Checkpoints Chapter 3 Energy

Question 77

You are given v = 0, u = 20 m/s, t = 4 secs, and you need to find 'x'.

Use $x = \frac{(u+v)}{2}t$

$\therefore x = \frac{(20+0)}{2} \times 4$

= **40 m (ANS)**

Question 78

As soon as the question mentions 'rate' you need to use 'time'. In this case it takes 4 secs to stop.
The rate that thermal energy is being dissipated is the rate at which energy is being used. This is the rate at which KE is being lost.

Rate of losing KE = $\frac{\Delta KE}{\Delta t} = \frac{\frac{1}{2} \times 900 \times 20^2}{4}$

= 45000

= **4.5×10^4 W (ANS)**

Question 79

Energy before collision

$\frac{1}{2}m_1u^2 = \frac{1}{2} \times 500 \times 5^2$

= 6250 J

Energy after the collision

$\frac{1}{2}m_1{v_1}^2 + \frac{1}{2}m_2{v_2}^2 = \frac{1}{2} \times 500 \times 1^2 + \frac{1}{2} \times 3000 \times 1^2$

= 1750 J

Therefore the final kinetic energy of the system is less that the initial kinetic energy of the system.

Question 80

This is a force displacement graph. The area under the graph is the work done, or the energy stored. The equation of the line is F = kx, where k is known as the spring constant.
Note that the units on the vertical axis are 'kN' i.e. kilo-Newton and the horizontal axis have units of milli-metres.

The force constant (spring constant) is given by the gradient of the graph.

$\frac{rise}{run} = \frac{5 \times 10^3}{10 \times 10^{-3}}$

= **5×10^5 N/m (ANS)**

Question 81

This is the area under the graph, make sure that you only calculate the area up to an 8 mm deformation.

$\frac{1}{2} \times 4 \times 10^3 \times 8 \times 10^{-3}$ = **16 J (ANS)**

Question 82

The energy stored in the ball must be equal to the work done on it. This assumes that all the energy is being stored as PE.

$\therefore$ **16 J (ANS)**

Question 83

You now need to assume that all this energy is going to be converted into KE. This is reasonable if you ignore any energy lost to sound and heat, and assume that the ball is perfectly elastic.
So the PE (16 J) = KE

$\frac{1}{2} \times m \times v^2 = 16$

$\frac{1}{2} \times 0.05 \times v^2 = 16$

$\therefore$ **v = 25.3 m/s (ANS)**

Question 84

In an elastic collision energy is conserved.
$\therefore$ the initial KE should equal to final KE.

$KE_i = \frac{1}{2} \times m \times 2^2 + \frac{1}{2} \times m \times 0^2 = 2m$ (J)

$KE_f = \frac{1}{2} \times m \times 0.5^2 + \frac{1}{2} \times m \times 1.5^2 = 1.25m$ (J)

$\therefore$KE is lost, so the collision is not elastic.

Question 85

KE_i = 2m (J) KE_f = 1.25m (J)

ratio = $\frac{2}{1.25}$

= **1.6 (ANS)**

Question 86

The potential energy required to lift herself 7 m
= mgh
= 60 × 10 × 7
= 4200 J.
If she intends getting 90% from the pole, then the pole needs to supply

90% of 4200 = 3780

= **3.8×10^3 J (ANS)**

Question 87

When the mat is compressed to its maximum, all her KE will be stored as PE in the mat.

Her KE = $\frac{1}{2} \times 60 \times 12^2 = 4320$ J.

The PE stored in the mat is the area under the graph.
The gradient of the graph is

$$'k' = \frac{2.5 \times 10^3}{2} = 1.25 \times 10^3 \text{ N/m.}$$

The area under the graph is given by $\frac{1}{2}k(\Delta x)^2$

$$\therefore 4320 = \frac{1}{2} \times 1.25 \times 10^3 \times (\Delta x)^2$$

$\therefore x^2 = 6.912$

$\therefore$ **x = 2.63 m (ANS)**

Question 88

In order to do this question you must find the difference between the initial KE and the final KE. Make sure that you convert the mass to kilograms.

