Work, Energy and Power – 2018

1. 9702/11/M/J/18/No.14

A train of mass 3.3×10^6 kg is moving at a constant speed up a slope inclined at an angle of 0.64° to the horizontal. The engine of the train is producing a useful output power of 14 MW.

Assume that there are no frictional forces opposing the motion of the train.

What is the speed of the train?

A $0.43\,\text{m s}^{-1}$ **B** $4.2\,\text{m s}^{-1}$ **C** $39\,\text{m s}^{-1}$ **D** $380\,\text{m s}^{-1}$

$\sin 0.64 = \frac{f_x}{W} = \frac{f_x}{3.3\times10^6 \times 9.81}$

$f_x = 361\,602\,N$

$P = F \times v$

$v = \frac{P}{F}$

$v = \frac{14\times10^6\,W}{361\,602\,N} = 38.7\,\text{m s}^{-1} \approx 39\,\text{m s}^{-1}$

2. 9702/11/M/J/18/No.15

A cannon-ball of mass 3.50 kg is fired at a speed of $22.0\,\text{m s}^{-1}$ from a gun on a ship at a height of 6.00 m above sea level.

The total energy of the cannon-ball is the sum of the gravitational potential energy relative to the surface of the sea and the kinetic energy.

What is the total energy of the cannon-ball as it leaves the gun?

A 206 J **B** 641 J **C** 847 J **D** 1050 J

Total Energy = gpe + ke $= mgh + \frac{1}{2}mv^2$

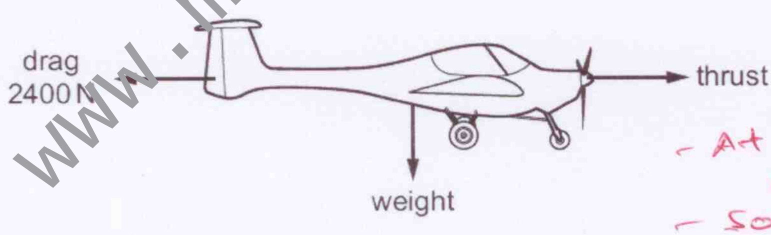
$E = (3.5\times9.81\times6) + (\frac{1}{2}\times3.5\times22^2)$

$= 1053.01\,J$

$= 1050\,J$

3. 9702/11/M/J/18/No.16

An aircraft travels at a constant velocity of $90\,\text{m s}^{-1}$ in horizontal flight. The diagram shows some of the forces acting on the aircraft.



The mass of the aircraft is 2000 kg.

What is the power produced by the thrust force?

A 1.8×10^5 W **B** 2.2×10^5 W **C** 1.8×10^6 W **D** 2.0×10^6 W

– At constant velocity R.F = 0.

– So forward force = Backward force.

– $P = F \times v$

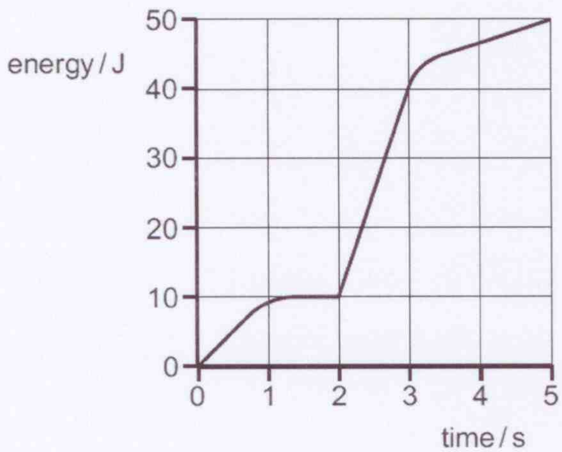
$= 2400\,N \times 90\,\text{m s}^{-1}$

$= 216000\,W$

$= 2.2\times10^5\,W$

4. 9702/11/M/J/18/No.17

An electrical generator is started at time zero. The total electrical energy generated during the first 5 seconds is shown in the graph.



$P = \frac{E}{t}$

– Power given by gradient

– max. Power given by steepest part of the gradient.

$P = \frac{40-10}{3-2} = \frac{30}{2} = 30\,W$

What is the maximum electrical power generated at any instant during these first 5 seconds?

