Solution 1

(18 marks)

(a) Estimate the velocity of the of the Chelyabinsk meteor. Give your answer to an appropriate number of significant figures. Show **all** workings. (4 marks)

Description	Marks
$E_k = 0.5\ m\ v^2$ $1.8 \times 10^{15}\ J = 0.5\ (12 \times 10^6) \times v^2$	1–2
$v^2 = 1.8 \times 10^{15} / 6 \times 10^6$ $v^2 = 3 \times 10^8$ $v = 17\ 320\ m\ s^{-1}$	1
$v = 1.7 \times 10^4\ m\ s^{-1}$ (<3 significant figures)	1
Total	**4**

(b) (i) The width, in Earth diameters, of the impact window is (circle your answer): (1 mark)

Description	Marks
One or more than one	1
Total	**1**

(ii) Calculate the length of time that an 'impact window' has for any collision of an object with the Earth, to occur. Ignore the size of the object. Show **all** workings. (3 marks)

Description	Marks
Velocity of Earth = 30.0 km s^{-1} = 3×10^4 m s^{-1}	1
Mean radius of the Earth (R_E) = 6.38×10^6 m (from data sheet) Mean diameter of the Earth = $2 \times 6.38 \times 10^6$ m = 1.276×10^7 m	1
The Earth will take 1.276×10^7 m / 3×10^4 m s^{-1} = 425 seconds to move out of the way of any incoming object.	1
Total	**3**

(c) The NEO Apophis is on an orbit that will bring it close to the Earth in 2036. it has an assumed mass of 4.00×10^{10} kg and diameter of 325 m.

(i) Suppose that a spacecraft arrives and begins interacting with Apophis in 2016. Determine the change in velocity required to avoid a collision with the Earth. (3 marks)

Description	Marks
$t = 2036 - 2016 = 20$	1
Change in velocity = 3.5×10^{-2} / t $\Delta v = 3.5 \times 10^{-2} / 20$	1
$\Delta v = 1.75 \times 10^{-3}\ m\ s^{-1}$	1
Total	**3**

(d) When using a gravity tractor, explain why 'the earliest of interventions' is desirable if an asteroid is to be deflected sufficiently to avoid collision with the Earth. (3 marks)

Description	Marks
Early intervention gives us more time to cause the change in velocity (acceleration)	1
From the equation $\Delta v = 3.5 \times 10^{-2} / t$ we can see that a smaller Δv is required.	1
This allows a smaller force to be exerted (and a less massive spacecraft is required)	1
Total	**3**

Chapter 9.1 Solution 2

(13 marks)

Jake is working on the top of a building which is 21.5 m above the ground. He drops both a nut and bolt.

(a) The nut has a mass of 5.55×10^{-2} kg and the bolt has a mass of 2.51×10^{-1} kg. Which of the two will reach the ground first? Explain your reasoning. (2 marks)

Description	Marks
Reasoning only e.g. one will be more resistant to moving through the air, so will fall slower (0 if only one goes slower without reasoning); or both items have negligible wind resistance, so both items will fall at the same rate because both accelerate at 'g'.	1–2
Total	**2**

(b) Assuming the bolt falls straight to the ground and there is no wind resistance, calculate

(i) the time it takes for the bolt to reach the ground; and (3 marks)

Description	Marks
$S = ut+1/2at^2$; $21.5 = 0+4.9\ t^2$	1
$t^2 = 4.387755...$	1
$t = 2.09$ s	1
Total	**3**

(ii) the final velocity of the bolt as it hits the ground. (3 marks)

Description		Marks
$v^2 = u^2 + 2as = 0^2 + 2 \times 9.8 \times 21.8$	or $v = u + gt$	1
$v^2 = 427.28$	$v = 0 + 9.8 \times 2.09$	1
$v = 20.5$ m s^{-1}	$v = 20.5$ m s^{-1}	1
Total		**3**

(c) The ground consists of soft soil and the bolt enters the soil and stops 2.25×10^{-2} m below the surface. Calculate the magnitude of the force that the ground has exerted on the bolt. If you were unable to determine an impact velocity in Part (b), use the value 25.0 m s^{-1}. (5 marks)

Description		Marks
$v^2 = u^2 + 2as$ $a = (v^2 - u^2)/2as$	OR $W = \frac{1}{2}mv^2$	1
$a = (0^2 - 20.5^2)/(2 \times 2.25 \times 10^{-2})$	$F = \frac{W}{s}$	1
$= -9339$ m s^{-2}	$F = \frac{1/2mv^2}{s}$	1
$F = ma = 2.51 \times 10^{-1} \times 9339$	$= \frac{1/2 \times 0.25 \times 20.5^2}{0.0225}$	1
$= 2.34 \times 10^3$ N (3.49×10^3 N if value of v = 25 used)		1
Total		**5**

Solution 3

(4 marks)

A 0.250 kg ball bounces on a hard surface after being dropped from a height. The ball retains 80% of its kinetic energy in the collision and rises to a maximum height of 0.870 m above the ground. Calculate its potential energy at A.

Description	Marks
At B: $E_P = mgh = 0.25 \times 9.8 \times 0.870$	1
$= 2.13$ J	1
$Ep_A \times 0.8 = 2.13$ J	1
$Ep_A = 2.66$ J	1
Total	**4**