$KE_i = ½ \times 0.45 \times 8^2 = 14.4$
$KE_f = ½ \times 0.45 \times 6^2 = 8.1$
$\Delta KE = KE_f - KE_i$
$\Delta KE = 14.4 – 8.1$
= **6.3 J (ANS)**

Question 89

The energy will have gone into heat, deformation and sound energy. The ball gets warmer, deforms (during the actual collision) and makes a sound when it hits the ground.

Question 90

If a collision is elastic, then the final kinetic energy is equal to the initial kinetic energy.

Question 91

The potential energy stored in the spring is converted into gravitational potential energy.

So $\frac{1}{2} k (\Delta x)^2 = mgh$

$$\therefore \mathbf{h = \frac{k(\Delta x)^2}{2mg}} \text{ **(ANS)**}$$

Question 92

The KE at the top of the hill is given by

$KE = \frac{1}{2} m v^2$
$= \frac{1}{2} \times 600 \times 10^2$
= 30 000 J
= **3.0×10^4J (ANS)**

Question 93

If there is no friction, this means that all the energy gained by the train, due to its loss in PE will be converted into KE. The easiest way to think about this is to consider the total energy at both points. Because there is no friction, the total energy at both points will be the same.
TE (at top) = KE + PE = 300 000 + mgh

= 30 000 + 600 × 10 × 20
= 150 000 J
TE (at bottom) = 150 000J = KE

$\therefore KE = \frac{1}{2} m v^2$
$= \frac{1}{2} \times 6\ 00 \times v^2$
$\therefore v^2 = \frac{150000}{300}$
$\therefore v^2 = 500$
$\therefore$ **v = 22.4 m/s (ANS)**

Question 94

Since its speed was only 18 m/s, then the KE at the bottom was $\frac{1}{2} \times 600 \times 18^2 = 97\ 200$ J.

The difference between the two energies is the amount of energy lost to heat.
$\therefore$ Energy lost = 150 000 – 97 200
= 52 800
= **5.3×10^4 J (ANS)**

Question 95

If the train gained 4MJ of energy, and this is equal to 20% of the energy supplied, then the train used 20 MJ of energy to get to the top of this hill.

20 MJ. (ANS)

Question 96

A power rating of 35 kW means 3.5×10^4 Joules every second.
So in 1 minute (60 sec) it will generate
$3.5 \times 10^4 \times 60 = 2.1 \times 10^6$J
2.1 MJ (ANS)

Question 97

In 10 minutes the petrol will supply 90 MJ of energy.
From the previous question, the car generates 2.1 MJ every minute, so 21 MJ in 10 minutes.

The efficiency is given by the ratio

$$\frac{\text{useful energy}}{\text{energy supplied}} = \frac{21}{90} \times 100\%$$

= 23% (ANS)

Question 98

$$\text{Power} = \frac{\text{work done}}{\text{time taken}}$$

$$= \frac{mgh}{t}$$

$$= \frac{25 \times 9.8 \times 10}{10}$$

= 245 W (ANS)

Question 99

You need to use the formula P = Fv.
This is a variation on the work done formula WD = f × d.
The rate at which work is being done by the force 'F' over a distance 'd' is given by

$$\frac{\text{work done}}{\text{time taken}} = \frac{F \times d}{t}$$

$$= F \times \frac{d}{t}$$

$$= F \times v.$$

To be travelling at a constant speed, the net force must be zero, so Jacinta needs to supply a force of 60N to overcome rolling resistance and the air resistance.

$\therefore P = 60 \times 15$

= 900 W (ANS)

Question 100

Since the power is given by P = F × v. When she doubles the cadence, (effectively, speed) she must double the power output.

