Exam Papers Practice

Work, Energy & Power

Mark Schemes

Course	HL IB Physics
Section	Space, Time & Motion
Topic	Work, Energy & Power
Difficulty	Medium

To be used by all students preparing for HL IB Physics
Students of other boards may also find this useful

1

The correct answer is **B** because:

- The trampolinist starts at their highest position
  - This means they have gravitational potential energy
- They start to descend
  - Since they are accelerating under the force of gravity, they are picking up speed
  - They are losing height but this means their gravitational potential energy is converted to kinetic energy
- As they land on the trampoline, it deforms under their force
  - Their kinetic energy is converted to elastic potential energy
- As they bounce back up, the trampoline rubber and springs go back to their original shape. The trampolinist then moves upwards
  - The elastic potential energy is converted back into kinetic energy
- The trampolinist returns back to their highest position
  - Their kinetic energy is finally converted back to gravitational potential energy

This type of question is common in examinations and requires you to carefully consider the motion of the object and the energy transfer taking place at each stage. Similar questions might include bouncing balls or jumping on the floor.

2

The correct answer is **D** because:

- Since the moon has no atmosphere, we don't have to worry about work done due to friction
  - This means the only energy transfers are from gravitational potential, *GPE* to kinetic, *KE*
- At $\frac{h}{3}$, the kinetic energy, KE of the object is the difference in gravitational potential energy between *h* and $\frac{h}{3}$
  - $KE = \Delta GPE = mgh - mg\frac{h}{3} = \frac{2}{3}mgh$

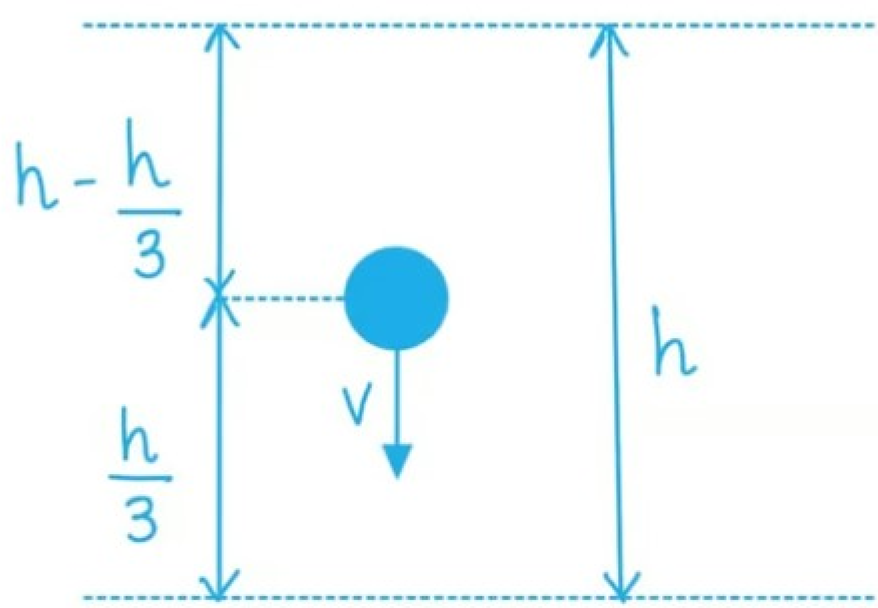
- The gravitational potential energy, GPE at h is
  - GPE = mgh
- Substituting these into the fraction gives:
  - $\frac{mgh}{\frac{2}{3}mgh} = \frac{3}{2}$

A is incorrect as the **difference** in GPE hasn't been taken, so the KE must be $\frac{2}{3}mgh$ instead of $\frac{1}{3}mgh$ at $\frac{h}{3}$.

B is incorrect as the **difference** in GPE hasn't been taken, so the KE must be $\frac{2}{3}mgh$ instead of $\frac{1}{3}mgh$ at $\frac{h}{3}$ and the KE and GPE have been substituted in the wrong way around.

C is incorrect as the KE and GPE have been substituted in the wrong way around.

The best way to visualise this scenario and the different heights is to draw a quick sketch. Here we can clearly see the **difference** in height that the object falls is $h - \frac{h}{3} = \frac{h}{1} - \frac{h}{3} = \frac{3h - h}{3} = \frac{2h}{3}$



3

The correct answer is **A** because:

- Since the mass moves on a frictionless surface, this means there is no work done due to friction
  - This means that the only energy transfer is from kinetic energy, *KE* to elastic potential, *EPE*
- All the kinetic energy of the object is transferred to the elastic potential of the spring to compress it
  - $KE = \frac{1}{2}mv^2 = EPE = \frac{1}{2}ky^2$ where y is the extension of the spring
  - So, $\frac{1}{2}mv^2 = \frac{1}{2}ky^2$
- Rearranging the equation for extension y gives:
  - $mv^2 = ky^2$
  - $\sqrt{\frac{mv^2}{k}} = y$
  - $\sqrt{\frac{m}{k}}v = y$

B is incorrect as m has been divided by k instead of k divided by m to correctly rearrange the equation for y^2.