A 10 W **B** 13 W **C** 30 W **D** 50 W

5. 9702/12/M/J/18/No.16

In 'normal driving conditions', an electric car has a range of 150 km. This uses all of the 200 MJ of energy stored in its batteries.

With the batteries initially fully charged, the car is driven 100 km in 'normal driving conditions'. The batteries are then recharged from a household electrical supply delivering a constant current of 13.0 A at a potential difference of 230 V.

What is the minimum time required to recharge the batteries?

A 0.95 hours

B 12.4 hours

C 18.6 hours

D 27.9 hours

150 km → 200 MJ.
100 km → ?

$\frac{100\,km \times 200\,MJ}{150\,km}$

= 133.3 MJ.

$E = VIt$

$t = \frac{E}{VI}$

$t = \frac{133.3 \times 10^6}{13 \times 230}$

= 44,582 s

1 hr → 3600 s
? → 44,582 s

$\frac{1\,hr \times 44582}{3600}$

= 12.38 hrs

≈ 12.4 hrs

6. 9702/12/M/J/18/No.18

A steel sphere is dropped vertically onto a horizontal metal plate. The sphere hits the plate with speed u, leaves it at speed v, and rebounds vertically to half of its original height. Ignore air resistance.

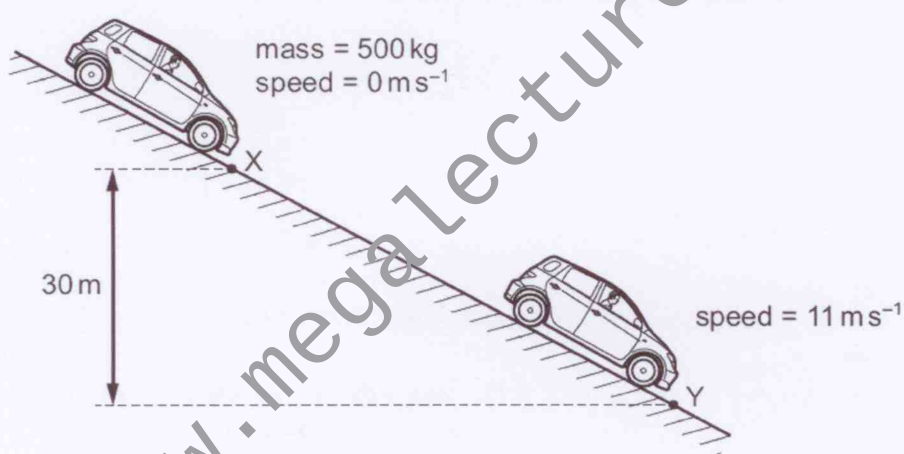
Which expression gives the value of $\frac{v}{u}$?

A $\frac{1}{2^2}$ **B** $\frac{1}{2}$ **C** $\frac{1}{\sqrt{2}}$ **D** $1 - \frac{1}{\sqrt{2}}$

7. 9702/12/M/J/18/No.19

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}.

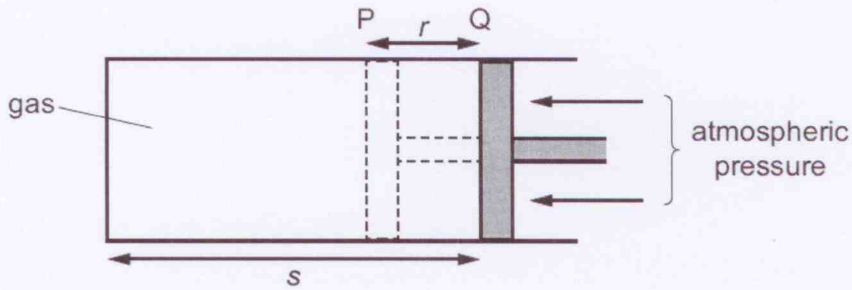


What is the energy dissipated by frictional forces when the car moves from X to Y?

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

8. 9702/13/M/J/18/No.14

Gas is trapped inside a cylinder by a piston of cross-sectional area *A*. The piston is **not** frictionless.



The gas is heated and this causes it to expand, pushing back the piston through distance *r* from position P to position Q. The length of the gas column is then *s*.

Which expression represents the amount of work done by the gas against the atmosphere during this expansion?

