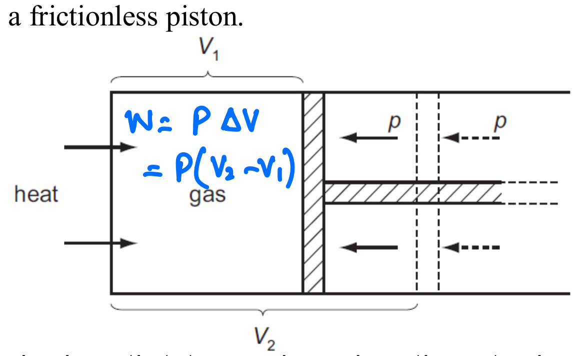
The percentage of the power from the engine which is used to raise the passengers and the train is 40 %.

What is the power of the engine?

A 1.1 MW **B** 2.8 MW **C** 6.9 MW **D** 14 MW

C{Q. 17/June 2013/12}

20. A gas is enclosed inside a cylinder which is fitted with a frictionless piston.



...ibrium
heated slowly so that it expands, pushing the piston back until the volume of the gas has increased to V_2.

How much work is done by the gas during this expansion?

A $p(V_2 - V_1)$ **B** $p(V_2 - V_1) / 2$
C $p(V_2 + V_1)$ **D** $p(V_2 + V_1) / 2$

A{Q. 18/June 2013/12}

21. A railway engine accelerates a train of total mass 800 tonnes (1 tonne = 1000 kg) from rest to a speed of 50 m s^{-1}. How much work must be done on the train to reach this speed?

A 1.0×10^6 J **B** 2.0×10^6 J
C 1.0×10^9 J **D** 2.0×10^9 J

C{Q. 20/Nov 2012/11}

22. The force resisting the motion of a car is taken as being proportional to the square of the car's speed. The magnitude of the force at a speed of 20 m s^{-1} is 800 N. What effective power is required from the car's engine to maintain a steady speed of 40 m s^{-1}?

A 32 kW **B** 64 kW **C** 128 kW **D** 512 kW

C{Q. 17/June 2012/11}

23. What is the internal energy of an object?

A It is the energy associated with the object's movement through space.

B It is the energy associated with the random movement of the molecules in the object.

C It is the energy due to the attractions between the molecules in the object.

D It is the sum of all the microscopic potential and kinetic energies of the molecules in the object.

D{Q. 19/June 2012/11}

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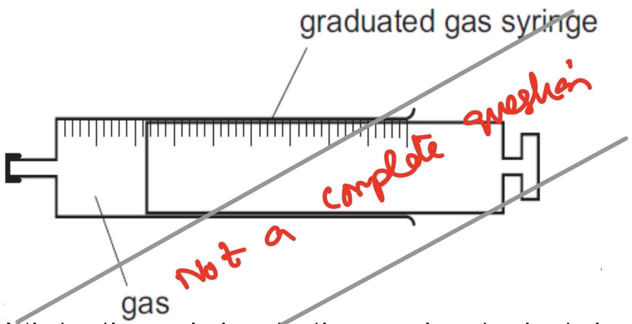
24. A gas is contained inside a sealed syringe, as shown.

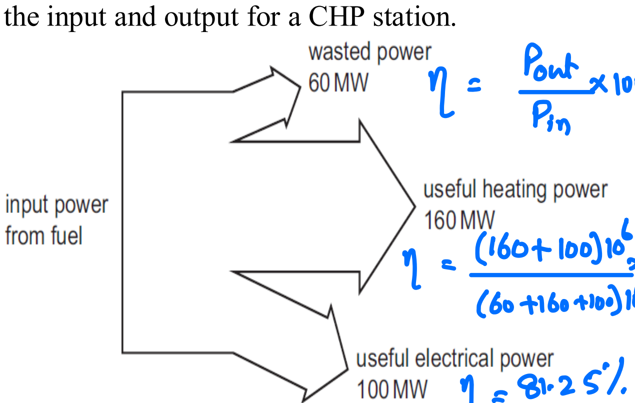


What is the work done by the gas when it is heated and expands to a volume of 6.0 cm3?

A 404μJ **B** 404mJ **C** 404J **D** 404kJ

{Q.15/ Nov 2015/variant 11}

25. A combined heat and power (CHP) station generates electrical power and useful heat. The diagram shows the input and output for a CHP station.



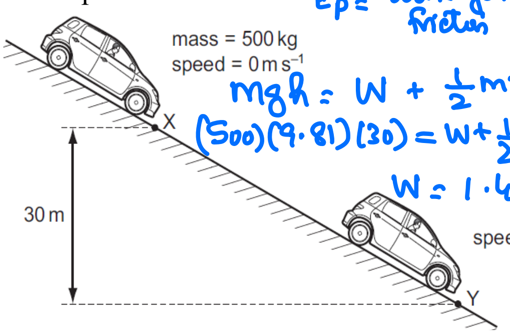
What is the efficiency of the CHP station for producing useful power?

A 31% **B** 38% **C** 50% **D** 81%

{Q.16/ Nov2015/variant 11}

26. A car of mass 500 kg is at rest at point X on a slope, as shown.

The car's brakes are released and the car rolls down the slope with its engine switched off. At point Y the car has moved through a vertical height of 30 m and has a speed of 11 m s^{-1}.



What is the energy dissipated by frictional forces when the car moves from X to Y?

