SINGAPORE JUNIOR PHYSICS OLYMPIAD 2017
SPECIAL ROUND

30 June 2017

ANSWER GUIDE

Section A: Multiple Choice Questions

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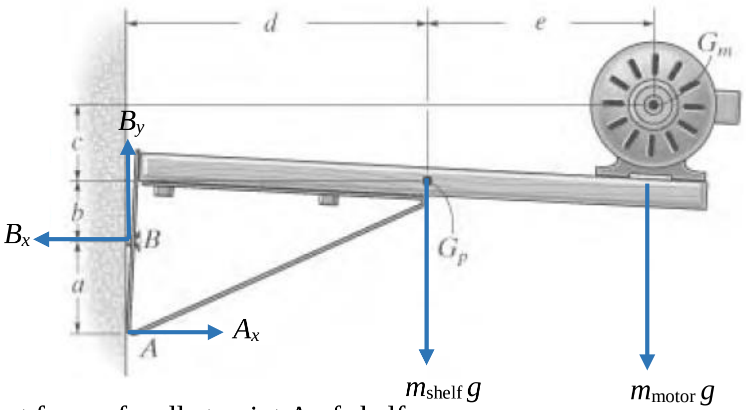
Answer	C	D	E	E	C	B	B	A	E	A

Section B: Structured Questions

1.(a)
(i) Translational equilibrium – Net force acting on a body is zero.
(ii) Rotational equilibrium – Net moment (torque) acting on a body about any point (axis), is zero.

(b)



Legend
A_x : Normal contact force of wall at point A of shelf
B_x : Horizontal force of bolt B on shelf
B_y : Vertical force of bolt B on shelf
$m_{\text{shelf}}\, g$: Weight of shelf
$m_{\text{motor}}\, g$: Contact force of motor on shelf (which in equilibrium, is equal to the weight of the motor)

(c)

$$\Sigma M_A = 0; \qquad B_x a - m_2 g d - m_1 g(d+e) = 0$$

$$B_x = g\,\frac{m_2\, d + m_1\, (d+e)}{a} \qquad \boxed{B_x = 989\ \text{N}}$$

$$\overset{+}{\rightarrow}\ \Sigma F_x = 0; \qquad A_x - B_x = 0$$

$$A_x = B_x \qquad \boxed{A_x = 989\ \text{N}}$$

$$+\uparrow \Sigma F_y = 0; \qquad B_y - m_2\, g - m_1\, g = 0$$

$$B_y = m_2\, g + m_1\, g \qquad \boxed{B_y = 186\ \text{N}}$$

(d)
The shelf is forced to vibrate due to the eccentric vibration of the motor. When the motor vibrates at a frequency equal to the natural frequency of vibration of the shelf, which acts like a cantilever, it may be possible for resonance to occur. The shelf amplitude of vibration of the shelf increases tremendously, which may cause the motor to be knocked off or to slide off the shelf.

Q2.

(i) $\lambda_n = \frac{2l}{n}$

(ii) Pitch – refers to the frequency of the sound produced.
Timbre – refers to the "richness" (or quality) of the sound, which is related to the presence and range of harmonics and the relative amplitudes between harmonics.

The pitch of the string should not change. However, plucking near the end of the string changes the relative amplitudes between harmonics, and could allow for the higher harmonics to sound louder, changing the timbre of the sound produced.

(c)
(i) From the given information, we have
$\frac{f_k}{f_0} = 2^{(k/12)}$, where k is the fret number, and f_0 is the frequency of sound for the 0th fret (open string).

If the two notes are played p frets apart, the frequencies are related by

$$\begin{aligned}\frac{f_{p+k}}{f_k} &= \frac{f_{p+k}}{f_0}\frac{f_0}{f_k} \\ &= 2^{(p+k)/12}2^{-(k/12)} \\ &= 2^{(p/12)}\end{aligned}$$

(ii)

$$\begin{aligned}v &= f\lambda \\ &= (110)(0.616\times 2)\text{ m/s} \\ &= 135.52\text{ m/s} \\ &\approx 136\text{ m/s}\end{aligned}$$

(iii) The relationship is $\frac{L_k}{L_0} = 2^{-(k/12)}$.

