2024 Promotion Examinations H2 Physics Solutions

1 **B** Actual mass of a single coin is 7.62 g.
The total mass of eight coins is about 60 g which is 0.6 N
0.06 N is too small as it means that the mass of a single coin is less than 1 gram.
6 N is about the weight of a full 500 ml water bottle, which is too high.
60 N is about the weight of a 6 kg mass, which is definitely too high.

2 **C** Acceleration $= \dfrac{8-2}{1} = 6 \text{ m s}^{-2}$

Distance $s = \frac{1}{2}(2\times 1) + \frac{1}{2}(8+2)\times 1 + \frac{1}{2}(8+10)\times 3 = 33 \text{ m}$

3 **A** $v^2 = u^2 - 2as$ where a is positive.

$v = \sqrt{u^2 - 2as}$

$= \sqrt{2a\left(\dfrac{u^2}{2a} - s\right)}$

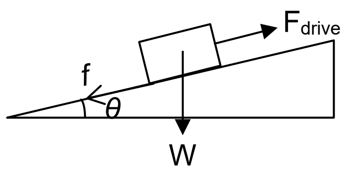
The graph of v against s is a "square-root" graph, i.e., a parabola. The gradient at the x-intercept should be infinite and the gradient at the y-intercept should be non-zero.

Option C is wrong as the gradient at x-intercept is not infinite and the gradient at y-intercept is zero.

4 **D** Change in momentum occurs in the horizontal direction (no change in the vertical direction)
Impulse = change in momentum = ($p \cos\theta$) – (– $p \cos\theta$) = $2p \cos\theta$

5 **B** The box is at rest on the seabed and there is no resultant force. $W = T + N + S$
If the box is lifted, $N = 0$ and $W \le T + S$. Hence, option A is wrong as it means that the box can be lifted.
The box has to be at rest on the seabed before the attempt was made to lift it. Option C is wrong as it implies that the box is moving into the seabed (the total downward force is greater than the total upward force).
Upthrust acts on the box and is not included in the equation. Option D is wrong as S has to be in the equation.

6 **D**



Angle of inclination of escalator $\theta = \sin^{-1}\left(\dfrac{30}{60}\right) = 30°$

To move the escalator at constant speed v without passengers,

$F_{drive} = f + W \sin 30°$

Power needed $P = F_{drive} v = 2.0 \text{ kW}$

With 15 passengers on the escalator, to move at the same constant speed v,

$F_{drive}' = f + W \sin 30° + 15(60)(9.81)(\sin 30°)$

$F_{drive}' = F_{drive} + 4414.5$

Power needed $P' = (F_{drive}')(v)$

$P' = (F_{drive} + 4414.5)(0.6)$

$P' = 2000 + 2648.7 = 4648.7 \text{ W} = 4.6 \text{ kW}$

7 **C** GPE per unit time $= (1.5\times10^{5})(9.81)(120) = 1.7658\times10^{8}$ W

$P_{in} = 1.7658\times10^{8}$ W

Since $P_{out} = 100$ MW,

Efficiency = $\dfrac{100\times10^{6}}{1.7658\times10^{8}}\times100\% = 56.6\%$

8 **B** The hour hand takes 12 hours to make a revolution.

$v = r\omega = 0.25\times\dfrac{2\pi}{12\times60\times60} = 3.6\times10^{-5}$ m s^{-1}

9 **A** The highest potential between P and Q is less than zero but greater than −60 MJ kg^{-1}.
To project the 1.0 kg mass from P to Q, it will require energy $E < 60$ MJ to reach this point of highest potential.

10 **D**

$$
\begin{aligned}
K_0 &= \frac{1}{2}mv_0^{\,2} \\
&= \frac{1}{2}m\left(\omega x_0\right)^2 \quad (\because v_0 = \omega x_0) \\
&= \frac{1}{2}m\left(\frac{2\pi}{T}x_0\right)^2 \quad \left(\because \omega = \frac{2\pi}{T}\right) \\
&= \frac{2\pi^2 m x_0^{\,2}}{T^2} \\
&= \frac{2\pi^2\left(0.25\right)\left(0.050\right)^2}{0.64^2} \\
&= 0.030 \text{ J} \\
&= 30 \text{ mJ}
\end{aligned}
$$

11 **C** This is a free oscillation as there are no driving forces acting on it.