A 3.0×10^4 J **B** 1.2×10^5 J
C 1.5×10^5 J **D** 1.8×10^5 J

{Q.16/ Nov2015/variant 12}

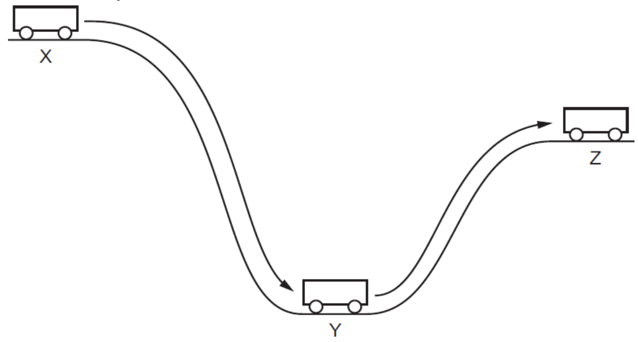
27. In which situation is no work done?

A The air in a bicycle tyre is released because of a puncture.
B A ball is dropped and falls to the ground.
C A box moves at constant speed across a smooth horizontal surface.
D A crane lifts a steel girder at constant speed.

{Q.17/ Nov2015/variant 12}

A uniform solid block has weight 500 N, width 0.4 m and height 0.6 m. The block rests on the edge of a

28. A trolley starts from rest at X. It rolls down to Y and eventually comes to rest at Z.



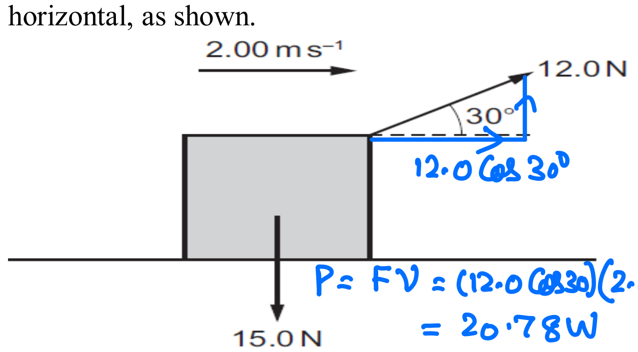
Which row is a possible summary of the energy changes during this process?

	X to Y	Y to Z
A	p.e. → k.e.	k.e. → p.e.
B	p.e. → k.e.	k.e. → p.e. + heat
C	p.e. → k.e. + heat	k.e. → p.e.
D	p.e. → k.e. + heat	k.e. → p.e. + heat

key
p.e. = potential energy
k.e. = kinetic energy

{Q.16/ Nov2015/variant 13}

29. An object of weight 15.0 N is pulled along a horizontal surface at a constant velocity of 2.00 m s^{-1}. The force pulling the object is 12.0 N at 30° to the horizontal, as shown.



What is the power used to move the object?

A 12.0W **B** 20.8W **C** 24.0W **D** 30.0W

{Q.17/ Nov2015/variant 13}

30. A team of nine dogs can pull a sledge with a combined force of 800 N at a speed of 1.5 m s^{-1} for 360 minutes. What is the average work done by each dog during this time?

A 4.8×10^4 J **B** 4.3×10^5J
C 2.9×10^6J **D** 2.6×10^7J

{Q.16/ June 2015/variant 11}

31. Which statement is correct?

A A ball lands on the ground and bounces. The kinetic energy changes sign, because the ball changes direction.
B A car drives up a slope at a steady speed. The power generated by the engine equals the potential energy gained per unit time.
C An electric heater can be 100% efficient.
D It is impossible for momentum to be conserved in a collision

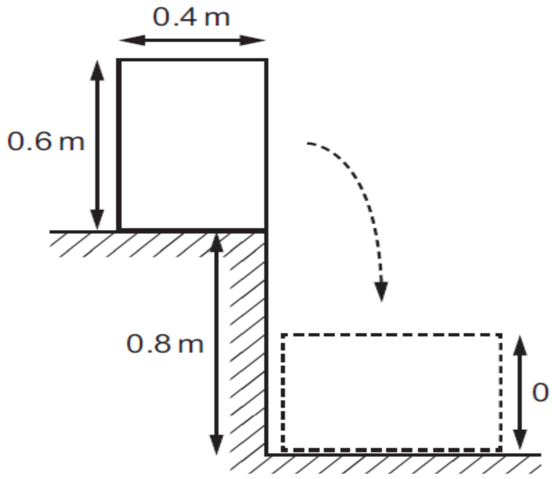
{Q.17/ June2015/variant 11}

32. A conveyor belt is driven at velocity v by a motor. Sand drops vertically on to the belt at a rate of m kg s^{-1}. What is the additional power needed to keep the conveyor belt moving at a steady speed when the sand starts to fall on it?

A (1/2) mv **B** $m v$ **C** (1/ 2) mv **D** mv

{Q.17/ June2015/variant 11}

33. step of depth 0.8 m, as shown.



The block is knocked over the edge of the step and rotates through 90° before coming to rest with the 0.6 m edge horizontal.
What is the change in gravitational potential energy of the block?