C is incorrect as the square root hasn't been taken to get y instead of y^2.

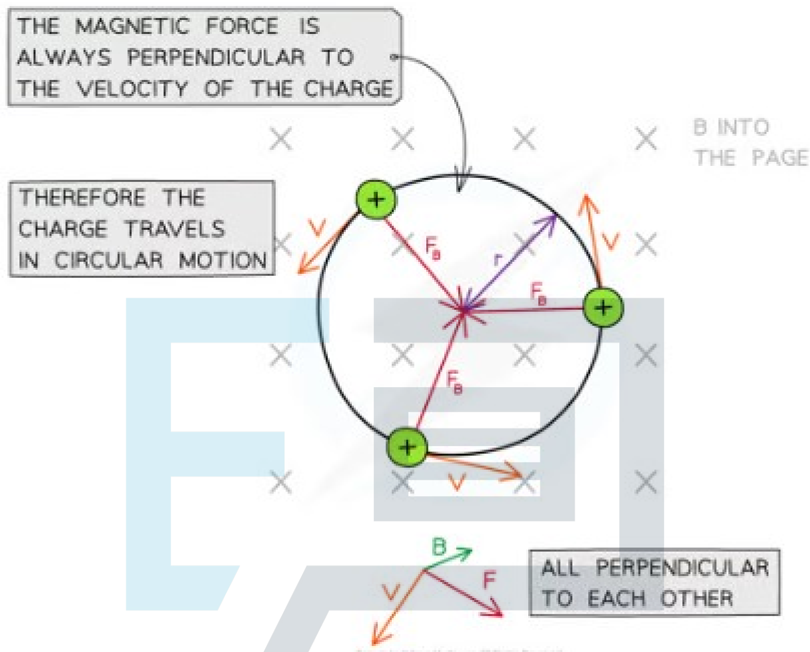
D is incorrect as m has been divided by k instead of k divided by m to correctly rearrange the equation for y^2 and the square root hasn't been taken to get y instead of y^2.

4

The correct answer is **C** because:

- Work is defined by the equation:
  - $W = Fs$ where F is the force and s is the displacement on the object
- The direction of F and s must either be in the same direction **or** exactly opposite

- Since a charged particle in a magnetic field travels in **circular** motion, the centripetal force, *F* acts towards the centre of its trajectory whilst its displacement, *s* is **perpendicular** to this
    - This means there is no work done for an object moving in circular motion



A is incorrect as a pulling force on a sledge at an angle still has some work done on the object. The component of the force in the same direction as the displacement is taken instead for the equation to become $W = Fs\cos\theta$.

B & **D** are incorrect as a pulling force on a sledge at an angle still has some work done on the object. The component of the force in the same direction as the displacement is taken instead for the equation to become $W = Fs\cos\theta$.

A drag force is in the opposite direction to a car's motion, so work is still done on it, but it will just be negative to signify it's a resistive force.

5

The correct answer is **C** because:

- Efficiency is defined by the equation:
    - Efficiency = $\frac{useful\ power\ out}{total\ power\ in}$
- Rearranging this for the useful power out gives:
    - Useful power out = Efficiency × Total power in
- Substituting in the values gives:
    - Useful power out = 60% of 35 = 21 GW
- The power that produces wasted energy is:
    - Wasted power = Total power in – Useful power out
    - Wasted power = 35 – 21 = 14 GW

A is incorrect as the efficiency has not been taken into consideration.

B is incorrect as this is the useful power out, and not the wasted power.

D is incorrect as the incorrect percentage has been taken.

Calculating 60 % of 35 can be done a number of ways. The easiest way would be to find 10 %, then multiply by six:

- 10 % of 35 = 3.5
- 3.5 × 6 = (3 × 6) + (0.5 × 6) = 18 + 3 = 21 GW

Another way to do this question is that if the efficiency is 60 %, then 40 % of the power must be wasted. Then you can find 40 % of 35 by the following:

- 10 % of 35 = 3.5
- 3.5 × 4 = (3 × 4) + (0.5 × 4) = 12 + 2 = 14 GW

Which gives the final answer in fewer steps!

