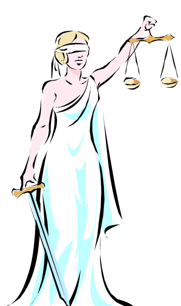
2010

physics

teacher's reference

5058

Learning objectives implemented



Learning objectives implemented in 2010 Part 1 5058/1

MCQs

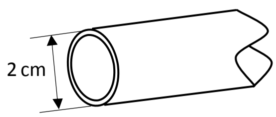
Answer all questions.

1. [Newtonian mechanics]

Method

Approach I – instruments

A plumber intends to use a length of pure copper pipe, of circular uniform cross–section and several metres long to carry water to a tap.



In order to check the purity of copper, he needs to calculate accurately the volume of copper in the pipe used.

∴ The volume of the copper is determined by the measurement of the internal and external diameters of the pipe, as well as the length of the entire pipe.

The instruments he should use are:

- *Tape* – length of pipe
- *Vernier Calipers* – internal and external diameters of pipe

Appropriate Means (Error)	Examples of Length	Approximate
Tape (± 1 cm)	Classroom, car, bench, corridor, small building, long pipe	5 cm up to 30 m
Rule (± 0.1 cm)	Book, pendulum, pencil, small table, short wire	0.5 cm up to 1 m
Vernier Calipers (± 0.01 cm)	Drain hole, cup, internal diameter of test tube	0.5 mm up to 15 cm
Micrometer (± 0.01 mm)	Steel ball, wire, grain of rice, thickness of a page	0.05 mm up to 5 cm

∴ The instruments he should use are:

☒ calipers and micrometer

☒ micrometer and rule

☒ rule and tape

☑ tape and calipers

(D) (ans)

☺ **CheckBack**

If the answer is *tape and calipers*,

- *Micrometer* – Can measure the external diameter of the pipe, but not its internal diameter.
- *Rule* – Cannot measure lengths beyond the metre.

Options suggesting using either the micrometer or the rule or both are not appropriate.

(checked)

☺ **Exam Report**

Most candidates gave the correct answer. Some gave the wrong answer as (A), these candidates did not realise that there is a need to measure internal diameters. Further, the micrometer has a very large anvil and spindle contact surfaces which are not suitable for measuring curved thickness.

§

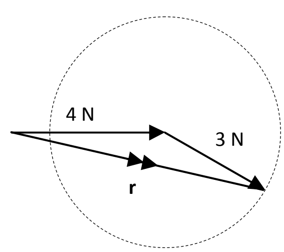
2. [Newtonian mechanics]

Method

Approach I – sum of forces

The magnitude (size) of the resultant force is derived by adding a force of 3 N and a force of 4 N acting on an object.

∴ The magnitude (size) of the resultant force (r) can be derived by laying the forces side by side in the sketch below:



- The minimum magnitude (size) of the resultant force is 4 N – 3 N = 1 N
- The maximum magnitude (size) of the resultant force is 4 N + 3 N = 7 N

∴ The magnitude (size) of the resultant force <u>cannot</u> be derived by laying the forces side by side is

☒ 1 N

☒ 3 N

☒ 5 N

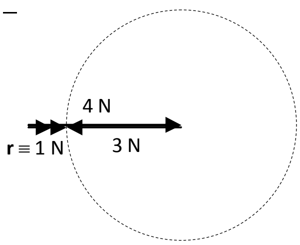
☑ 8 N

(D) (ans)

☺ **CheckBack**

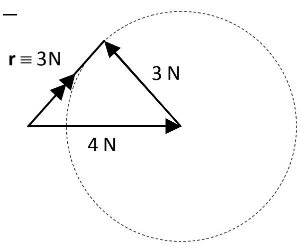
If the answer is 8 N,

- 1 N –



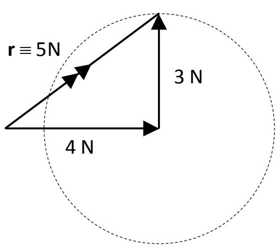
– possible magnitude

- 3 N –



– possible magnitude

- 5 N –



– possible magnitude

(checked)

☺ **Exam Report**

Most candidates gave the correct answer.

§

3. [Newtonian mechanics]

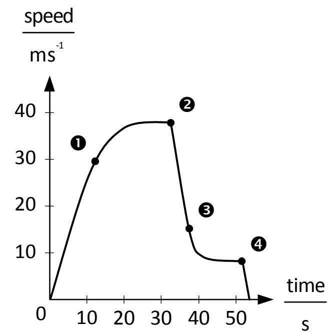
Method

Approach I – motion of body

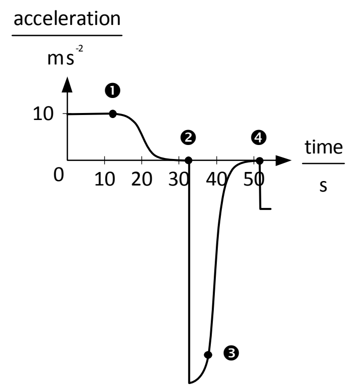
A sky diver falls freely from an aircraft.