12 **D**

intensity $= \dfrac{2.9\times10^{-6}}{0.60\times10^{-4}} = \dfrac{P}{4\pi(3.0)^2}$

$P = 5.5$ W

13 **B** Intensity $I_1 = (\cos 20^{o})^2 I_0 = 0.88 I_0$

Intensity $I_2 = (\cos 30^{o})^2 I_1 = 0.66 I_0$

14 **C** Q and R are in phase as they are between the same two adjacent nodes.
For option A, all particles separated by a node are in antiphase.
For option B, R and Q are equal distance from the antinode and have the same amplitude.
For option D, since P is the antinode, its amplitude and hence maximum speed are the largest.

15 **A** $d\sin\theta = n\lambda$

$$\lambda = \frac{\left(\dfrac{1}{500(1000)}\right)\sin 42^{o}}{2} = 6.7\times10^{-7} \text{ m}$$

16 (a) (i)

$$\text{units of } E = \frac{(\text{N})(\text{m})}{(\text{m}^2)(\text{m})} = \text{N m}^{-2}$$ B1

$$\text{Pa} = \frac{\text{N}}{\text{m}^2} = \text{units of } E$$

Marker's comments:
- The working for this question was very poorly done with students equating quantities to units, or wrongly using square brackets to indicate dimensions e.g. *F* = [N].
- Many students went on auto pilot and derived the base units of *E* and equated it to Pa without explaining that the units of *E* is equivalent to that of force divided by area which is therefore Pa.

(ii)

$$E = \frac{FL}{Ae}$$

$$= \frac{(10.0)(0.500)}{\frac{\pi(0.5\times10^{-3})^2}{4}(0.21\times10^{-3})}$$ M1

$$= 1.2126\times10^{11} = 1.21\times10^{11}\text{ Pa}$$ A1

Marker's comments:
- Common mistakes were:
  - Forgetting to convert mm to m
  - Using the diameter instead of the radius in the formula πr^2
  - Using the wrong formula for cross-sectional area
  - Not being able to round of the answer to **three** significant figures
  - Rounding up instead of rounding off the final answer.

(iii)

$$\frac{\Delta E}{E} = \frac{\Delta F}{F} + \frac{\Delta L}{L} + \frac{\Delta A}{A} + \frac{\Delta e}{e}$$

$$= \frac{\Delta F}{F} + \frac{\Delta L}{L} + 2\left(\frac{\Delta d}{d}\right) + \frac{\Delta e}{e}$$ M1

$$= \frac{0.1}{10.0} + \frac{0.001}{0.500} + 2\left(\frac{0.1}{0.5}\right) + \frac{0.01}{0.21}$$

$$\Delta E = 0.4596\times(1.2126\times10^{11}) = 0.6\times10^{11}\text{ Pa (1 sf)}$$ M1

$$E = (1.2\pm0.6)\times10^{11}\text{ Pa}$$ A1

Marker's comments:
- An alternative method would be to use the maximum minimum method.
  - However, a large number of students failed to recognise that to get maximum *E*, maximum values for *F* and *L* as well as **minimum** values for *A* (and hence *d* or *r*) and *e* have to be used. The opposite is true to find minimum *E*.
  - Also, many students forgot to divide the difference between maximum and minimum by 2.
- Common mistakes following the determination of $\frac{\Delta E}{E}$ were
  - Forgetting to multiply this value by *E* to get ΔE
  - Not rounding off ΔE to 1 s.f.
  - Not rounding off *E* to the correct number placement.