In questions like this, it is best to avoid doing unit conversions till the end. Although it is a great habit to adopt converting the GW here into W at the start you can see from the answer options the final answer is required in GW, so you don't need to do that here.

6

The correct answer is **B** because:

- As the mass loses height from X to Y, its gravitational potential energy is converted to some kinetic energy
- The kinetic energy gained is equal to the **difference** in gravitational potential energy that it has between points X and Y
  - KE = ΔGPE = GPE at X – GPE at Y
  - So, $\Delta GPE = mgh - mg\frac{3}{5}h = \frac{2}{5}mgh$
- Equate this to the kinetic energy equation
  - $\frac{2}{5}mgh = \frac{1}{2}mv^2$
  - $\frac{2}{5}gh = \frac{1}{2}v^2$
- Rearrange for velocity, v:
  - $\frac{2 \times 2gh}{5} = v^2$
  - $\sqrt{\frac{4gh}{5}} = v$
  - $2\sqrt{\frac{gh}{5}} = v$

A is incorrect as the 4 has been square rooted to get 2 but not taken outside the square root sign, as $\sqrt{\frac{4gh}{5}} = v$ becomes $2\sqrt{\frac{gh}{5}} = v$.

C is incorrect as when taken outside of the square root sign the 4 must be square rooted. So, $\sqrt{\frac{4gh}{5}} = v$ becomes $2\sqrt{\frac{gh}{5}} = v$ and not $4\sqrt{\frac{gh}{5}}$.

D is incorrect as $\frac{3}{5}$ is the GPE at Y and not the change in GPE from X to Y which is $\frac{4}{5}$.

Remember that the kinetic energy is only equal to the difference in gravitational potential energy at that point. This means that the difference in vertical height, Δh is required between point X and Y.

The calculation $mgh - mg\frac{3}{5}h$ might look a bit confusing at first, but remember that mgh is the same as $1 \times mgh$. Therefore, $1mgh - \frac{3}{5}mgh$ means $(1 - \frac{3}{5})mgh = \frac{2}{5}mgh$.

7

The correct answer is **D** because:

- At constant speed, power, P is defined by:
  - $P = Fv$ where F is the force and v is the speed
- The force F is the weight of the student:
  - $F = mg = 50 \times 10 = 500$ N
- Speed is defined by the equation:
  - Speed = $\frac{distance}{time} = \frac{d}{t}$
- Therefore, P is equal to:
  - $P = \frac{Fd}{t}$
- Substituting in the values gives:
  - $P = \frac{500 \times 4.0}{8.0} = \frac{2000}{8.0}$
  - $P = 250$ W

A is incorrect as the mass has **not** been multiplied by g to calculate the weight for F.

B is incorrect as incorrect calculation at the end when values have been substituted.

C is incorrect as the time and distance have been substituted in the wrong way around.

Since calculators are not allowed in the multiple choice paper, it is fine to just approximate the acceleration due to gravity, g as 10 m s^{-2} (instead of the usual 9.81 m s^{-2} that you would be required for structured questions.). This is a much easier number to work with than 9.81!

8

The correct answer is **B** because:

- Efficiency is defined by the equation:
  - Efficiency = $\frac{useful\ work\ out}{total\ work\ in}$
- From the consideration of energy:
  - Total work in = Wasted work + Useful work by the motor
  - Total work in = $E_w + W$
- Therefore, the efficiency equation can be written as:
  - $0.8 = \frac{W}{W + E_w}$
- Rearranging for W gives:
  - $0.8(W + E_w) = W$
  - $0.8W + 0.8E_w = W$
  - $0.8E_w = 0.2W$
  - $W = \frac{0.8}{0.2}E_w$
  - $W = 4E_w$

A is incorrect as the final equation has been incorrectly rearranged as $\frac{0.2}{0.8}$ instead of $\frac{0.8}{0.2}$

C is incorrect as the brackets $0.8(W + E_w)$ have not been fully expanded i.e. $0.8W + E_w$ instead of $0.8W + 0.8E_w$

D is incorrect as the fraction $\frac{0.8}{0.2}$ has been calculated incorrectly

9

The correct answer is **C** because:

- During the decent of the lift, energy is conserved
- The lift is moving at constant **speed**

- Kinetic energy is defined by:
  - KE = $\frac{1}{2}$ mv^2 where m is the mass and v is the speed
- This means that as it descends, its kinetic energy also remains constant
  - As a result, this means its kinetic energy has **not** been converted from other types of energy, such as gravitational potential
- Therefore, the only energy transformations that we know definitely happen are from the electric motor to the thermal energy created from the motion of the lift

It is a common misconception to always think that a decrease in height always results in an energy transformation from gravitational potential to kinetic energy. This is only the case if an object is accelerating, because then its speed changes, and therefore its kinetic energy changes. If the kinetic energy is constant, it is not going to be transferred to another energy form because energy cannot just be created or destroyed.