A 300 J **B** 400 J **C** 450 J **D** 550 J

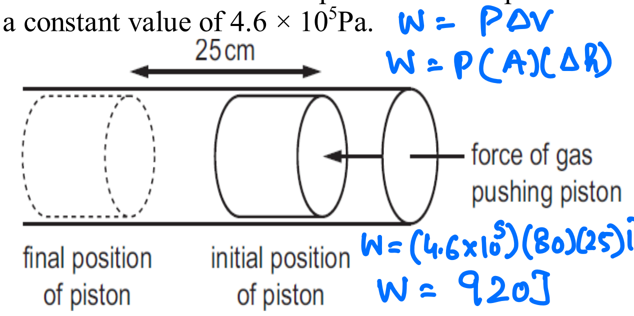
{*Q.15/ June2015/variant 12*}

34. A fisherman lifts a fish of mass 250 g from rest through a vertical height of 1.8 m. The fish gains a speed of 1.1 m s^{-1}.
What is the energy gained by the fish?

A 0.15 J **B** 4.3 J **C** 4.4 J **D** 4.6 J

{*Q.17/ June2015/variant 12*}

35. The gas in an engine does work on a piston of cross-sectional area 80 cm^2. The pressure on the piston has a constant value of 4.6×10^5 Pa.



How much work is done by the gas on the piston when it moves through a distance of 25 cm?

A 9.2×10^2 J **B** 9.2×10^4 J
C 9.2×10^6 J **D** 9.2×10^8 J

{*Q.17/ June2015/variant 13*}

36. A loaded aeroplane has a total mass of 1.2×10^5 kg while climbing after take-off. It climbs at an angle of 23° to the horizontal with a speed of 50 m s^{-1}. What is the rate at which it is gaining potential energy at this time?

A 2.3×10^6 J s^{-1} **B** 2.5×10^6 J s^{-1}
C 2.3×10^7 J s^{-1} **D** 2.5×10^7 J s^{-1}

{*Q.18/ June2015/variant 13*}

37. When a horizontal force F is applied to a frictionless trolley over a distance s, the kinetic energy of the trolley changes from 4.0 J to 8.0 J. If a force of 2*F* is applied to the trolley over a distance of 2s, what will the original kinetic energy of 4.0 J become?

A 16 J **B** 20 J **C** 32 J **D** 64 J

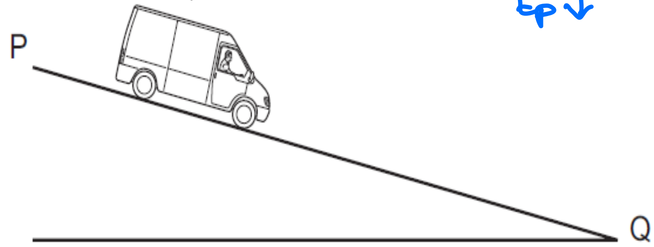
{*Q.19/ June 2015/variant 13*}

38. A projectile is launched at 45° to the horizontal with initial kinetic energy *E*. Assuming air resistance to be negligible, what will be the kinetic energy of the projectile when it reaches its highest point?

A 0.50*E* **B** 0.71*E* **C** 0.87*E* **D** *E*

{*Q.16/ Nov2014/variant 11*}

39. A van driver adjusts the force on a van's brakes so that the van travels at constant speed down a hill from P to Q.

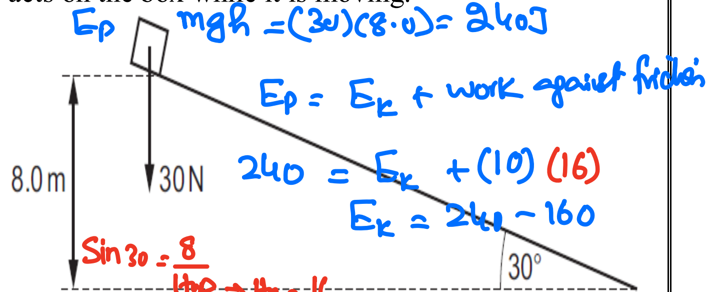


The magnitude of the change in the van's kinetic energy is ΔE_k. The magnitude of the change in its gravitational potential energy is ΔE_p.
Which statement is correct?

A $\Delta E_k > \Delta E_p$ **B** $\Delta E_k = \Delta E_p$
C $\Delta E_p > \Delta E_k > 0$ **D** $\Delta E_k = 0$

{*Q.19/ Nov.2014/variant 13*}

40. A box of weight 30 N is released from rest on a ramp that is at an angle of 30° to the horizontal. The box slides down the ramp so that it falls through a vertical distance of 8.0 m. A constant frictional force of 10 N acts on the box while it is moving.

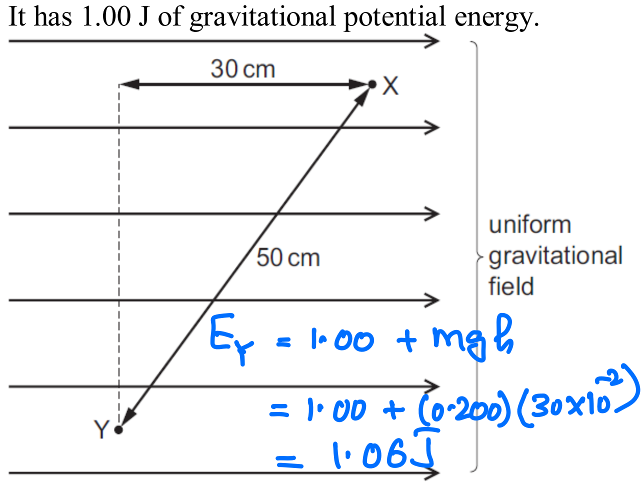


What is the kinetic energy of the box after falling through this distance?

