Year 5 July Physics Common Test Solution

16 **(a)** units of g = m s^{-2}
units of m = kg
units of ρ = kg m^{-3}
units of v = m s^{-1}
units of d^2 = m^2

$$\text{units of } C_d = \frac{(\text{kg})(\text{m s}^{-2})}{(\text{kg m}^{-3})(\text{m s}^{-1})^2(\text{m}^2)}$$ M1

$$= 1$$ A1

Some candidates incorrectly answered “0”. Take note that having no units is not the same as saying the unit of a constant is “0”.

(b) **(i)** Vernier callipers B1

Many candidates incorrectly identified micrometer screw gauge. Take note that the resolution of a micrometer screw gauge is 0.01 mm.

(ii)

$$C_d = \frac{8mg}{\pi\rho v^2 d^2} = \frac{8\left(\frac{3.64}{1000}\right)(9.81)}{\pi(1.23)(39.8)^2\left(\frac{9.6}{1000}\right)^2} = 0.5064036$$ B1

$$\frac{\Delta C_d}{C_d} = \frac{\Delta m}{m} + \frac{\Delta g}{g} + \frac{\Delta\rho}{\rho} + 2\frac{\Delta v}{v} + 2\frac{\Delta d}{d}$$

$$\frac{\Delta C_d}{0.5064036} = \frac{0.01}{3.64} + \frac{0.03}{9.81} + \frac{0.02}{1.23} + 2\left(\frac{0.1}{39.8}\right) + 2\left(\frac{0.1}{9.6}\right)$$ M1

$$\Delta C_d = 0.0243$$

$$\Delta C_d = 0.02 \text{ (to 1 s.f.)}$$ B1

$C_d = 0.51 \pm 0.02$ A1

Some candidates used the max-min method which is also accepted. Candidates who did not obtain full credit either made careless calculation errors or forgot to change the units to SI units. Some candidates did not provide the 5sf value for the intermediate value of C_d and used the 3 sf value instead for further calculations.

(iii) 1 Use an instrument with greater resolution such as micrometer screw gauge/travelling microscope. B1

2 Measure the length of two or more steel balls placed side by side and divide the length by number of steel balls. B1

Many candidates gave the answer of taking multiple readings of diameter of the same steel ball. This method does not reduce uncertainty in the measurement of diameter. It merely reduces the random error of measurements. The resolution of the instrument directly affects the uncertainty in the measurements taken. Some candidates gave the incorrect answer of using a larger steel ball to reduce uncertainty.

17 **(a)** $u_x = 15\cos 30°$

$= 13.0 \text{ m s}^{-1}$ B1

$u_y = 15\sin 30°$

$= 7.50 \text{ m s}^{-1}$ B1

*1 mark to be awarded if student uses radian mode instead

(b) Length of 14 crates = 1.5 × 14 = 21 m
Distance between top of ramp and top of crates = 2.5 – 1.5 = 1.0 m
To go over the 14 crates, the motorbike has to travel at least distance of 21 m after it has moved 1.0 m below the top of the ramp.

$$s = ut + \frac{1}{2}at^2$$

$$-1.0 = 15\sin 30° t + \frac{1}{2}(-9.81)t^2$$ M1

$$t = \frac{-(-1.0) \pm \sqrt{(-7.5)^2 - 4\left(\frac{1}{2}\right)(9.81)(-1.0)}}{2\left(\frac{1}{2}\right)(9.81)}$$

$$= 1.65243 \text{ s} \quad \text{or} \quad -0.12338 \text{ s (N.A.)}$$

$$s_x = u_x t$$

$$= 15.0\cos 30°(1.65243)$$ M1

$$= 21.4657 \text{ m}$$

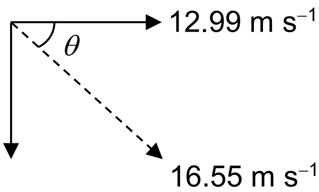
Since s_x is greater than 21 m, the motorbike will be able to go over the crates. A1

To go over the 14 crates without hitting them, the motorbike should be 1.5 m above ground at the end of the 14th crate. Many students either used ground level or 2.5 m height above ground to determine instead, which is wrong.