After some fall distance, he opens a parachute and later lands safely on the ground.

His speed of descent is recorded and shown in the sketch below.



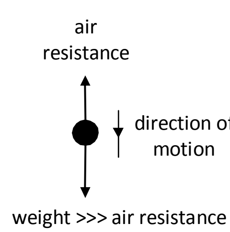
∴ To understand the graph better, the acceleration–time (a = dv/dt) graph is drawn.



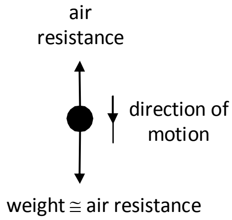
The non–linear parts of the acceleration–time graph will signify abrupt changes in the forces acting.

When the diver first jumps off the aircraft,

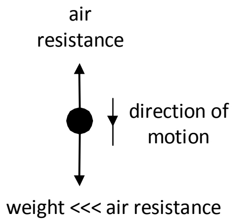
- He descends as if like a rock, acted upon only by a constant gravitational downward pull of the earth and negligible upward frictional (resistive) force offered by the clothing of the diver. The increase in speed is <u>linear</u> up to the point ❶.



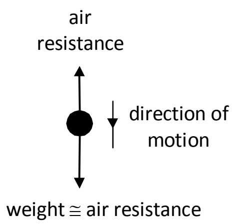
- The resistive force is dependent on the squared of speed of the moving object (turbulent flow), the higher the speed, the higher the resistance. After point ❶, the resistive force starts to "catch–up" with the gravitational pull. The increase in velocity slows. At point ❷, the resistance equals the weight of the diver. The diver descents at its *first terminal velocity*.



- At point ❷, the diver opens his parachute **fully**. The parachute starts to "catch" the wind and as a result, the air resistance increases to a very high value (due to the high speed). In fact it is so high that the resistive force now is much greater than its weight. The speed instead of holding steady, now decelerates sharply and linearly to a low value to point ❸.



- At the new low speed, the resistive force is again lowered to balance its own weight. At just before point ❹, the resistance equals the weight of the diver. The diver descents at its *second terminal velocity*.



- At point ❹, the diver lands and breaks into a short run on the landing pad.

∴ **The point that the diver's parachute fully open is**

Point ❸. **(ans)**

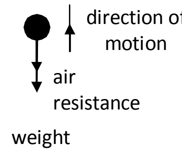
☒ A ☒ C ☒ D ☑ B

(B) (ans)

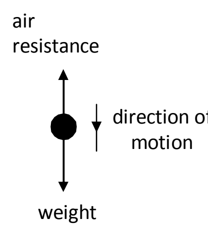
☺ **Air resistance**

Air resistance is a resistive *force* that opposes the *motion* of a body as it tries to push air (fluid) particles out of the way. *Air resistance* depends on the shape and speed of the body.

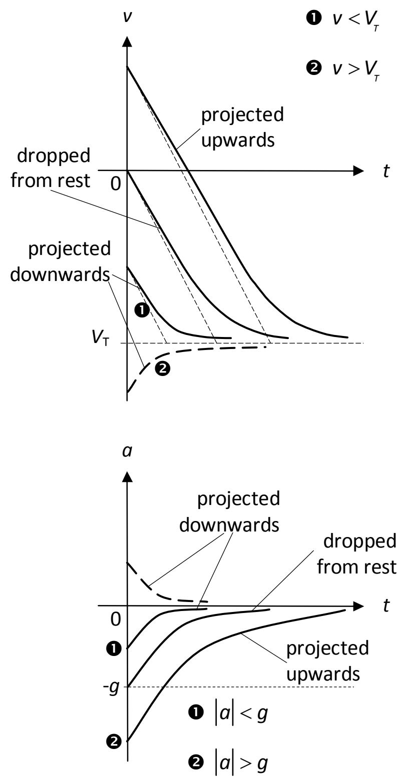
- Its *direction* is always opposite to the direction of motion. Its *magnitude* (f) is usually approximately proportional to the square of the speed (v) *i.e.*, $f \propto v^2$.
- Consider a body being projected vertically upwards. While the projectile is moving upwards, air resistance acts in the same direction as its weight, *i.e.*, downwards, and the body will decelerate at a higher rate than *g*.