Question 101

$$\text{Initial KE} = \tfrac{1}{2}\, m\, 5^2 + \tfrac{1}{2}\, M\, 5^2$$

$$= 12.5\,(M + m)$$

$$\text{Final KE} = \tfrac{1}{2}\, m\, 1.5^2 + \tfrac{1}{2}\, M\, 1.5^2$$

$$= 1.125\,(M + m)$$

The amount lost is
(12.5 - 1.125) (M + m) = 11.375 (M + m)

$$\text{The percentage lost is } \frac{11.375(M+m)}{12.5(M+m)} \times 100\%$$

$$= \frac{11.375}{12.5} \times 100\%$$

= 91% (ANS)

Question 102

The amount of energy that is needed to be absorbed is all the KE of the vaulter. This assumes that at the bottom the vaulter will actually come to rest, ie. will have zero KE. This KE is in the form of PE at the top of the vault, but you need to assume that at a point the vaulter is actually stationary at the top. This is not such a good approximation, because you would expect the pole-vaulter to have a reasonably constant horizontal velocity throughout the vault.

PE = mgh
= 80 × 9.8 × 7.0
= 5488 = **5.5×10^3 J (ANS)**

Question 103

The force constant is the gradient of the Force vs compression graph.

$$\text{Gradient} = \frac{22500}{2.0}$$

= 11250 N/m

= 1.13×10^4 N/m (ANS)

Question 104

The work done under compression is given by Energy stored, which is the area under the force-extension graph. $E = \frac{1}{2} \times k \times (\Delta x)^2$

$$\therefore 6000 = \tfrac{1}{2} \times 11250 \times (\Delta x)^2$$

$\therefore x^2 = 1.067$

$\therefore$ x = 1.03 m (ANS)

Question 105

The brakes are in good condition, so you can assume that the braking force remains constant. The stopping distance has two components, the distance travelled due to the reaction time the distance travelled whilst stopping.
When the speed doubles, the reaction distance will double (assuming same reaction time).
The distance travelled whilst slowing down is governed by WD = Fd = ΔKE
The ΔKE is given by $\Delta\frac{1}{2}mv^2$. As the velocity has increased by a factor of 2, v^2 increases by a factor of 4.
$\therefore \Delta$KE is now 4 times as great.
On the assumption that the force is constant, then the distance will be $\times 4$
Considering both these effects means that the stopping distance increases by a factor greater than 2

Question 106

The power developed is the rate of change of the PE.
The rate of change of PE is given by
$\frac{mgh}{t} = mg\frac{h}{t} = mgv$.

$\therefore$Power = $100 \times 10 \times 5$
= 5000 W.
= 5.0 × 10³ W (ANS)

Question 107 (2010 Q4, 2m, 55%)

To find the kinetic energy, we need to find the velocity, but to find the velocity we need to know the acceleration. To find the acceleration, we use $a = \frac{m_1}{m_1 + m_2}g$ (from the forces notes).
This gives the acceleration to be
$\frac{0.1}{0.1+0.4} \times 10 = 2\ ms^{-2}$.
Using this acceleration in the following
$v^2 = u^2 + 2ax$
gives $v^2 = 0 + 4$
$\therefore v = 2$ m/s.
Both masses have the same velocity so the KE of block 1 is given by
KE = $\frac{1}{2} mv^2$
= $\frac{1}{2} \times 0.4 \times 2^2$
= 0.8 J (ANS)

Question 108 (2010 Q7, 2m, 85%)

The loss in PE is equal to the gain in KE as the car moves from A to B.
At A Total Energy = $PE_A + KE_A$
= mgh + 0
= 1000 × 10 × 20
= 2.0×10^5 J

At B Total Energy = $PE_B + KE_B$
= 0 + $\frac{1}{2} mv^2$
= 2.0×10^5 J
$\therefore \frac{1}{2} mv^2 = 200\ 000$
$\therefore v^2 = 400$
$\therefore$ **v = 20 m/s (ANS)**