(b) *d* contributes most significantly. M1
Use a micrometer screwgauge to measure the diameter. A1

Marker's comments:
- Many students correctly identified diameter as the quantity with the largest percentage uncertainty.
- Many students suggested to use a wire with a larger diameter. This is wrong as it changes the whole experiment.
- There were suggestions to measure the diameter of the wire several times in different places and take the average of the readings. This does not affect the uncertainty in *E*.
- Students who suggested to use a "more precise instrument" should provide the name of the instrument.
- Vernier Calipers (VC) is not accepted unless it is specifically stated that a digital VC with a higher precision to at least 0.01 mm is to be used. Otherwise, a standard VC's precision is 0.1 mm which is the same as the uncertainty in the diameter.
- Putting several wires together to measure the diameter will not work. The wires are assumed to be round and will not be able to stay in a straight line that allows you to measure all the diameters in one straight line. This introduces more uncertainty and random error into the measurement.
- Winding up the wires to do the same is a slightly better method but also introduces a significant amount of random error into the measurement.
- Using the "instrument used to measure *e*" to measure *d* is not acceptable as the method and instrument used to measure extension cannot be used to measure diameter.

17 **(a)** Consider motion in the *x*-direction.

$$4.0 = u\cos 60° \times t$$

$$t = \frac{4.0}{u\cos 60°}$$ M1

Consider motion in the *y*-direction. By $s = ut + \frac{1}{2}at^2$,

$$1.0 = u\sin 60°\left(\frac{4.0}{u\cos 60°}\right) - \frac{1}{2}(9.81)\left(\frac{4.0}{u\cos 60°}\right)^2$$ M1

$$u = 7.28 \text{ m s}^{-1}$$ A1

Marker's comments:
Most students are able to write down the corrections describing the horizontal and vertical motion. However, a significant number of students encounter difficulties solving the two equations simultaneously. There were also a number of students who mixed up *t* and t^2.
Some students set v_y to 0 to find *t*, without realizing that the value of *t* found is for the highest point of the trajectory, not when the ball enters the net.

(b) $$t = \frac{4.0}{u\cos 60°} = \frac{4.0}{7.28\cos 60°} = 1.10 \text{ s}$$ A1

Marker's comments:
This part is generally well done. However, students who quoted a value for *t* obtained in **(a)** using wrong physics are not given any credit here. ECF is given only if they used a wrong value from **(a)** and apply it to a correct equation in **(b)**.

(c) By $v^2 = u^2 + 2as$,

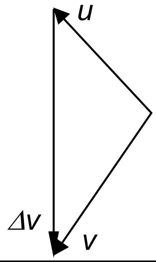
$0 = (u\sin\theta)^2 - 2gs$ M1

$s = \dfrac{(7.28\sin 60°)^2}{2\times 9.81} = 2.02$ m M1

Hence, maximum height $= 2.02 + 2.0 = 4.0$ m A1

Marker's comments:
Most of the mistakes stem from confusing the time found in **(b)** with the time to reach the highest points.

(d) The horizontal component of *u* and *v* are the same.
Hence, the change in velocity Δv is the change in the vertical velocity.



$\Delta v = gt$

$= 9.81 \times 1.10$ M1

$= 10.8$ m s^{-1} A1

Marker's comments:
Only a small number of students get this part correct. Many students determined the magnitude of the final velocity and subtract the initial magnitude from it. That is, they calculated $|v| - |u|$, instead of $|v - u|$ asked by the question. The two are equal only if *v* and *u* are parallel. There are a number of students who visualized the wrong vector diagram that implied $v + u = \Delta v$.

18 (a) The seats are moving in circular motion, hence a centripetal force that is directed towards center of circular motion is required. B1
There are only weight of the seat (gravitational force) and tension in the cable acting on each seat. B1
As weight is always pointing downwards, the cables must incline at an angle to the vertical away from the axis of rotation such that the horizontal component of the tension in the cable provides the centripetal force. B1

Marker's comments:
Many students explained why the centripetal force acts towards the center of the carousel or why centripetal force is perpendicular to the direction of motion/velocity of the seats. These are not relevant in explaining the inclination of the cable.
Other explanations that are not relevant include explaining that the vertical component of the tension is equal to the weight of the seat or explaining what happens if the cable is not inclined. Students should use key terms such as "centripetal force", "tension", "weight", "horizontal component" and "provides". In particular, students should not use the following terms in place of "provides", such as "account for", "compensates", "opposes", "balances", "counteracts" or "combats".