(c) By conservation of energy,
$KE_{initial} + GPE_{initial} = KE_{final} + GPE_{final}$

$$\frac{1}{2}m(15)^2 + 0 = \frac{1}{2}mv^2 + m(9.81)(-2.5)$$

$$v = 16.6 \text{ m s}^{-1}$$



$$\cos\theta = \frac{12.99}{16.55}$$

$$\theta = 38.3°$$

Direction of velocity is 38.3° clockwise from the horizontal

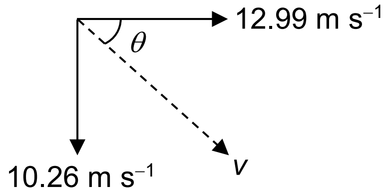
Or Taking upwards as positive,

$$v^2 = u^2 + 2as$$

$$v_y^2 = 7.50^2 + 2(-9.81)(-2.5)$$

$$v_y = -10.26 \text{ m s}^{-1}$$

$$v = \sqrt{10.26^2 + 12.99^2} = 16.6 \text{ m s}^{-1}$$



$$\tan\theta = \frac{10.26}{12.99}$$

$$\theta = 38.3°$$

Direction of velocity is 38.3° clockwise from the horizontal

Many students did not state the direction of velocity clearly. Stating that the velocity is 38.3° with the horizontal is not clear enough as it does not indicate whether it is above or below the horizontal.

We do not accept using North, South, East, West to indicate direction in this question as the question did not indicate which direction is North.

(d) With a greater angle and same horizontal component of velocity, the initial vertical velocity is higher. B1
Hence, the motorbike will be able to stay in the air longer and the motorbike will travel further horizontally. B1

Calculation of initial vertical component of velocity,

$$15\cos 30° = u\cos 35°$$

$$\begin{aligned} u_y &= u\sin 35° \\ &= \frac{15\cos 30°}{\cos 35°}\sin 35° \\ &= 9.1 \text{ m s}^{-1} \end{aligned}$$

Explaining that initial velocity is higher is insufficient. Students must explain that longer time duration is due to higher initial vertical velocity.

One mark is deducted for students who just wrote vertical component has increased as it can be interpreted as vertical component of displacement or velocity. The component that you are referring to must be clearly stated.

The question stated that Captain America left the ramp with a velocity that has the same horizontal component as indicated in **(a)**. However, a number of students did not read the question carefully and stated that the initial horizontal component of velocity has changed, hence changing the conditions stated in the question. No marks are awarded even if parts of the explanation are correct as students have changed the question.

18 **(a)** 1. Weight A1
2. Tension

Both forces must be correct to score the mark. Some students put down normal contact force, but that is exerted by sphere A on sphere B and vice versa, and are therefore internal forces (since both A and B are part of the system).

(b) Both the tension and the weight are acting in the vertical direction. M1
(weight and tension are perpendicular to the velocity/momentum just before the impact)
They do not affect the momentum in the horizontal direction. A1

- The most common mistake is to assume that the upward tension is equal and opposite to the weight. This is incorrect for sphere A because it is swinging in a vertical circular path and hence the tension is larger than the eight so that $T - W$ is equal to the required centripetal force.
- Weight and tension are negligible compared to normal contact force is not acceptable as this assumption is not required in this scenario.

Students should take note that “the external forces do not act in the same direction as the momentum” is not the same as the two being perpendicular which is what is required in the answer.

(c) Show understanding that area under graph is impulse and demonstrate a reasonable method on how to estimate the area. M1
Counting squares (5×5) = 12 squares $\times$ 2.5 $\times$ 0.005 = 0.15 N s A1
Accuracy of answer: 0.142 to 0.158 Ns.

An answer that is way out of the expected value is not awarded any marks.

> Students should state clearly that they are calculating the area under the graph. Showing some calculations without any explanation will be panelised.