A 80J **B** 160J **C** 240J **D** 400J

{*Q.17/ Nov.2014/variant 13*}

41. A mass at point X inside a uniform gravitational field experiences a gravitational force of 0.200 N.
It has 1.00 J of gravitational potential energy.



The mass is then moved to point Y.
What is its new gravitational potential energy?

A 0.90J **B** 0.94J **C** 1.06J **D** 1.10J

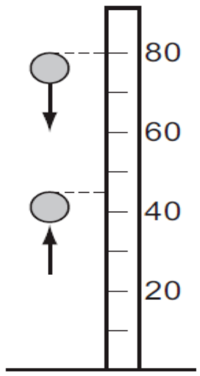
{*Q.14/ June2014/variant 12*}

42. A ball drops onto a horizontal surface and bounces elastically. What happens to the kinetic energy of the ball during the very short time that it is in contact with the surface?

A Most of the kinetic energy is lost as heat and sound energy.
B The kinetic energy decreases to zero and then returns to its original value.
C The kinetic energy remains constant because it is an elastic collision.
D The kinetic energy remains constant in magnitude but changes direction.

{*Q.18/ June2014/variant 13*}

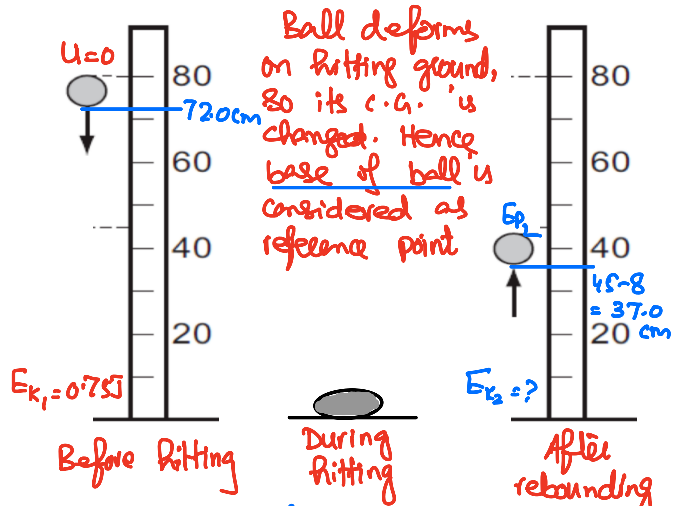
(14) A solid rubber ball has a diameter of 8.0 cm. It is released from rest with the top of the ball 80 cm above a horizontal surface. It falls vertically and then bounces back up so that the maximum height reached by the top of the ball is 45 cm, as shown.



If the kinetic energy of the ball is 0.75 J just before it strikes the surface, what is its kinetic energy just after it leaves the surface?

A 0.36 J **B** 0.39 J **C** 0.40 J **D** 0.42 J

***B**{Q. 17/June 2013/11}*



By Principle of Conservation of energy

$$\frac{E_{K_2}}{E_{K_1}} = \frac{E_{P_2}}{E_{P_1}} \Rightarrow \frac{E_{K_2}}{E_{K_1}} = \frac{mg\,h_2}{mg\,h_1}$$

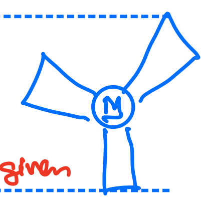
$$\frac{E_{K_2}}{0.75} = \frac{37.0}{72.0} \Rightarrow E_{K_2} = 0.385\,J$$

(15) A wind turbine has blades that sweep an area of 2000 m^2. It converts the power available in the wind to electrical power with an efficiency of 50%. What is the electrical power generated if the wind speed is 10 m s^{-1}? (The density of air is 1.3 kg m^{-3}.)

A 130 kW **B** 650 kW **C** 1300 kW **D** 2600 kW

***B**{Q. 18/June 2013/11}*

$A = 2000 m^2$
$\eta = 50\%$
P_{out} = ?
P_{in} = FV = given



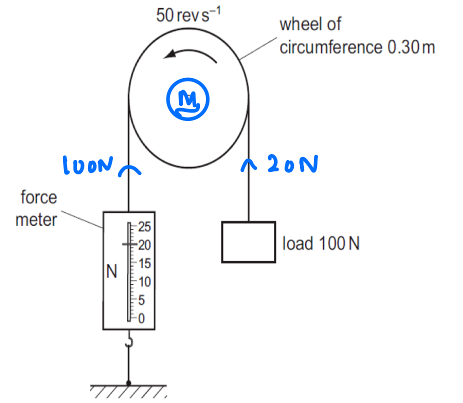
$$\eta = \frac{P_{out}}{P_{in}} \Rightarrow \eta = \frac{P_{out}}{\frac{\frac{1}{2}mv^2}{t}}$$

$$\frac{50}{100} = \frac{P_{out}}{\frac{\frac{1}{2}(\rho V)v^2}{t}} \Rightarrow \frac{50}{100} = \frac{P_{out}}{\frac{1}{2}\rho(A)(\frac{L}{t})v^2} \Rightarrow \frac{50}{100} = \frac{P_{out}}{\frac{1}{2}(\rho)(A)(v)(v^2)}$$

$$\frac{50}{100} = \frac{P_{out}}{\frac{1}{2}(\rho)(A)(v^3)} \Rightarrow 0.5 = \frac{P_{out}}{\frac{1}{2}(1.3)(2000)(10)^3}$$

$$P_{out} = 650,000\,W$$

Q.16) The diagram shows a wheel of circumference 0.30 m. A rope is fastened at one end to a force meter. The rope passes over the wheel and supports a freely hanging load of 100 N. The wheel is driven by an electric motor at a constant rate of 50 revolutions per second.
When the wheel is turning at this rate, the force meter reads 20 N.