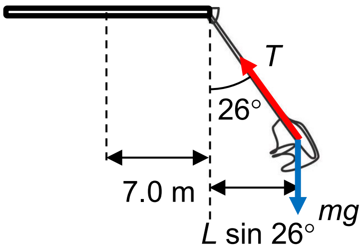
(b) B1

$\omega = \dfrac{2\pi}{T} = \dfrac{2\pi}{8.7} = 0.72221 = 0.72$ rad s^{-1}

(c) The distance from the seat to the centre of the circular path is (7.0 + L sin 26°) M1

Vertically: $T\cos\theta = mg$ — (1)

Horizontally: $T\sin\theta = m(R + L\sin\theta)\omega^2$ — (2) M1



$\frac{(2)}{(1)}$: $\tan\theta = \frac{(R+L\sin\theta)\omega^2}{g}$

$$\tan 26° = \frac{(7.0 + L\sin 26°)(0.72)^2}{9.81}$$

$L = 5.09$ m A1

> Marker's comments:
> This question is similar to the Motion in a Circle tutorial question SP7. It was surprising that many students mistook it for an Oscillations question and tried to use $T = 2\pi\sqrt{\frac{l}{g}}$ to solve this question. Students should not quote $\tan\theta = \frac{r\omega^2}{g}$ or $\tan\theta = \frac{v^2}{rg}$ to solve this question as recalling of these equations is not required in the syllabus. Students should derive the necessary equation using Newton's Second law.

(d) The <u>equation</u> $\tan\theta = \frac{(R+L\sin\theta)\omega^2}{g}$ relating the angle with angular velocity <u>is independent of the mass</u>. Hence, there is no change in the angle. B1

19 **(a)** The <u>gravitational force provides the centripetal force</u> for the circular motion. B1

$$G\frac{Mm}{r^2} = mr\omega^2$$

$$G\frac{Mm}{r^2} = mr\left(\frac{2\pi}{T}\right)^2$$ M1

$$T^2 = \frac{4\pi^2}{GM}r^3$$

> Marker's comments:
> Students should explain that "the <u>gravitational force provides the centripetal force</u> for the circular motion" to get this B1 mark.

(b) **(i)** The larger the orbital period T, the further the planet is to the star. B1
In increasing order of distance from star: ρ–Cancri A (e, b, c, f, d).

(ii)

$$M = \frac{4\pi^2 r^3}{GT^2}$$

From data on planet ρ – Cancri A d,

$$M_1 = \frac{4\pi^2(8.83\times10^{11})^3}{6.67\times10^{-11}(5480\times24\times3600)^2} = 1.8177\times10^{30}\text{ kg}$$ M1

From data on planet ρ – Cancri A e,

$$M_2 = \frac{4\pi^2(5.69\times10^{9})^3}{6.67\times10^{-11}(2.80\times24\times3600)^2} = 1.8631\times10^{30}\text{ kg}$$ M1

average value of $M = \frac{1.8177\times10^{30} + 1.8631\times10^{30}}{2} = 1.84\times10^{30}$ kg A1

Marker's comments:
Many students did not convert days to seconds. Many also did not square the period and cube the radius when working out the numerical answers for the masses.

(c) (i) gravitational field strength, $g = G\dfrac{M}{R^2}$

$$\frac{g_{\text{star}}}{g_{\text{sun}}} = \frac{\left(M/R^2\right)_{\text{star}}}{\left(M/R^2\right)_{\text{sun}}} = \frac{0.905}{(0.943)^2}$$ M1

$$= 1.0177 = 1.02$$ A1

Marker's comments:
Many students gave the wrong formula for gravitational field strength.

(ii) Mass of Sun = $\dfrac{1.84\times10^{30}}{0.905} = 2.033\times10^{30}$ kg

$$T^2 = \frac{4\pi^2}{GM}r^3$$

$$(365\times24\times3600)^2 = \frac{4\pi^2}{G\times2.033\times10^{30}}r^3$$ M1

$$r = 1.51\times10^{11}\text{ m}$$ A1

Marker's comments:
Quite a number of students did not know what the period of orbital motion of the Earth around the Sun is, or did not convert 365 days to seconds.