(d) $\text{speed of A} = \dfrac{0.050 \times 4.0 - 0.150}{0.050} = 1.00 \text{ m s}^{-1}$ B1

$\text{speed of B} = \dfrac{0.150}{0.050} = 3.00 \text{ m s}^{-1}$ B1

> The most common mistake is to use the relative speed of approach = relative of separation which is true only for elastic collisions. If the question did not state the collision is elastic, please do not make such an assumption. The only exceptions are the collisions between elementary particles which will always be elastic.

(e) **(i)** t = 0.0125 s A1

> For graph readings, students should not round off the answer. They should read to the correct number of dp following the rules in practical. 0.013 is not acceptable.

(ii) By the principle of conservation of momentum,
$2mv = m\,(4.0)$ M1
$v = 2.0 \text{ m s}^{-1}$ A1

> Some students were penalised for very sloppy workings which are essential to score the marks. Simply scribbling some arithmetic calculations without explaining the physics will not score any marks.

19 **(a)** 1. The net force acting on the window panel is zero. B1
2. The net moment/torque about any point acting on the window panel is zero. B1

> Students need to refer to the panel (or the system) in some way in their answers. For rotational equilibrium, many students left out the "about any point" part, which is essential.

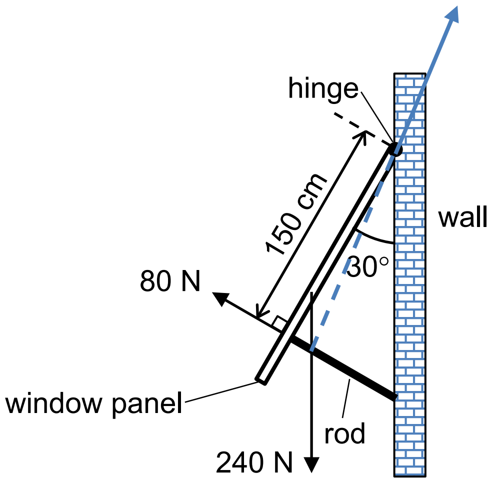
(b) The centre of gravity of the window panel is the point where its weight appears to act. B1

> The "appears to" part (or phrases to the same effect) is essential since weight does not in fact act on a single point but acts on every single subatomic particle within the object.

(c) Taking moments about the hinge. Let the distance be L.
sum of clockwise moments = sum of anticlockwise moments
$80 \times 150 = 240 \times L \times \sin 30°$ M1
$L = 100 \text{ cm}$ A1

> There were many careless mistakes regarding the angle, sine or cosine function, and distance vs. perpendicular distance. More care needs to be taken.

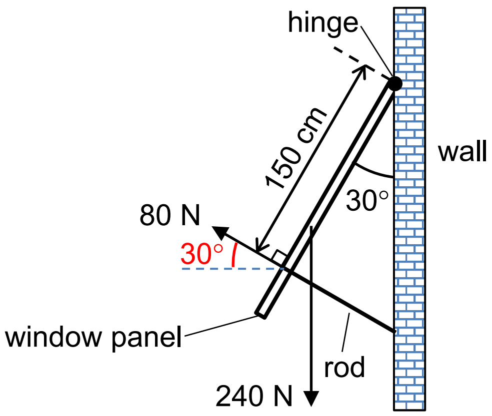
(d)



Line of action goes through the intersection of weight and force due to rod.	B1
Arrow points up and right and starts at hinge.	B1

The line of action passes through the intersection of the other two forces for rotational equilibrium. The arrow points up-rightwards for translational equilibrium (net force = 0). Many students considered only one type of equilibrium but not both.
Many students were under the impression that the force at the hinge must be along the rod, which is wrong. The force at the hinge can be in any direction, the only requirement is for the system to be in equilibrium.

(e)



horizontal component $= 80 \times \cos 30° = 69.3$ N
vertical component $= 240 - 80 \times \sin 30° = 200$ N
magnitude $= \sqrt{69.3^2 + 200^2} = 211.6 = 212$ N

B1
B1
B1

Some students used scale drawing. While the method itself is acceptable, many students did not draw sufficiently precisely, hence were penalised for obtaining different answers. The other two methods, namely vector resolution and cosine rule, yield the correct answer without much effort, as long as the correct number of s.f. is retained, hence are more recommended.