Question 109

The loss in gravitational potential energy is given by $\Delta PE = mg\Delta h$
$\therefore \Delta PE/kg = g \times \Delta h$
= 10 × 20
= 200 J/kg (ANS)

Question 110 (2010 Q14, 2m, 35%)

The initial energy stored in the spring is zero.
The initial GPE of the 2 kg mass can be said to be mgh = 2.0 × 10 × 0.4
= 8 J
The final energy stored in the spring is given by $E = \frac{1}{2} kx^2$
Use mg = fx to give k
$\therefore k = \frac{2.0 \times 10}{0.4}$
= 50
$\therefore E = \frac{1}{2} \times 50 \times 0.4^2$
$\therefore$ E = 4 J

Therefore the spring gained 4 J whilst the mass lost 8 J of GPE.
The difference is **4.0 J (ANS)**

Question 111 (2010 Q15, 2m, 45%)

Since the collision is elastic, the final KE will be the same as the initial KE. During the collision energy is stored in the spring, so the KE will decrease.
$\therefore$ **A (ANS)**

Question 112 (2011 Q14, 2m, 70%)

This question is best left until Chapter 4.
Use p = mv
To find v, use ∆mgh = ∆PE

$\therefore 60 \times 10 \times 12.8 = \frac{1}{2} \times 60 \times v^2$

$\therefore v^2 = 256$
$\therefore v = 16\ ms^{-1}$
Substitute into p = mv
$\therefore p = 60 \times 16$
$\therefore$ p = 960 kg ms^{-1} (ANS)

Question 113 (2011 Q15, 2m, 65%)

Use F × ∆t = m × ∆v,
$\therefore F \times 6 = 960$
$\therefore$ F = 160 N (ANS)

Question 114 (2011 Q16, 2m, 55%)

The force acting is mg = 1.0 × 10
= 10 N
The extension is 70 – 40 = 30 cm (0.3 m)
F = k × ∆x
$\therefore 10 = k \times 0.3$
$\therefore$ k = 33.3 Nm^{-1} (ANS)

Question 115 (2011 Q17, 1m, 40%)

The kinetic energy will start from zero, go to a maximum and then return to zero.
$\therefore$ D (ANS)

Question 116 (2011 Q18, 1m, 70%)

The total energy of the system will remain constant.
$\therefore$ C (ANS)

Question 117 (2011 Q19, 1m, 50%)

The gravitational energy will start at a minimum, when L = 80 cm, and increase as L decreases to 60 cm.
$\therefore$ B (ANS)

Question 118 (2011 Q20, 3m, 27%)

The strain energy is minimum (but not zero) at 60 cm. It will increase until 80 cm.

The increase is not linear as, $E = \frac{1}{2}kx^2$

$\therefore$ F (ANS)

Question 119 (2012 Q1a, 1m, 90%)

The block has a KE of 5.4 J.
$\therefore \frac{1}{2}mv^2 = 5.4$
$\therefore v^2 = \frac{2 \times 5.4}{1.2}$
$\therefore$ v = 3 m/s (ANS)

Question 120 (2012 Q1b, 1m, 70%)

Work done by the spring on the block is the energy stored in the spring, which is given to the block as KE.
$\therefore$ 5.4 J (ANS)

Question 121 (2012 Q1c, 2m, 55%)

Energy stored in the spring is given by
$E = \frac{1}{2}k(\Delta x)^2$
$\therefore 5.4 = \frac{1}{2} \times k \times 0.08^2$
(Make sure that you use ∆x in metres)
$\therefore k = \frac{2 \times 5.4}{0.08^2}$
$\therefore k = 1688\ Nm^{-1}$
$\therefore$ k = 1.7 × 10^3 Nm^{-1} (ANS)

Question 122 (2012 Q1d, 2m, 80%)