20 **(a)** There is a <u>constant phase difference</u> between the waves. B1

Marker's comments:
There are some students who continue to discuss the wave having the same frequency, which is not a required answer for this question.

(b) $x = \dfrac{18\times10^{-3}}{5.5}$ C1

$$x = \frac{\lambda D}{a}$$

$$a = \frac{(5.2\times10^{-7})(2.8)}{\left(18\times10^{-3}\right)/5.5} = 4.45\times10^{-4}\text{ m}$$ A1

Marker's comments:
There are a number of students who did not managed to calculate the correct value of the fringe separation. The fringe separation is the distance between two adjacent bright fringes or dark fringe.
There are also a small number who spend time deriving the formula instead of recalling the formula directly.

(c) (i) 180° A1

Marker's comments:
There are some students who did not realise that a dark fringe corresponds to the waves meeting in anti-phase or 180° out of phase.

(ii) One fringe separation corresponds to 360°.

$$\phi = \frac{\text{distance}}{\text{fringe separation}}\times360^\circ = \frac{4.0\times10^{-3}}{\left(18\times10^{-3}\right)/5.5}\times360^\circ = 440^\circ$$ M1 A1

(d) **(i)** No change as wavelength, slit separation and distance between slits and screen remain the same. B1

Marker's comments:
There are some students who did not explain why there is no change in the fringe separation even though the question mentions "state and explain".

(ii) Lower intensity as less light passes through the narrower slit. B1

Marker's comments:
The greater spreading results in lower intensity from one slit.

(iii) Higher intensity as there is no total cancellation of the two waves (due to different amplitudes). B1

Marker's comments:
There are some students did not state clearly the intensity of the dark fringe has increased.

21 **(a)** For a longitudinal wave, vibration / oscillation (of particles) is parallel to direction of energy transmission/transfer.
For a transverse wave, vibration / oscillation (of particles) is perpendicular to direction of energy transmission/transfer
Correct direction of vibration/oscillation B1
Direction of energy transfer B1

Marker's comments:
"Oscillation is in the same direction of energy transfer" for longitudinal wave is not correct as particles undergoing oscillation changes direction every half a period.
It is required to state the direction of energy transfer instead of direction of propagation of wave.

(b) **(i)** Let t be the time taken for the S-waves to travel from the epicentre of the earthquake to the seismograph.

$$v_P\left(t-\Delta t\right)=v_S t$$

$$7.98\left[t-\left(2\times 60+50\right)\right]=4.75t$$ M1

$$t=420\text{ s}$$ A1

Marker's comments:
Many students found the time taken (150 s) for the P-waves instead of S-waves (420 s).

(ii)

$$\begin{aligned} d &= v_S t \\ &= 4.75\left(420\right) \\ &= 1995 \\ &= 2000\text{ km} \end{aligned}$$ A1

(c) S-waves (transverse waves) cannot travel through fluid / liquid / liquid outer core. B1

Marker's comments:
Transverse (mechanical) waves cannot travel through fluid as there is no mechanism in fluids to drive the perpendicular motion of the particles. However, light is an exception because it does not require a medium to travel.

Water waves can travel along surface between the water and air due to surface tension.

Below is a good video animation to explain how P-waves and S-waves travel during earthquake.

scan QR code to watch or via this link:
https://www.youtube.com/watch?v=7eeqzRUg4DU&t=111s (Seismic Shadow Zones – Introduction to P and S wave shadow zones)

(d) (i)

$$a_0 = \omega^2 x_0 = \omega(\omega x_0) = \omega v_0 = (2\pi f) v_0$$

$$f = \frac{a_0}{2\pi v_0}$$

$$= \frac{0.90}{2\pi(0.081)} \qquad \text{M1}$$

$$= 1.7684$$

$$= 1.77 \text{ Hz} \qquad \text{A1}$$

$$v_0 = \omega x_0$$

$$x_0 = \frac{v_0}{\omega}$$

$$= \frac{v_0}{2\pi f}$$

$$= \frac{0.081}{2\pi(1.7684)}$$

$$= 7.29 \times 10^{-3} \text{ m} \qquad \text{A1}$$

Marker's comments:

Avoid rounding off values to 2 or 3 s.f. in intermediate steps, e.g. $\omega = \frac{0.90}{0.081} = 11.11...$

Some students round off to 11.1 and it affects the final value of frequency and amplitude.