A (atmospheric pressure) × *Ar*

B (atmospheric pressure) × *As*

C (pressure inside the gas) × *Ar*

D (pressure inside the gas) × *As*

W = F × d. F = P × A, d = r.
= P × A × r.
= P × Ar. P = atm. pressure
= atm pressure × Ar.

9. 9702/13/M/J/18/No.15

Water from a reservoir is fed to the turbine of a hydroelectric system at a rate of $510\,kg\,s^{-1}$. The reservoir is 280 m above the level of the turbine.

The electrical output from the generator driven by the turbine is a current of 205 A at a potential difference of 5800 V.

What is the efficiency of the system?

A 8.3% **B** 12% **C** 83% **D** 85%

mgh = 510 × 9.81 × 280
= 1,400,868 J.

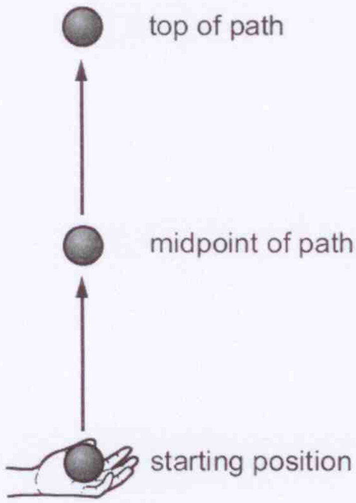
Power in = E/t = 1,400,868 J / 1 s
= 1,400,868 W

Power out = V I
= 5800 × 205
= 1,189,000 W

E = Pout/Pin × 100 = 84.5 %
≃ 85 %

10. 9702/13/M/J/18/No.16

A ball is thrown vertically up into the air. It rises to the top of its path before beginning to fall vertically downwards.



Assume that the gravitational potential energy of the ball is zero at its starting position.

Which statement about the ball is **not** correct?

A As it rises, its kinetic energy is transferred to gravitational potential energy.

B At the midpoint of its path, its gravitational potential energy is equal to its initial kinetic energy.

C At the top of its path, its kinetic energy is zero.

D At the top of its path, its total energy is less than its initial total energy.

11. 9702/13/M/J/18/No.17

A force of 1000 N is needed to lift the hook of a crane at a constant velocity. The crane is then used to lift a load of mass 1000 kg at a constant velocity of $0.50\,m\,s^{-1}$.

What is the power needed to lift the hook and the load?

A 4.9 kW **B** 5.4 kW **C** 20 kW **D** 22 kW

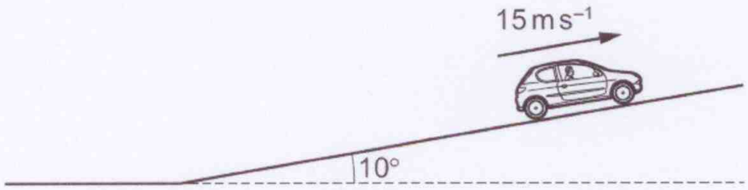
P = F × V
F = m × g
= 1000 kg × 9.81 N/kg
= 9810 N

Total force = 1000 + 9810
= 10981 N

P = 10981 × 0.5
= 5,405 W
= 5.4 kW

12. 9702/12/F/M /18/No.14

A car of mass 1100 kg is travelling at a constant speed of $15\,m\,s^{-1}$ up a slope inclined at 10° to the horizontal. The combined frictional forces acting on the car are directed down the slope and are equal to $\frac{W}{5}$, where W is the weight of the car.



What is the useful output power of the car's engine?

A 28 kW **B** 32 kW **C** 60 kW **D** 190 kW

W = mg
= 1100 × 9.81
= 10,791 N

friction = 10,791 / 5
= 2158 N

– Down slope force due to W = 10791 sin 10
= 1874

– Total force down slope
2158 + 1874
= 4032 N

– At constant speed, up force = down force
P = F × v
= 4032 × 15 ms⁻¹
= 60480 W
≃ 60 kW

13. 9702/12/F/M /18/No.15

An old-fashioned 60 W lamp converts 95% of its energy supply into heat. A 4.0 W modern lamp has the same power output of light as the old-fashioned lamp.

What is the efficiency of the modern lamp?