Impulse given to the block is equal to the change of momentum of the block.
$\therefore F\,\Delta t = m\,\Delta v$
$\therefore I = 1.2 \times (3 - 0)$
$\therefore$ I = 3.6 Ns (ANS)

Question 123 (2013 Q5b, 3m, 43%)

If collision is elastic, the $KE_{final} = KE_{initial}$
$KE_{initial} = \frac{1}{2} \times 2.0 \times 6^2 + \frac{1}{2} \times 4 \times 0^2$
= 36 J
From Q3a, final velocity is 12 ÷ 6 = 2 m/s.
$\therefore KE_{final} = \frac{1}{2} \times 6 \times 2^2$
= 12 J
The collision is inelastic as the final KE is less than the initial KE.

Question 124 (2013 Q6a, 1m, 81%)

From the graph, at Z, the GPE is zero, so the total energy is 20 J
$\therefore$ 20 J (ANS)

Question 125 (2013 Q6b, 2m, 45%)

From the graph, at the point Y, the SPE = 5 J, the GPE = 10 J. Since the TE = 20 J, and remains constant, the KE must be 5 J.

$\therefore \frac{1}{2}mv^2 = 5$ J

$\therefore \frac{1}{2} \times 1 \times v^2 = 5$

$\therefore v^2 = 10$

$\therefore$ **v = 3.16 m/s (ANS)**

Question 126 (2013 Q6c, 3m, 17%)

The students have assumed that the SPE at Q = 0.

This is not correct because the spring has already been extended from its original length of 2.0 m.

$SPE_Q = \frac{1}{2}k(\Delta x)^2$, where $\Delta x = 0.5$.

$\therefore SPE_Q = \frac{1}{2} \times 10 \times 0.5^2$

$= 1.25$ J

$\therefore TE_Q = 10 + 1.25 = 11.25$J

$SPE_P = \frac{1}{2}k(\Delta x)^2$, where $\Delta x = 1.5$.

$\therefore SPE_P = \frac{1}{2} \times 10 \times 1.5^2$

$= 11.25$ J

$\therefore TE_P = 0 + 1.25 = 11.25$J

Question 127 (2014 Q2b, 3m, 20%)

If the four 50 g masses were allowed to hang under their weight, the spring would be extended to 80 cm.

If they are released from 40 cm, then the spring will extend 40 cm past the 80 cm point.

$\therefore$ the extension will be 80 cm.

$\therefore$ **0.8 m (ANS)**

This is on the assumption that the spring has not exceeded its elastic limit.

Question 128 (2014 Q2c, 2m, 35%)

The total energy is the sum of three forms of energy, spring potential energy, gravitational potential energy and Kinetic energy.

Since Jo is not including the kinetic energy, she is wrong, and the varying kinetic energy needs to be added to the other two to get a constant total energy at any point.

Question 129 (2014 Q2d, 4m, 13%)

The maximum speed will occur in the middle of the oscillation.

This is when $\Delta x = 0.4$. This is when a = 0, because $\sum F = 0$.

At the lowest point, when it is momentarily stationary, the KE = 0.

We also take this point to have GPE = 0.

$\text{Total Energy}_{(\text{lowest point})} = KE + GPE + SPE$

$= 0 + 0 + \frac{1}{2} \times 5 \times 0.8^2$

$= 2.5 \times 0.64$

$= 1.6$

At $\Delta x = 0.4$

TE = KE + GPE + SPE

$1.6 = KE + 0.2 \times 10 \times 0.4 + \frac{1}{2} \times 5 \times 0.4^2$

$\therefore KE = 1.6 - (0.8 - 0.4)$

$\therefore KE = 0.4$

$\therefore \frac{1}{2} \times 0.2 \times v^2 = 0.4$

$\therefore 0.1 \times v^2 = 0.4$

$\therefore v^2 = 4$

$\therefore$ **v = 2 m/s (ANS)**