(ii)

$$a_0 = \sqrt{a_x{}^2 + a_y{}^2 + a_z{}^2} \qquad \text{M1}$$

$$= \sqrt{8.0^2 + 2(1.5^2)} \qquad \text{M1}$$

$$= 8.3 \text{ m s}^{-2} \ (\text{shown})$$

Marker's comments:
Some students merely added the accelerations without considering the directions which is incorrect. Students are to express their final answer as 8.3 m s^{-2} as given by the question.

(iii) Accelerations in the three directions may not be at peak values at the same time. B1

Marker's comments:
The maximum ground accelerations given are measured, and are therefore due to the resultant forces in the three perpendicular directions. As such, answers that stated or referred to the existence of frictional forces for e.g., there is loss in energy (to heat and sound) were not given credit. Some students incorrectly stated that some of the accelerations are positive while others are negative. This is incorrect as directions of accelerations do not cause the resultant ground acceleration to change (squaring eliminates the negative signs if any). Answers that are inaccurate such as "ground does not accelerate in all three directions simultaneously" were not accepted.

(e) suitable test for e.g., $r \times \text{PGA} = \text{constant}$ M1
applied for at least 2 values
conclusion that data does not support proposal as the values are very different A1

distance r from epicentre / km	56	84	120	220
PGA / m s^{-2}	0.71	0.60	0.50	0.32
r PGA	40 000	50 000	60 000	70 000

Marker's comments:
One common wrong approach was to test the homogeneity of the equation even though the units of k are not known. Some students divided the distance r by 1000 or multiplied it by 100 (instead of multiplying it by 1000) which confounded the marker but were otherwise not penalised (as long as the factor used was consistent). A handful of students did not provide any reason before concluding and some did not state the conclusion.
Students are advised to test for three values instead of two. In cases where the values of k are close, it is not sufficient to simply state that because values of k vary (or are not constant) then the relationship is not valid. There also needs to be a reference to the amount of variation for e.g., percentage difference between the largest and smallest k values to justify the conclusion made. In practice, the k values do not have to be exactly equal for suggested equations to be valid.

(f) (i) resonance B1

Marker's comments:
A few students gave answers such as damping or forced oscillations. Although not wrong, forced oscillations do not cause much larger amplitude of oscillations than that of the driving force. Some students did not understand the command word 'state'. When asked to 'state' or 'name' a phenomenon, there is no need to write excessively and give the definition of the phenomenon.

(ii) any 2 from: B2
natural frequency of vibrations of building
level of damping included in design of building
mass of building
height of building / position of centre of gravity
stiffness of building

Marker's comments:
Good answers made reference to properties of building that affect resonance and resonance response, i.e., natural frequency of vibrations of building and level of damping. Factors that affect natural frequency e.g., mass of building, height of building and stiffness / flexibility of building were accepted. Factors that affect stability of the building for e.g., base area of building was not given credit.
Vague terms such as dimension, size, thickness, width, strength (of foundation), sturdiness, structural integrity, compressibility, design of building were ignored. Students are encouraged to use precise physics terms when answering questions.
Responses that are not related to the properties of building, for e.g., distance between building and epicentre were penalised. Students are again reminded to just write what are expected of them and not go on to elaborate unnecessarily how does each property affect the resonance response.

22 **(a)** It is the product of the force and the perpendicular distance from the line of action of the force to the point. B1

Marker's comments:
Key words such as "from line of action of force to the point" were missing in most answers.
Common mistakes:
- omitting the word "perpendicular" distance
- stating the definition as "perpendicular distance from force to centre of gravity". The pivot point may not necessarily always be the centre of gravity.
- stating the principles of moments as the definition.