20 **(a)** let a be the acceleration of the box

$W = F s$
$= ma\, s$ B1
$= m \times \frac{1}{2}(v^2 - u^2)$
$= \frac{1}{2} m v^2 - \frac{1}{2} m u^2$ B1
= increase in E_K

This question requires students to derive the expression for the increase in E_K. However, some students quote the expression instead from the start and link it to work done. This flow of argument is not correct. There is a significant number of students who wrote incorrectly the increase in E_K as $\frac{1}{2} m(v - u)^2$. Students must realise that $\frac{1}{2} m(v^2 - u^2) \neq \frac{1}{2} m(v - u)^2$.

(b) **(i)** Work done by F = gain in KE + gain in GPE + WD against friction C1

$25 \times 3.0 = \frac{1}{2}(5.0)\, v^2 + (5.0)(9.81)(3.0 \sin 20°) + (4.0)(3.0)$ M1

$v = 2.25 \text{ m s}^{-1}$ A1

Students must make it a point to explain their workings. When the answer is incorrect, it is difficult for the marker to award any method marks when no explanation is given to the strings of numbers and workings. It is not uncommon to see students computing the contribution of GPE more than once, giving rise to an erroneous answer.

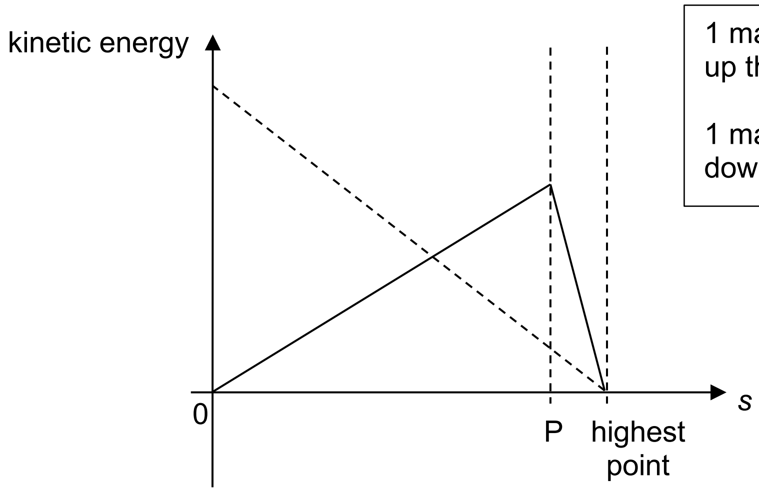
(ii) Friction is always opposite to the direction of change in displacement (throughout whole of the journey)
(The direction of friction changes and is always opposite to that of change in displacement). B1

There is negative work done by friction both on the way up and on the way down. B1

Hence total work done is not zero / the student is wrong / disagree.

Common mistakes include students defining work done in terms of "distance" instead of "displacement" and hence argued that direction is not needed. **Work done by a force is defined as the product of the force and displacement in the direction of the force.** A significant number of students also stated that since work done is a scalar, hence not necessary to consider directions. Although work done is a scalar, the quantity of force and displacement are vectors. Their directions will determine whether work done is a positive or negative number. If force and displacement are in the same direction, work done will be positive. If they are in opposite directions to each other, then work done will be negative. This is the case for friction. On the way up, friction acts downslope, while the displacement is upslope. On the way down, friction acts upslope while the displacement of its motion is downslope. Hence directions of the force and displacement are important in the calculation of the value of work done. Another common mistake is students stating "work done by friction is against the direction of motion". It is unclear whether students are refering to "work done" opposite in direction to velocity or is it "friction" in opposite in direction to velocity.

(iii)



1 mark: correct shape for E_K up the slope

1 mark: correct shape for E_K down slope

Note :
$\boldsymbol{E_K} = \frac{1}{2} mv^2 = \frac{1}{2} m(u^2 + 2a\boldsymbol{s})$ hence E_K **varies linearly** with s (straight line).

The value of the vertical intercept (for the downslope journey) is not assessed, as additional calculations will be needed to know its relative value compared to the value at P on the way up.

Only if the trend of **both** graphs is correct, but curves are drawn instead, one mark (out of two) is awarded.