- The projectile will eventually come to an instantaneous rest, at which point the body has risen to the maximum height of the projection, which will be lower than that without air resistance. Air resistance at this point is again zero.
- Thereafter, the projectile will reverse its motion vertically and increase speed as it falls, initially at a rate equal to *g*.
- As the projectile is moving downwards, air resistance acts in the opposite direction to its weight. The body will accelerate slower than *g*. It will therefore take a longer time to return to its original projection position. As the speed of the body increases, the magnitude of the air resistance increases and so the resultant force on the body decreases.



- Eventually, the body attains a speed at which the magnitude of the air resistance is equal to its weight, *i.e.*, the resultant force on the body is zero, and the speed of the body remains constant thereafter. This speed is referred to as the **terminal velocity**.
- The vertical *velocity-time* graph, where v_T denotes the *terminal velocity*, could be as shown.



☺ **CheckBack**

The knowledge from the *Ordinary Level syllabus* is inadequate in answering this question. The knowledge must come from the *Advanced Level syllabus* concerning **air resistance** and **terminal velocity**.

- The acceleration–time graph is an important graph to sketch. From this sketch, the candidate can deduce the abrupt change in the force deployment as Force, $\mathbf{F} = m\mathbf{a}$. An abrupt change in the acceleration is an abrupt application or loss of force(s).
- Only points ❷ and ❹ satisfy this condition. Point ❷ (high speed) therefore must represents the full opening of the chute and point ❹ (low speed) must represents the point of landing.
- The linear gradient of the speed–time graph usually represents an application of a constant singular force or a resultant of a constant force.

(checked)

☺ **Exam Report**

More than 50% of candidates did not give the correct answer to this question. The choice was frequently the wrong option (C). Candidates should be aware that the reduction of speed from a high 35 m s^{-1} (point ❷) to 15 m s^{-1} (point ❸) must be due to an application of a very large counteractive force to gravity. If the answer is point ❸, the reduction is only from 15 m s^{-1} (point ❸) to 9 m s^{-1} (point ❹).

If the chute is not deployed fully, how can the "effect" be so effective? If option (C) is ever allowed, then wouldn't the logical conclusion would be that the chute is better off half–deployed than fully deployed? Candidates were advised that when the deduction is difficult, the obvious choice is to select what appears to be the most logical.

§

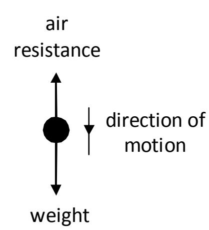
4. [Newtonian mechanics]

Method

Approach I – free body diagram

Galileo conducted an experiment regarding gravity. He dropped from the tower of Pizza two outwardly identical objects, *i.e.*, of the same size and shape, but of different weight. They are each dropped from rest.

∴ Comparing the initial accelerations and terminal velocities of the two objects,



Let the lighter object be named L.

Let the heavier object be named H.

Initially, velocities of the objects are zero.

⇒ Air resistance is negligible,

- For the light object (L),

  Net force = Weight

  $\mathbf{F}_{net} = \mathbf{W}_L \Rightarrow m_L \mathbf{a}_{initial} = m_L \mathbf{g} \Rightarrow \mathbf{a}_{initial} = \mathbf{g}$

- For the light object (H),

  Net force = Weight

  $\mathbf{F}_{net} = \mathbf{W}_H \Rightarrow m_H \mathbf{a}_{initial} = m_H \mathbf{g} \Rightarrow \mathbf{a}_{initial} = \mathbf{g}$

⇒ The initial accelerations for both objects = **g** (same, downwards) **(ans)**

After some time, the objects would have gained sufficient velocities and reached their respective terminal velocities, *i.e.*, their air resistances are balanced by their own weights.

$\Rightarrow$ Air resistance is no longer negligible.

- For the light object (L),

  Net force = Weight – Air resistance

  $\mathbf{F}_{net} = \mathbf{W}_L - \mathbf{R}_L = \mathbf{0} \Rightarrow \mathbf{W}_L = \mathbf{R}_L \Rightarrow m_L\mathbf{g} = \mathbf{k}v_L^2$

  $\Rightarrow v_L^2 = m_L\mathbf{g}/\mathbf{k} \Rightarrow v_L = (m_L\mathbf{g}/\mathbf{k})^{½}$

- For the heavier object (H),

  Net force = Weight – Air resistance

  $\mathbf{F}_{net} = \mathbf{W}_H - \mathbf{R}_H = \mathbf{0} \Rightarrow \mathbf{W}_H = \mathbf{R}_H \Rightarrow m_H\mathbf{g} = \mathbf{k}v_H^2$

  $\Rightarrow v_H^2 = m_H\mathbf{g}/\mathbf{k} \Rightarrow v_H = (m_H\mathbf{g}/\mathbf{k})^{½}$

$\Rightarrow$ Since $m_H > m_L$,

$v_H > v_L$ (downwards) **(ans)**

∴ Comparing the initial accelerations and terminal velocities of the two objects,

the heavier object has

☒ the higher initial acceleration and the higher terminal velocity.