(b) **(i)** Taking moments about the front wheels

$1400 \times 9.81 \times 1.4 = 2 \times F \times (1.4 + 1.1)$ M1

$F = 3850$ N A1

Marker's comments:
Common mistakes:
- Not accounting for 2 rear springs
- Forgetting to multiply 1400 by 9.81 to get weight in N
- Using wrong value of 1.1m instead of 2.5m as the perpendicular distance between force on rear spring to pivot point (front wheel)

(ii) Force by spring on truck = force by truck on spring (Newton's 3rd Law)

$F = k\,x$

$3850 = 100000 \times x$ M1

$x = 0.0385$ m A1

Marker's comments:
Students are strongly encouraged to show clear substitution and working to earn both marks.

(iii) Weight of box has no effect on the front springs (taking moment about rear wheels, the weight of the box does not change the force of front spring on the truck)

Force acting on each rear spring due to box = $\dfrac{2500}{2} = 1250$ N

$F = k\,x_{final}$

$1250 + 3850 = 100000 \times x_{final}$ M1

$x_{final} = 0.0510$ m

gain in E_P of each rear spring

$= (\tfrac{1}{2}\,k\,x_{\text{final}}{}^2) - (\tfrac{1}{2}\,k\,x_{\text{initial}}{}^2)$

$= (\tfrac{1}{2} \times 100000 \times 0.0510^2) - (\tfrac{1}{2} \times 100000 \times 0.0385^2)$ M1

$= 55.9$ J A1

Marker's comments:
Common mistakes:
- Overlooking that the weight of the box was given in Newtons already. There is no need to multiply by 9.81
- Overlooking that the weight of the box is shared by 2 rear springs and should be halved when calculating the final extension of each spring
- Mathematical mis-operations such as assuming $\dfrac{1}{2}k(x_f{}^2 - x_i{}^2) = \dfrac{1}{2}k(x_f{}^2 - x_i)^2$, and forgetting to square the extension
- Quoting wrong formula such as $F = \dfrac{1}{2}kx^2$

(c) Resistive force = driving force (moving at constant speed, resultant force = 0)

$$P = Fv$$

$$70000 = F\left(\frac{60 \times 1000}{3600}\right)$$ M1

$$F = 4200 \text{ N}$$ A1

Marker's comments:
Common mistakes:
- Not recognizing that resultant force is zero when the truck is traveling at max speed.
- Overlooking that speed was given in km h^{-1}, hence there is a need to convert to m s^{-1}
- Wrong conversion of km h^{-1} to m s^{-1}

(d) **(i)** Friction f = 0.030 × (1.8 × 10^4 × cos 20°) = 507.4 N C1

$$F_{net} = ma$$

$$T - mg\sin\theta - f = ma$$

$$9000 - \left(1.8 \times 10^4 \times \sin 20°\right) - 0.030 \times 1.8 \times 10^4 \times \cos 20° = \left(\frac{1.8 \times 10^4}{9.81}\right)a$$ M1

$$a = 1.27 \text{ m s}^{-2}$$ A1

Marker's comments:
Some candidates attempted to resolve forces in the vertical and horizontal directions.
This approach is useful if object is revolving in a horizontal circular motion.
In this question, there is no circular motion. The acceleration is along the slope. Hence need to resolve forces along the slope and perpendicular to the slope.
This will give rise to the equation $N = mg\cos\theta$, rather than $mg = N\cos\theta$.
Other common mistakes include not using the value of the weight for this part of the question and not converting weight to mass when using $F_{net} = ma$.
When substitution of values is not shown in the workings, no method marks will be awarded as it is not possible to check if the final wrong answer is due to a calculation error or a substitution error.

(ii) **1.** Immediately after tow cable breaks, the truck continues to move up the slope and friction acts down the slope