Student can plot several possibilities (list is not exhaustive), from the above relationship:

y-axis	x-axis	Gradient	y-intercept
$\text{Log}_2 (L_k / L_0)$	k	-1/12	0
$\text{Log}_2 (L_0 / L_k)$	k	12	0
$\text{Log}_{10} (L_k / L_0)$	k	$-(1/12)\ \text{Log}_{10}(2)$	0
$\text{Log}_{10} (L_0 / L_k)$	k	$12\ \text{Log}_{10}(2)$	0
L_k	$2^{-(k/12)}$	L_0	0

(v)

$$\Delta l_k \approx 2\Delta l \approx 2\times\left(\text{half of smallest division on metre rule}\right) = 2\times\left(0.0005\,\text{m}\right) = 0.001\,\text{m}$$

Or, add errors in quadrature:

$$\Delta l_k \approx \sqrt{2\Delta l^2} = \sqrt{2}\times\left(0.0005\,\text{m}\right) \approx 0.0007\,\text{m}$$

Leave the uncertainty estimate to 1 significant figure.

Note: Bonus marks were awarded for clarity in the presentation of graph and accurate representation of tabulated data. This means taking care of relevant significant figures and decimal places with sound scientific reason, rather than the standardized exam-oriented O level SPA sense.

Q3.

(i)

$$[\rho][A][v^2] = \text{M}\,\text{L}^{-3}\,\text{L}^{2}\,\text{L}^{2}\,\text{T}^{-2} = \text{M}\,\text{L}\,\text{T}^{-2} = [F]$$

(ii) At terminal velocity,

$$F_{drag} + U - mg = 0$$

$$\frac{1}{2}C_D\rho_{\text{air}}Av_t^2 + \rho_{\text{air}}Vg - \rho_{\text{water}}Vg = 0$$

$$v_t^2 = \frac{2(\rho_{\text{water}} - \rho_{\text{air}})Vg}{C_D\rho_{\text{air}}A}$$

$$v_t = \sqrt{\frac{2(1000-1.29)(\frac{4}{3}\pi\times 0.0015^3)9.81}{0.5\times 1.29\times(\pi\times 0.0015^2)}}\ \text{m/s}$$

$$\approx 7.8\ \text{m/s}$$

Note: Students may omit upthrust in the calculation since that is small. However, this should be accompanied by sound reasoning.

(iii) Use the value of terminal velocity found in part (ii).

$$P = \frac{N}{A} = \frac{nmv_t + mg}{A} \approx 0.028\,\text{Pa}$$

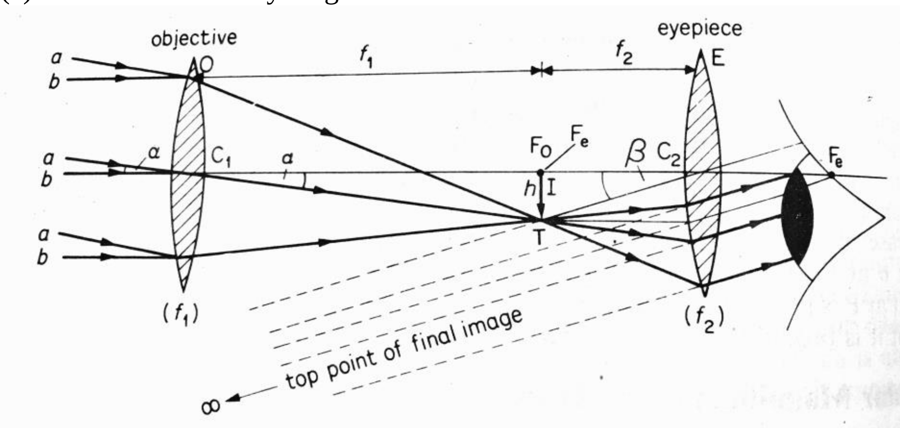
Note: Students may also obtain the same numerical answer by merely consideration of change of momentum, due to the small weight of the raindrops. However, this has to be accompanied by sound reasoning.