For the journey up the slope, E_K starts from zero and increases until point P. When the external force stops acting, the box will slow down to a rest (zero E_K) at its highest point.

For the journey down the slope, the box starts from rest and slides down with an acceleration due to the force of gravity. Hence the value of E_K increases from highest point to s = 0.

Students need to understand that the horizontal axis is displacement and not time.

(iv) For the same F, friction and distance moved along the slope, work done by F and work done by friction are the same. Since the angle is increased, the increase in GPE is larger and the increase in KE is smaller. B1

Hence, the ratio decreases.

When the angle of the slope is increased, the work done by F will result in a greater increase in gPE and hence lesser increase in E_K.
The value of W is the same (for the same distance from start to point P and the same values of F and friction), but E_K is a smaller value. Hence the ratio will be smaller.

21 (a) Although the speed of the body is constant, its <u>direction is changing all the time</u>. Hence, its velocity is not constant but changes continuously. B1

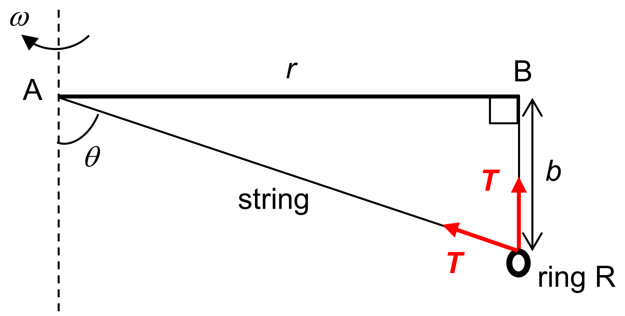
<u>Velocity is a vector</u>. Therefore, changes in direction means there is an acceleration. B1

Or Since the body is not travelling in a straight line, by <u>Newton's first law, it experiences a net force</u>. B1

By Newton's second law, it must have an acceleration. B1

This part was mostly answered correctly.

(b)



(i) Arrows representing T should be equal in length and drawn correctly. A1

Quite a number of students drew the arrows indicating the tension outside of the string. Some forgot to label with the letter "T".

(ii) Horizontally,

$$T\sin\theta = mr\omega^2$$ B1

$$\text{Since } \sin\theta = \frac{r}{L-b} \Rightarrow T\left(\frac{r}{L-b}\right) = mr\omega^2 \Rightarrow \frac{T}{L-b} = m\omega^2 \quad \ldots\ldots (1)$$

Vertically,

$$T\cos\theta + T = mg$$ B1

$$T(\cos\theta + 1) = mg$$

$$\text{Since } \cos\theta = \frac{b}{L-b} \Rightarrow T\left(\frac{b}{L-b}+1\right) = T\left(\frac{L}{L-b}\right) = mg \quad \ldots\ldots (2)$$

Dividing equation (1) by equation (2)

$$\frac{1}{L} = \frac{\omega^2}{g} \Rightarrow \quad \omega^2 = \frac{g}{L}$$

B1: use of $\sin\theta = \dfrac{r}{L-b}$ and $\cos\theta = \dfrac{b}{L-b}$

B1: correct manipulation of equations to get final answer

Very few students could do this part correctly. Some were able to write $T\sin\theta = mr\omega^2$ and $T\cos\theta + T = mg$ correctly, but were not able to proceed further with writing $\sin\theta = \dfrac{r}{L-b}$ and $\cos\theta = \dfrac{b}{L-b}$ to simplify the equations in order to show that $\omega^2 = \dfrac{g}{L}$.

(iii) **1.** $\omega = 2\pi f$

$$f = \frac{\omega}{2\pi} = \frac{\sqrt{\frac{g}{L}}}{2\pi} = \frac{\sqrt{\frac{9.81}{0.83}}}{2\pi}$$ M1

$$= 0.547 \text{ Hz}$$ A1

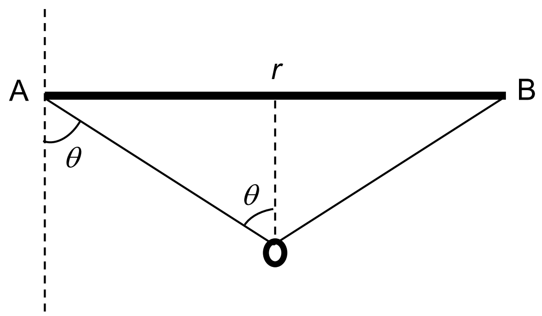
This part was not done as well as expected. Many students forgot to take the square root of *g*/*L* after substituting the numerical values of *g* and *L*. And quite many related *f* to ω wrongly.