$$mg\sin\theta + f = ma$$

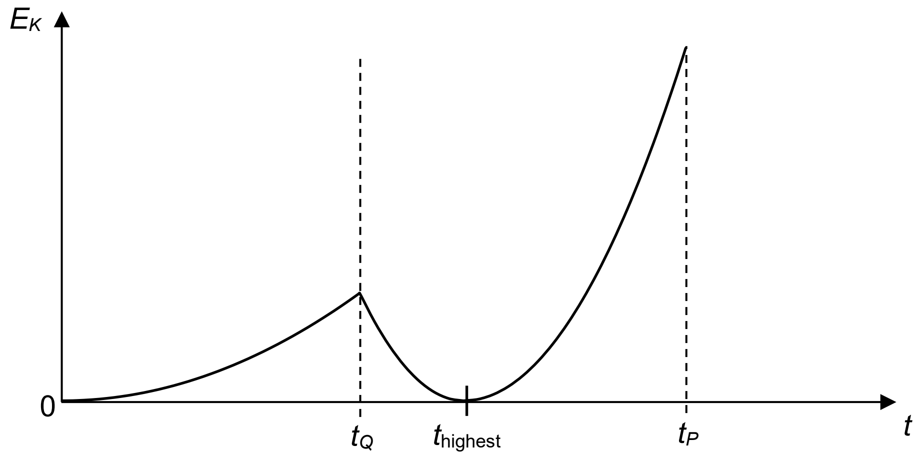
$$\left(1.8 \times 10^4 \times \sin 20°\right) + \left(0.030 \times 1.8 \times 10^4 \times \cos 20°\right) = \left(\frac{1.8 \times 10^4}{9.81}\right)a$$ M1

$$a = 3.63 \text{ m s}^{-2}$$ A1

Note: Acceleration acts down the slope

Marker's comments:
Candidates failed to realise that the truck will still continue to move up the slope even when the upward pulling force is removed.
Hence, the resultant force is down the slope and it is due to the component of the weight and the frictional force (both in the same direction down the slope).

2.



0 to t_Q: <u>curve</u>, increasing value of E_k	B1
t_Q to $t_{highest}$: (curve), decreasing to E_k = 0 for $t_{highest}$	B1
$t_{highest}$ to t_P: (curve) increasing E_k; <u>final value of E_k greater than at t_Q</u>	B1
0 to t_Q is more than t_Q to $t_{highest}$	B1

For information:
After reaching highest point, the truck will move down the slope and friction acts up the slope.

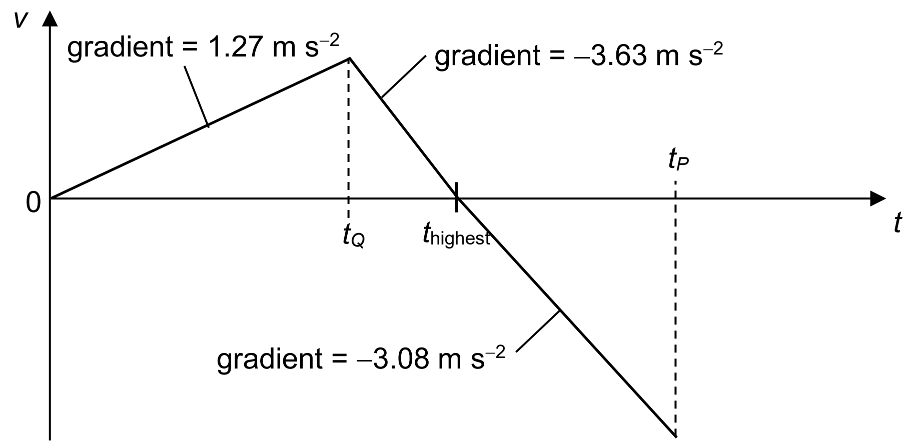
$$mg\sin\theta - f = ma$$

$$\left(1.8\times10^4\times\sin 20°\right)-\left(0.030\times1.8\times10^4\times\cos 20°\right)=\left(\frac{1.8\times10^4}{9.81}\right)a$$

$$a = 3.08 \text{ m s}^{-1}$$

After reaching highest point, acceleration acts down the slope.

To obtain the E_K–t graph, the v–t graph can be sketched first.



Marker's comments:
Most candidates are able to obtain the first slope (from 0 to t_Q).
However, many candidates failed to note that the lorry will still continue to move up the slope when the tension from the cable is removed. This is because the lorry has already acquired a speed up the slope, hence it will slow down to a rest to a higher point.
It will then roll back down the slope due to the component of the weight.
The magnitude of the downward acceleration (from highest point) is greater than that when moving up (from point P to Q), and this causes the final speed to be larger than that at point Q.