What is the output power of the motor?

A 0.3 kW **(B)** 1.2 kW **C** 1.8 kW **D** 3.8 kW

B{Q. 19/June 2013/11}

$P = \frac{\text{Work done by motor}}{\text{time}} \Rightarrow P = (F)\left(\frac{s}{t}\right)$

$= (\text{Resultant force})(2\pi r)\left(\frac{\text{no. of revolutions}}{\text{time}}\right)$

$= (F)(2\pi r)(f)$

$= (100 - 20)(0.30)(50)$

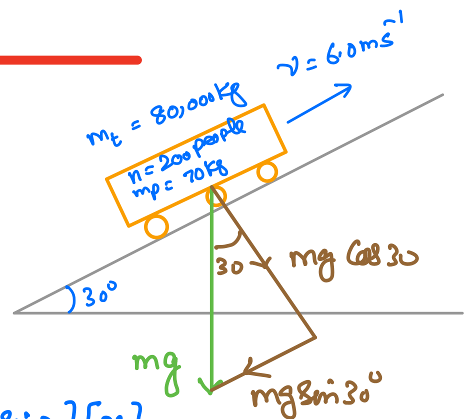
$= 1200\ W$

$= 1.2\ kW$

Q19) A train on a mountain railway is carrying 200 people of average mass 70 kg up a slope at an angle of 30° to the horizontal and at a speed of 6.0 m s⁻¹. The train itself has a mass of 80 000 kg.
The percentage of the power from the engine which is used to raise the passengers and the train is 40 %.
What is the power of the engine?

A 1.1 MW **B** 2.8 MW **(C)** 6.9 MW **D** 14 MW

C{Q. 17/June 2013/12}



$\eta = \frac{Fv}{P_{in}} \Rightarrow \eta = \frac{[(m_t + n_p m_p) g \sin 30][v]}{P_{in}}$

$\frac{40}{100} = \frac{[[80{,}000 + (200)(70)](9.81) \sin 30][6.0]}{P_{in}}$

$P_{in} = 6916050\ W \Rightarrow P_{in} = 6.92 \times 10^6\ W$

Q22) The force resisting the motion of a car is taken as being proportional to the square of the car's speed. The magnitude of the force at a speed of 20 m s⁻¹ is 800 N. What effective power is required from the car's engine to maintain a steady speed of 40 m s⁻¹?

A 32 kW **B** 64 kW **(C)** 128 kW **D** 512 kW

C{Q. 17/June 2012/11}

$F \propto v^2 \Rightarrow F = Kv^2$

$800 = K(20)^2 \Rightarrow K = 2$

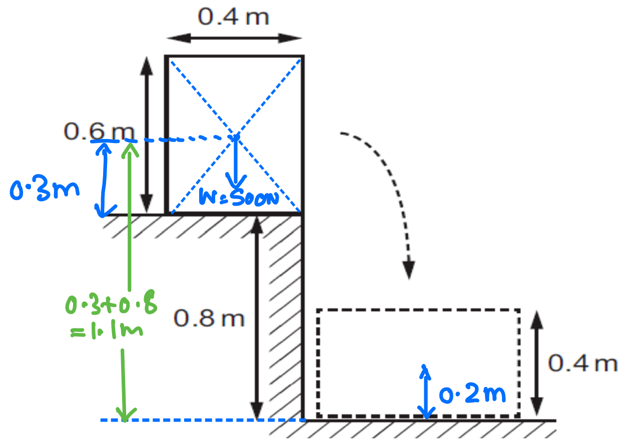
$P = Fv \Rightarrow P = (Kv^2)(v)$

$P = Kv^3$

$P = (2)(40)^3 \Rightarrow P = 128000\ W$

Q.33)

A uniform solid block has weight 500 N, width 0.4 m and height 0.6 m. The block rests on the edge of a step of depth 0.8 m, as shown.



$\Delta E_p = mgh_2 - mgh_1$

$\Delta E_p = mg(h_2 - h_1)$

$= (500)[0.2 - 1.1]$

$= -450\,J$

-ve sign shows that Gravitational potential energy is lost by solid block.

The block is knocked over the edge of the step and rotates through 90° before coming to rest with the 0.6 m edge horizontal.

What is the change in gravitational potential energy of the block?

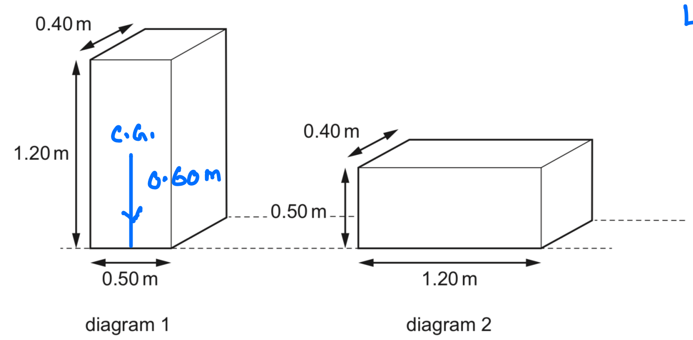
A 300 J **B** 400 J **C** 450 J **D** 550 J

{Q.15/ June2015/variant 12}

June 14/13/ Q.14

A* grade

14 A uniform solid cuboid of concrete of dimensions 0.50 m × 1.20 m × 0.40 m and weight 4000 N rests on a flat surface with the 1.20 m edge vertical as shown in diagram 1.