(iv) Larger raindrops may experience greater drag as the drag force deforms the raindrop into a flatter shape, thereby increasing the cross-sectional area exposed to drag.

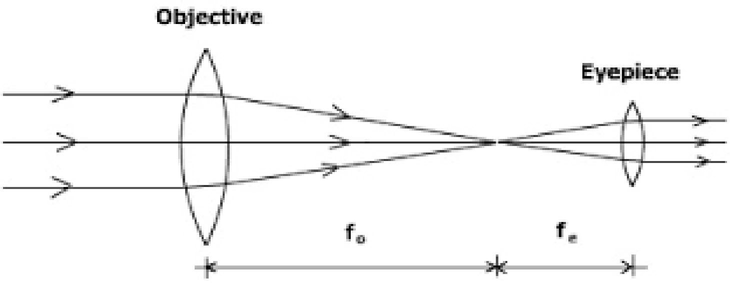
(v) An increase in atmospheric temperature decreases the density of the air. This increases the terminal velocity since less dense air means less air resistance.

Q4.

(a) Either one of the ray diagrams below:



OR



The big lens in the **telescope** (objective lens) collects much more light than your eye can from a distant object and focuses the light to a point (the focal point) inside the **telescope**. A smaller lens (eyepiece lens) takes the bright light from the focal point and magnifies it so that it uses more of your retina. Hence the distance between the objective lens and eyepiece lens in the telescope must be equal to the sum of the two focal length (f_1 + f_2).

(b)
M = 120/5 = 24.
The angular magnification is also the magnifying power. (It is called the angular magnification because it is also given by the fraction $\frac{\beta}{\alpha}$ (see diagram), which is the ratio of the angle of the image subtended at the eye to the angle of the object subtended by the unaided eye.)

With reference to the first diagram above, $\tan(\alpha) = \frac{h}{f_1}$ and $\tan(\beta) = \frac{h}{f_2}$. Therefore the magnification:

$$M = \frac{f_1}{f_2} = \frac{h}{\tan(\alpha)} \cdot \frac{\tan(\beta)}{h} = \frac{\tan(\beta)}{\tan(\alpha)} \approx \frac{\beta}{\alpha} \quad \text{(for small α and β)}$$

(c)
Statement I – False.
The *smaller* the value of θ, the closer together two distant objects can be for a telescope to resolve them.

Statement II – False.
The magnification is independent of the resolving power of a telescope.

Q5

(a)

When sweat evaporates, it changes from liquid to vapour. This takes heat (energy) to break the bonds of the liquid. The heat comes from the skin. Therefore, as sweat evaporates, it takes heat away from the skin, lowering its temperature.

(b)

$P_{\text{jog}} = (0.80)(1300\text{ W}) = 1.04 \times 10^3$ J/s.

(c) $H_{net} = (1.85)(1.00)(5.67 \times 10^{-8})(306^4 - 311^4)\text{ W} =$ -61.6 W.

The person gains 61.6 W of heat each second by radiation.

(d) 1102 J/s.

(e) 27 g

(f)

Note: Students need to give any sensible estimate of the heat capacity of the human body and calculate from there.

$\Delta T = \dfrac{Q}{mc}$

E.g. $Q = 1.98 \times 10^6 J,\ \Delta T \approx 6 \sim 8℃$

Note: Bonus marks have been given to part (f) only: 1 bonus mark is given for any sensible estimation of specific heat of human body and 5 bonus marks are given for getting a differential equation.