2. From Fig. 21.1,

$$r^2 + b^2 = (L - b)^2$$

$$r^2 + 0.25^2 = (0.83 - 0.25)^2$$ M1

$$r = 0.5234 \text{ m}$$



The ring will come to rest directly below the midpoint of rod AB.

$$\sin\theta = \frac{\frac{1}{2}r}{\frac{1}{2}L} = \frac{0.5234}{0.83}$$

$$\theta = 39.1°$$ A1

This part was also not well done. Many students mixed up sin θ with cos θ.

22 **(a)** The higher pressure in the air cushion produces an <u>upward force</u> on the hull that is <u>equal (in magnitude) to the weight</u> of the hovercraft. B1
Or Resultant force due to the pressure difference is equal to the weight of the hovercraft.

Many students went into great detail about how the upward force came about but did not state that it balanced the downward force due to weight which results in the hovercraft floating (i.e. the hovercraft is in equilibrium) Many students also incorrectly identified the upward force as upthrust. Note that even though this upward force is indeed due to a pressure difference, this pressure difference did not come about due to a difference in height of the fluids surrounding it.

(b) $P = \dfrac{\text{force}}{\text{area}} = \dfrac{(230+350)\times 9.81}{8.5}$ M1

$= 669 \text{ Pa}$ A1

Many students failed to note the mass of a fully loaded hovercraft includes the mass of the empty hovercraft and the mass of the maximum load.

(c) (i) Ice is a solid and flat surface that allows the hovercraft to always float above it without any contact. B1

OR Ice is a solid and flat surface. No water needs to be displaced when moving over it.

Many students just restated the question, or incorrectly suggested that this maximum speed was due to the smooth ice providing the least friction.

In order for friction to do any work, the hovercraft has to be in contact with the ice.

However, a hovercraft hovers, and hence does not touch the ice, so a smooth surface would ensure that the skirting does not come in contact with any protrusions.

(ii)

$$P = Fv$$

$$0.7 \times 40.5 \times 10^3 = F \times \frac{80 \times 10^3}{3600}$$

$$F = 1.28 \times 10^3 \text{ N}$$

B1 substitution of P
B1 conversion of speed into m s^{-1}
A1 final answer

(d) (i) In 1 sec, B1

$$m = \pi r^2 \times \rho \times v = \pi\left(\frac{0.71}{2}\right)^2 \times 1.2v = 0.475v$$

(ii)

$$F = \frac{\Delta(mv)}{\Delta t} = m\frac{\Delta v}{\Delta t}$$

$$630 = \frac{0.475v \times (v-0)}{1}$$ M1

$$v = 36.4 \text{ m s}^{-1}$$ A1

(iii)

$$F = ma$$

$$630 = (230+350)a$$ M1

$$a = 1.09 \text{ m s}^{-2}$$ A1

Many students again failed to note the mass of a fully loaded hovercraft includes the mass of the empty hovercraft and the mass of the maximum load.

(e) (i) At constant speed, driving force F = resistive force
$P = Fv = kv^2 \times v = kv^3$ C1

$$\frac{P_{max}}{P_{cruising}} = \left(\frac{v_{max}}{v_{cruising}}\right)^3$$ M1