Length of diagonal

$= \sqrt{(1.20)^2 + (0.50)^2}$

$= 1.3\,m$

C.G. from base of Cuboid

$= \frac{1.3}{2} = 0.65\,m$

Increase in height

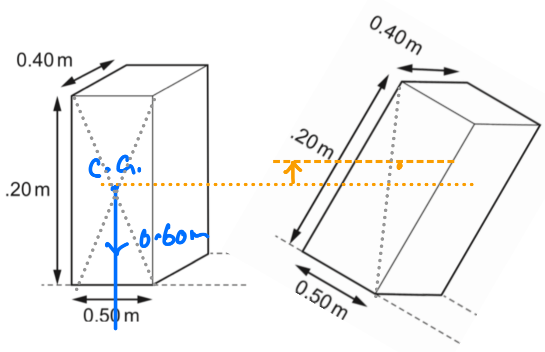
$= 0.65 - 0.60 = 0.05\,m$

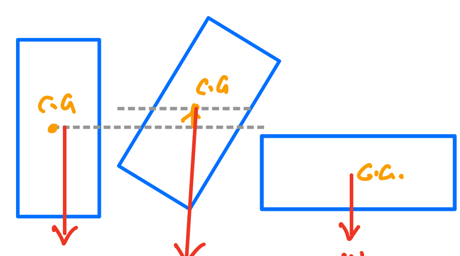
What is the minimum energy required to roll the cuboid through 90° to the position shown in diagram 2 with the 0.50 m edge vertical?

Minimum work done $= \Delta E_p = mg\Delta h = (4000)(0.05)$

$= 200\,J$

A 200 J **B** 400 J **C** 1400 J **D** 2600 J





C.G. of cuboid is raised to increase its P.E. so that it can topple into new position.

Q.34)

A fisherman lifts a fish of mass 250 g from rest through a vertical height of 1.8 m. The fish gains a speed of 1.1 m s^{-1}.

What is the energy gained by the fish?

A 0.15 J **B** 4.3 J **C** 4.4 J **(D)** 4.6 J

{*Q.17/ June2015/variant 12*}

$E_T = E_K + E_P$

$= \frac{1}{2}mv^2 + mgh$

$= \frac{1}{2}(250\times10^{-3})(1.1)^2 + (250\times10^{-3})(9.81)(1.8)$

$= 4.566$ J

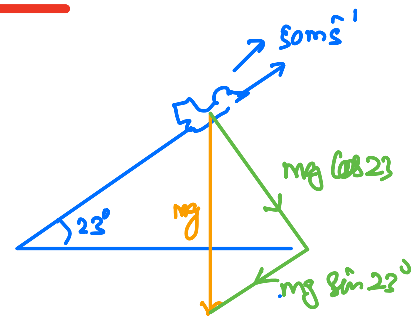
Q.36)

A loaded aeroplane has a total mass of 1.2×10^5 kg while climbing after take-off. It climbs at an angle of 23° to the horizontal with a speed of 50 m s^{-1}. What is the rate at which it is gaining potential energy at this time?

A 2.3×10^6 J s^{-1} **B** 2.5×10^6 J s^{-1}

(C) 2.3×10^7 J s^{-1} **D** 2.5×10^7 J s^{-1}

{*Q.18/ June2015/variant 13*}



$\frac{E_p}{t} = \frac{(mg\sin23°)(s)}{t} = (mg\sin23°)\left(\frac{s}{t}\right)$

$\frac{E_p}{t} = (mg\sin23)(v) \Rightarrow P = (1.2\times10^5)(9.81)(\sin23°)(50)$

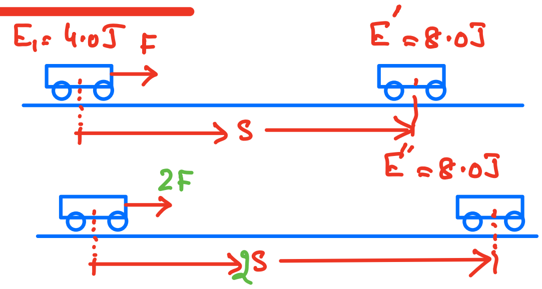
$P = 2.299 \times 10^7$ W

Q.37)

When a horizontal force F is applied to a frictionless trolley over a distance s, the kinetic energy of the trolley changes from 4.0 J to 8.0 J. If a force of 2*F* is applied to the trolley over a distance of 2s, what will the original kinetic energy of 4.0 J become?