10

The correct answer is **A** because:

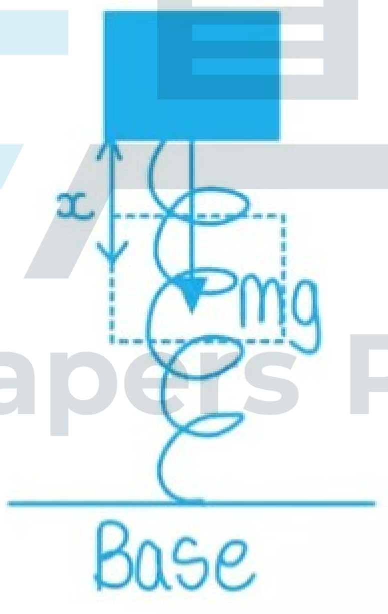
- The force on the spring is due to the mass's weight
  - $W = mg$
- From Hooke's law, the force F is defined by:
  - $F = kx$ where k is the spring constant and x is the extension of the spring
- Therefore, rearranging for extension x gives:
  - $mg = kx$
  - $x = \frac{mg}{k}$
- The elastic potential energy is defined by the equation:
  - EPE = $\frac{1}{2}kx^2$
- Substituting in the equation for x gives:
  - EPE = $\frac{1}{2}k\left(\frac{mg}{k}\right)^2 = \frac{1}{2}k\frac{m^2g^2}{k^2}$
  - EPE = $\frac{m^2g^2}{2k}$

Since the MCQ paper 1 is non-calculator, expect to work with a lot of algebra. The distractor answers are all simple algebraic mistakes, so make sure to avoid these by expanding brackets and cancelling appropriately.

You will be expected to remember the Hooke's law equation $F = kx$ from (i)GCSE level. This is very commonly linked with the elastic potential energy equation.

Since none of the answers, or the question refer to the extension 'x' (which can be named as anything – it's up to you), this implies that the extension should not appear in the final equation. Therefore, you need to rearrange for this in another equation that is related and substitute it in.

A diagram of the scenario would look like:



11

The correct answer is **D** because:

- The equations for specific energy and energy density are;
  - Specific energy, $E_S = \frac{E}{m}$ where E is the energy of the substance and m is its mass

- Energy density, $E_D = \frac{E}{V}$ where E is the energy of the substance and V is its volume

- We can write $E_S \times x = E_D$ and determine the factor x algebraically:
  - $\frac{E}{m} \times x = \frac{E}{V}$
  - $x = \frac{E}{V} \times \frac{m}{E} = \frac{m}{V}$
  - Therefore, the correct answer is **D**

With a question like this where you are looking for an algebraic relationship, always start by writing what you know already then looking for a pattern. Often you will just have to 'play' with the options by trying them out.

12

The correct answer is **B** because:

- To calculate density, use the equation;
  - Density, $\rho = \frac{E_D}{E_S} = \frac{3.5 \times 10^{10}}{4.5 \times 10^{7}}$
  - $\frac{3.5}{4.5}$ gives a ratio of $\frac{7}{9}$ which approximates to 0.78
  - $\frac{10^{10}}{10^{7}}$ gives $10^{(10-7)} = 10^3$
  - Therefore, $\rho \approx 0.78 \times 10^3 = 780$ kg m^{-3}
- This is closest in magnitude to option **B**

A is incorrect as specific energy was divided by energy density rather than the other way around.

C is incorrect as this is the value for energy density.

D is incorrect as energy density was multiplied by specific energy density rather than divided.

13

The correct answer is **C** because:

- The width of each arrow on the Sankey diagram represents the number of energy units
- Counting squares shows that:
  - Input electrical energy = 13 units
  - Thermal energy = 9 units
  - Light energy = 1 unit
  - Sound energy = 3 units
- From the data booklet:
  - Efficiency = $\frac{useful\ energy\ out}{total\ energy\ in}$
- The useful energy out while watching a film includes both light and sound
  - Useful energy out = 1 + 3 = 4 units
  - Efficiency = $\frac{4}{13}$ which we can see is about one third, making option **C** the only possible answer

A is incorrect as the answer has not been multiplied by 100, leaving it as a ratio rather than a percentage.

B is incorrect as only the output energy of light was included in the calculation, sound was ignored.

D is incorrect as the output thermal energy was used in the calculation, but this is the wasted energy.