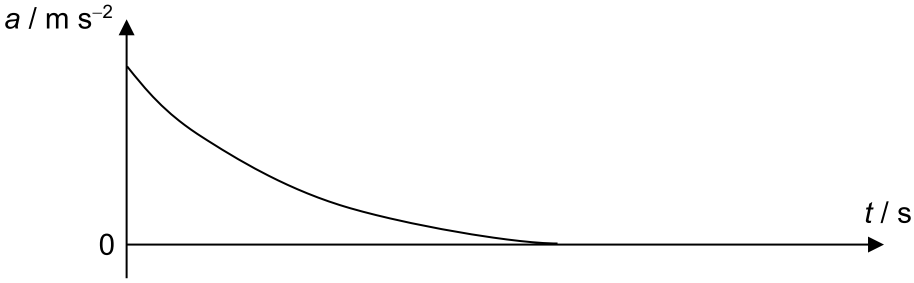
A1

$$\frac{0.7 \times 40.5 \times 10^3}{0.7 \times P} = \left(\frac{72 \times 10^3 / 3600}{56 \times 10^3 / 3600}\right)^3$$

$$P = 19.1 \text{ kW}$$

Most students were unable to answer this question. The maximum power output and maximum speed over calm water are provided in Table 22.1 and are required in answering this question.

(ii) B1



For information
$P = Fv$, at maximum power, as the velocity increases, the thrust T decreases.
The resistive force F_D also increases with the square of the velocity.
By Newton's second law, $T - F_D = ma$
Initially, the acceleration will be large and as velocity increases, the acceleration will decrease at a decreasing rate.
This is similar to an object falling from rest with air resistance and reaching a terminal velocity. The difference is the weight W of the object is constant.
$W - F_D = ma$

Many interesting graphs were drawn.

(iii) Power is proportional to the cube of the speed. If speed is doubled, the power required will be 8 times. B1

For the same distance travelled, the time taken is halved (as speed is doubled) and the overall fuel consumed will be 4 times. B1

Or

At a higher speed, the thrust is larger. For the same distance, the work done by the thrust is larger. B1

Hence, the amount of fuel (energy) required for the same distance is also larger and the distance travelled per litre of fuel is smaller. B1

For information
Let energy produced per litre of fuel to be E.
At speed v, $P_1 = kv^3$ and the time taken to travel distance d is t.

Amount of fuel used to travel distance d at speed v = $\dfrac{kv^3 \times t}{E}$

At speed $2v$, $P_2 = 8kv^3$ and the time taken to travel distance d is $\dfrac{t}{2}$.

Amount of fuel used to travel distance d at speed $2v$ = $\dfrac{8kv^3 \times \frac{t}{2}}{E} = 4\dfrac{kv^3 \times t}{E}$

In general, if speed is increased from v to αv, the amount of fuel used to travel the same distance will be α^2 times the original amount. The distance travelled per litre of fuel will be $\frac{1}{\alpha^2}$ times the original value.

When a hovercraft travels at a higher speed, the distance travelled per litre of fuel is smaller. Many students explained why it takes more energy to accelerate to a higher speed. Many students wrongly stated that the resistive force F_D increases exponentially with velocity. $F_D = kv^2$ is a quadratic function. $f(x) = k\,a^x$ is an exponentially equation. Students should **not** use the word “overcome”. The meaning of “overcome” is to succeed in controlling or dealing with something. When a force F moves an object through a distance d in the direction of the force, the work done by the force is $F \times d$. Power is rate of work done. Due to the force, there is work done and power. Hence, it is wrong to state that “At higher speed, more fuel/work done/power is required to overcome the resistive force”. Fuel contains chemical potential energy that can be converted to other forms of energy. Students need to explain how fuel is related to power by considering the same distance travelled.

(f) 1) A boat requires a minimum depth of water, but a hovercraft does not. Hence, it is able to reach very shallow waters that a boat cannot reach. B1

2) Survivors in water are in no danger of coming in contact with boat propellers that are in water. B1

3) A hovercraft is able to deliver casualties directly onto land whereas a boat requires a dock/pier or suitable beach.

4) Hovercrafts have higher speeds than boats and can reach survivors in a shorter time.

Students are required to apply the information provided in the main passage and consider the context of the question. For a rescue mission, the key consideration is reaching the accident site as quickly as possible. Hence, fuel efficiency, disturbance to marine life, wear and tear, maintenance costs and bring environmentally friendly are not important factors. Similarly, for operations in Singapore waters, the ability to operate in severe weather conditions or on ice or on land is irrelevant.