A 16 J **(B)** 20 J **C** 32 J **D** 64 J

{*Q.19/ June 2015/variant 13*}



work done on trolley = Gain of kinetic energy

$FS = \Delta E_K$

$\frac{F_2 S_2}{F_1 S_1} = \frac{\Delta E_2}{\Delta E_1} \Rightarrow \frac{(2F)(2s)}{(F)(s)} = \frac{\Delta E}{8.0 - 4.0}$

$\Delta E = 16$ J

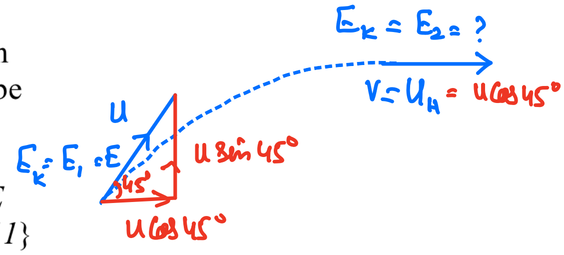
original E_K = Initial E_K + change of energy

$= 4.0 + 16 = 20$ J

Q.38) A projectile is launched at 45° to the horizontal with initial kinetic energy *E*. Assuming air resistance to be negligible, what will be the kinetic energy of the projectile when it reaches its highest point?

(A) 0.50*E* **B** 0.71*E* **C** 0.87*E* **D** *E*

{*Q.16/ Nov2014/variant 11*}



$$\frac{E_2}{E_1} = \frac{\frac{1}{2} m v^2}{\frac{1}{2} m u^2} \Rightarrow \frac{E_2}{E} = \frac{(U\cos 45)^2}{U^2} \Rightarrow \frac{E_2}{E} = \frac{U^2\left(\frac{1}{\sqrt{2}}\right)^2}{U^2}$$

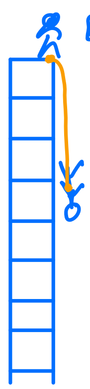
$$E_2 = \frac{E}{2} \Rightarrow E_2 = 0.50E$$

Q47. A bungee jumper has 24 kJ of gravitational potential energy at the top of his jump. He is attached to an elastic rope which starts to stretch after a short time of free fall. The values of gravitational potential energy, elastic potential energy and kinetic energy are given for the top and the bottom of the jump.

	gravitational potential energy/kJ	elastic potential energy/kJ	kinetic energy/kJ
top	24	0	0
bottom	0	24	0

Which row of the table below shows possible values of these three energies when the jumper is half-way down? Losses of energy through air resistance are negligible.

	gravitational potential energy/kJ	elastic potential energy/kJ	kinetic energy/kJ
A	12 ✓	10 ✗	2 ✗
(B)	12 ✓	8 ✓	4 ✓
C	8 ✗	8 ✓	8 ✗
D	12 ✓	2 ✗	10 ✗



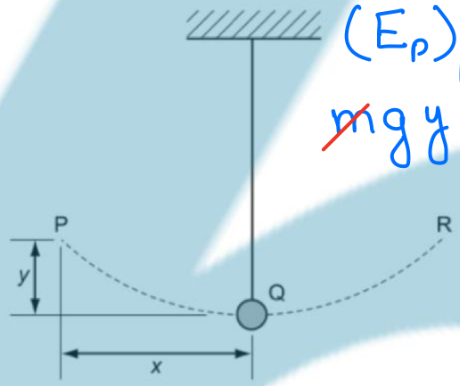
$E_p = 24KJ$

wire stretch after a short time of fall, so wire gain elastic potential / strain energy.

Also at half way, Kinetic energy

Students' problems

A pendulum bob oscillates between P and R.



$(E_p)_P = (E_k)_Q$

$\cancel{m}gy = \frac{1}{2}\cancel{m}v^2$

$v^2 = 2gy$

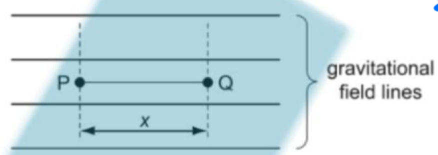
$v = \sqrt{2gy}$

Assuming the gravitational potential energy lost in moving from P to Q is converted into kinetic energy, what is the speed of the bob at Q?

A $\sqrt{2gx}$ **B** $2gx$ **(C)** $\sqrt{2gy}$ **D** $2gy$

(Question 17 of Paper 1, Winter, 2008)

A mass m is situated in space in a uniform gravitational field.



Since $E_p \downarrow$ so work is done in the direction of Gravitational force (weight). So field lines are from P to Q.

When the mass moves through a displacement x, from P to Q, it loses an amount of potential energy E.

Which row correctly specifies the magnitude and the direction of the acceleration due to the gravity in this field?

	magnitude	direction
(A)	$\frac{E}{mx}$	→ ✓
B	$\frac{E}{mx}$	← ✗
C	$\frac{E}{x}$	→ ✓
D	$\frac{E}{x}$	← ✗

Work done = Loss of GEp

$Fx = E$

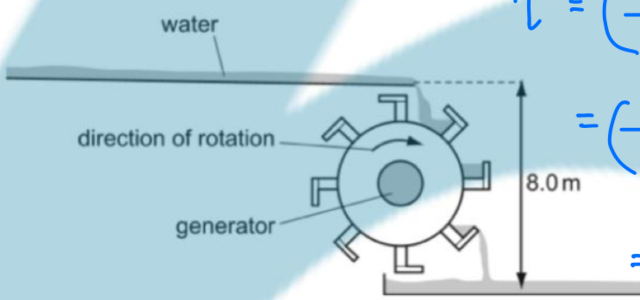
$max = E$

$a = \frac{E}{mx}$

Space for working

(Question 19 of Paper 1, Variant 3, Winter, 2011)

The diagram shows the design of a water wheel which drives a generator to produce electrical energy. The flow rate of the water is 200 kg s^{-1}. The generator supplies a current of 32 A at a voltage of 230 V.