☒ the higher initial acceleration and the same terminal velocity.

☒ the same initial acceration and the same terminal velocity.

☑ the same initial acceleration and the higher terminal velocity.

(C) (ans)

☺ **Terminal velocity**

In fluid dynamics, an object is moving at its **terminal velocity** if its speed is <u>constant</u> due to the restraining force exerted by the air, water or other fluid through which it is moving.

☺ **CheckBack**

The knowledge from the *Ordinary Level syllabus* is <u>inadequate</u> in answering this question. The knowledge must come from the *Advanced Level syllabus* concerning **air resistance** and **terminal velocity**.

- **Recall**, in the famous Galileo's experiment that Galileo proved that the acceleration due to gravity is <u>always the same</u> for objects of different mass. Therefore, a light object and a heavy object, when dropped, will both reach the ground at the same time, given negligible air resistance.

- But, if air resistance is not negligible and the two objects are <u>identical in their outward appearance</u>, then they will experience the <u>same air resistance</u> (**f**), given the same velocity (**v**).

  When the objects reaches the *terminal velocity* of the lighter object, *i.e.*, $\mathbf{f}_L = \mathbf{W}_L$, this air resistance ($\mathbf{f} = \mathbf{f}_L$) is still not enough to prevent the heavier object from continuing to accelerate towards the ground, the heavier object therefore, will only attain *terminal velocity* at a higher velocity, *i.e.*, $\mathbf{f}_H = \mathbf{W}_H \Rightarrow \mathbf{f}_H > \mathbf{f}_L \Rightarrow \mathbf{k}v_H^2 > \mathbf{k}v_L^2 \Rightarrow v_H > v_L$.

(checked)

☺ **Exam Report**

Quite a large number of candidates did not give the correct answer to this question. The choice was frequently the wrong option (D): "*the same initial acceration and the same terminal velocity*", based on the assumption the difference in mass did not affect the initial acceleration and terminal velocities.

This is incorrect. A heavier object will always have a much higher inertia to overcome and therefore will attain a higher velocity, before the resistive force can balance its own weight.

§

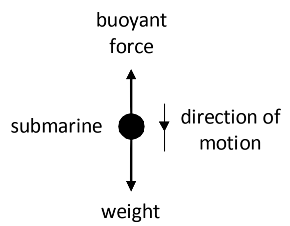
5. [Newtonian mechanics]

Method

Approach I – uniform speed

In a marine exploration, a small submarine of mass 1000 kg is made to sink in the sea with a **uniform speed** of 2 m s^{-1}.

∴ To deduce the resultant force exerted on the submarine as it sinks,



When the submarine dives (sinks) at a uniform speed,

It is not accelerating. $\Rightarrow$ acceleration = 0

∴ The resultant force exerted on the submarine as it sinks is

Net resultant force = mass × acceleration

$\mathbf{F}_{net} = m \times \mathbf{a} = m \times (0)$

$= \mathbf{0}$ **(ans)**

☒ 500 N

☒ 2 000 N

☒ 10 000 N

☑ 0 N

(A) (ans)

☺ **CheckBack**

If the answer is 0 N,

- Net resultant force = mass × acceleration

  0 = mass × acceleration

  Since mass ≠ 0,

  $\Rightarrow$ Acceleration = 0

  $\Rightarrow \dfrac{dv}{dt} = 0$

  Since change in speed is zero, the submarine must be travelling at constant speed.

(checked)

☺ **Exam Report**

The majority of the candidates gave the correct answer.

§

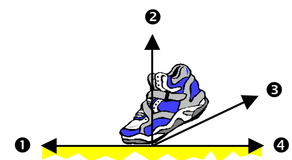
6. [Newtonian mechanics]

Method

Approach I – free body diagram

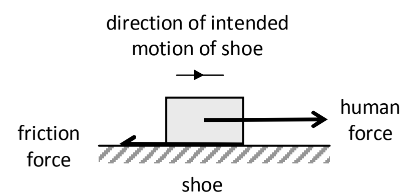
At a field event, the runner positions himself at the starting line in the diagram shown.

∴ To deduce the direction of the force of friction acting on the runner's shoe, when the runner starts to run,



The direction of the force of friction always opposes motion.

Sketching the free body diagram:



Since the shoe always wanted to slip to the right,

∴ The direction of the force of friction acting on the runner's shoe, when the runner starts to run, is

Direction ❶. (opposing motion) **(ans)**

☒ ❷ ☒ ❸ ☒ ❹ ☑ ❶

(A) (ans)