A 5.0% **B** 6.7% **C** 75% **D** 95%

E = Useful Pout / Total Pin

0.05 = Pout / 60

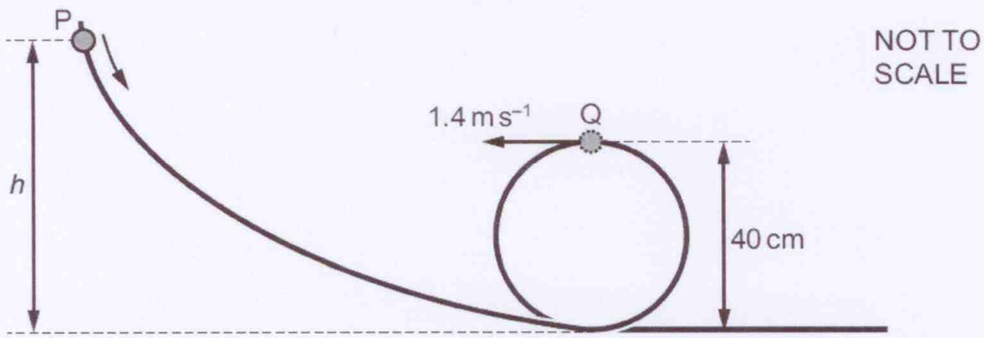
Pout = 60 × 0.05
= 3 W

Modern lamp

E = Useful Pout / Total Pin × 100
= 3 W / 4 W × 100
= 75 %

14. 9702/12/F/M /18/No.16

A bead is released from rest at point P and slides along a wire, as shown.



The track loops around and forms a vertical circle of diameter 40 cm. At point Q, the bead has a speed of $1.4\,m\,s^{-1}$.

Air resistance and friction on the wire are negligible.

What is the height *h* from which the bead is released?

A 0.30 m **B** 0.40 m **C** 0.50 m **D** 0.60 m

15. 9702/12/F/M /18/No.17

A small diesel engine uses a volume of $1.5 \times 10^4\,cm^3$ of fuel per hour to produce a useful power output of 40 kW. It may be assumed that 34 kJ of energy is transferred to the engine when it uses $1.0\,cm^3$ of fuel.

What is the rate of transfer from the engine of energy that is wasted?

A 102 kW **B** 142 kW **C** 182 kW **D** 470 kW

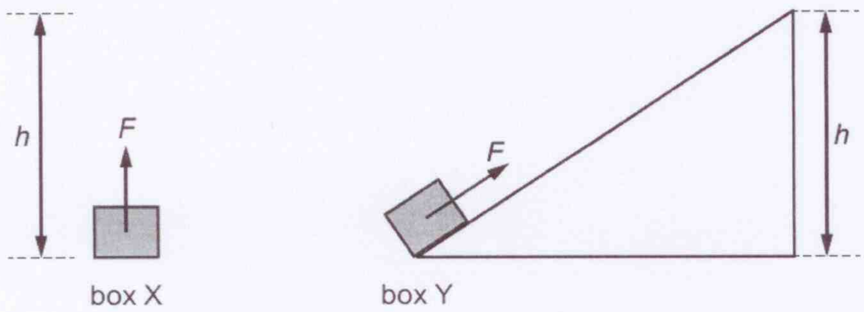
1W = 1Js⁻¹
1 cm³ → 34000 J
1.5 × 10⁴ cm³ → ?
1.5 × 10⁴ × 34000 / 1
= 510,000,000 J hr⁻¹ / 3600 s
= 141,666 Js⁻¹

P_in = 141,666 W
P_out = 40,000 W
Wasted Power = 141,666 − 40,000
= 101666 W
= 101666 Js⁻¹
= 102 kW

16. 9702/12/F/M /18/No.18

Two boxes X and Y have the same mass. Box X is lifted vertically through a height *h* by a force of magnitude *F*.

Box Y is pulled along a slope by a force of the same magnitude to reach the same height, as shown.



Which statement is correct?

A Both boxes gain the same amount of gravitational potential energy and the same amount of work is done by the two forces.

B Both boxes gain the same amount of gravitational potential energy but more work is done by the force acting on box Y than by the force acting on box X.

C Box Y gains less gravitational potential energy than box X because the weight of box Y is less than the weight of box X.

D Box Y gains more gravitational potential energy than box X as more work is done by the force acting on box Y than by the force acting on box X.