$\eta = \left(\frac{\text{Electrical } P_{out}}{\text{Total } P_{in}}\right)100 = \left(\frac{VI}{\frac{mgh}{t}}\right)100 = \left(\frac{VI}{(\frac{m}{t})gh}\right)100$

Ignoring any changes in kinetic energy of the water, what is the efficiency of the system?

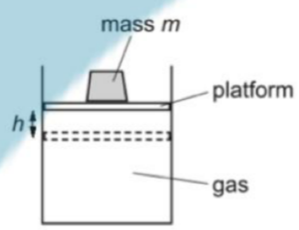
A 14 % **B** 16 % **C** 22 % **(D)** 47 %

$\eta = \left[\frac{(230)(32)}{(200)(9.81)(8.0)}\right]100$

$\eta =$ ____ %

(Question 18 of Paper 1, Variant 2, Summer, 2012)

A mass m is on top of a platform that is supported by gas in a cylinder of cross-sectional area A, as shown.



The platform has negligible mass and can move freely up and down.

The gas is heated and expands so that the mass is raised through a height h. Atmospheric pressure is p.

What is the ratio $\frac{\text{gain in gravitational potential energy of the mass}}{\text{work done by the gas}}$?

$\frac{mgh}{p\Delta V + mgh}$

A $\frac{mg}{pA}$ **(B)** $\frac{mg}{mg + pA}$ **C** $\frac{pA}{mg}$ **D** $\frac{mg - pA}{mg}$

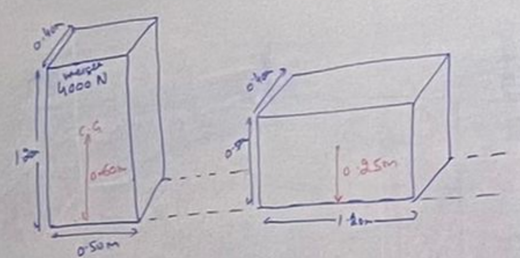
$\frac{mgh}{pAh + mgh}$

$\frac{mgh}{h(pA + mg)} = \frac{mg}{pA + mg}$

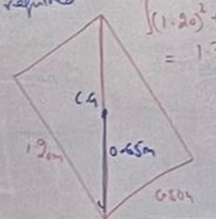
(Question 15 of Paper 1, Variant 1, Winter, 2018)

J-14
P13/Q14)

Q14



Calculate minimum energy required

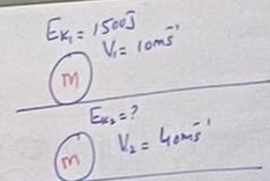


$\sqrt{(1.20)^2 + (0.50)^2}$
$= 1.30\,m$

$E_p = mg\Delta h$
$= (4000)(0.65 - 0.60)$
$= 200\,J$

Q46

M/J 11/P11/Q17
M/J 11/P13/Q16



$E_K = \frac{1}{2} m v^2$

$\frac{E_2}{E_1} = \frac{\frac{1}{2} m V_2^2}{\frac{1}{2} m V_1^2}$

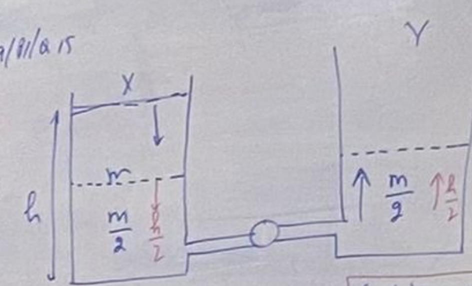
$\frac{E_2}{1500} = \frac{(40)^2}{(10)^2}$

$E_2 = \frac{(1600)(1500)}{100}$

$E_2 = 24000J$

Q50

M/J 9/P1/Q15



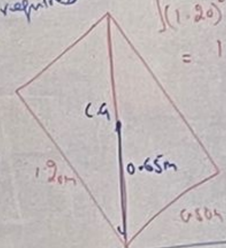
How much potential energy is lost by water

$E_p = \left(\frac{m}{2}\right)(g)\left(\frac{h}{2}\right)$

$= \frac{mgh}{4}$

0.50m

Calculate minimum energy required



$\sqrt{(1.20)^2 + (0.50)^2}$

$= 1.30\text{ m}$

$E_p = mg\Delta h$

$= (4000)(0.65 - 0.60)$

$= 200\text{ J}$

1500 (10)

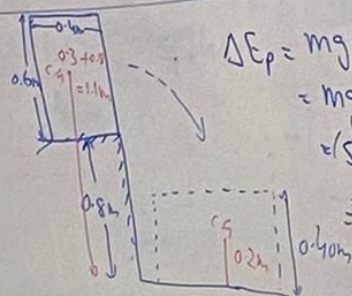
$E_2 = \frac{(1600)(1500)}{100}$

$E_2 = 24000\text{ J}$

$= \frac{\ldots}{4}$

Q.29

M/J 15/P12/Q15



$\Delta E_p = mg\Delta h$

$= mg(h_2 - h_1)$

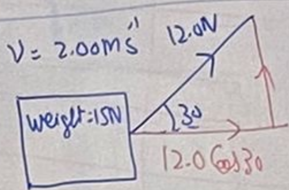
$= (500)(0.2 - 1.1)$

$= \_\_\_\_\text{ J}$

Q33

O/N 15/P13/Q17

$v = 2.00\text{ ms}^{-1}$



$P = Fv$

$= (12\cos 30)(2.00) = 20.78\text{ W}$ (B)