(c) In space, an object of mass 28 kg travelling with velocity 88 m s^{-1} collides with a second object of mass 17 kg travelling in the same direction with a velocity of 53 m s^{-1}. The collision is inelastic.

After the collision, the 28 kg object continues to move in the original direction but with a velocity of 67 m s^{-1}.

Calculate the loss in kinetic energy in the collision.

loss in kinetic energy = ……………………………J [3]

(d) In **(c)**, the force exerted by the 28 kg object on the 17 kg object will not have a constant value during the time they are in contact with one another.

Sketch two graphs on the axes shown in Fig. 2.1 to show how the force varies with time if the collision in **(c)** is between

(i) two steel objects (label this line S),

(ii) two rubber objects (label this line R).

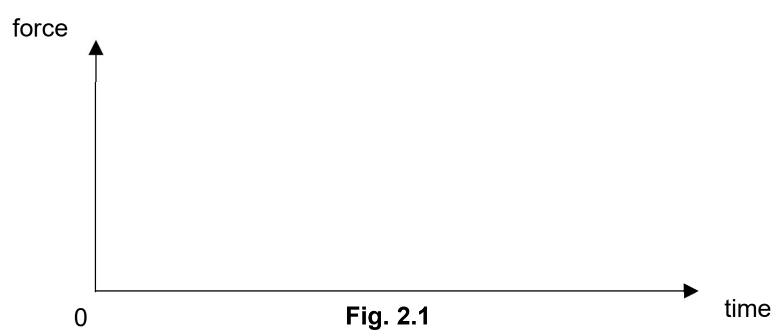
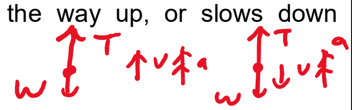
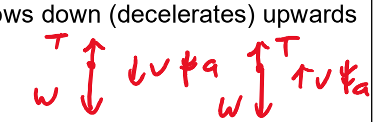


Fig. 2.1

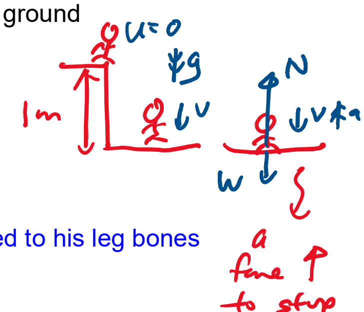
[2]

TUTORIAL 3: DYNAMICS SOLUTIONS

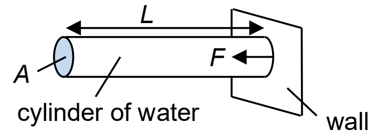
Level 1 Solutions

1 (a)	(Newton's First Law states that every body continues in a state of rest or uniform motion in a straight line unless a net external force acts on it.) Since the parachutist is falling with a steady speed, the net force acting on him is zero.	[1]
(b)	Since the net force acting on him is zero, total upward force (air resistance) is equal to total downward force (his total weight). Hence the air resistance acting on him and the parachute is equal in magnitude to his total weight = mg = (60.0)(9.81) = 5.9×10^2 N	[1]
3	The general eqn of motion is either Case 1: if lift speeds up (i.e. accelerates) on the way up, or slows down downwards (F_{net} and a are both upwards), then: ↑: T – mg = ma  Case 2: if lift speeds up on the way down, or slows down (decelerates) upwards (F_{net} and a are both downwards), then: ↓: mg – T = ma  Case 3: for constant speed in either direction, T = mg since a = 0. a) 7710N b) 6530N c) 8890N d) 8890N e) 6530N	[1] [1]
12	Change in momentum = area under F-t graph = 4 + ½ (2 + 6) (4) = 20 kg m s^{-1}	[1] [1]
15	Ans: C Total momentum of system before collision = (6.0)(5.0) – (10)(3.0) = 30 Ns – 30 Ns = 0 Ns By Principle of conservation of momentum, total final momentum is thus 0 (since no net force acts on the system). Hence **both** trolleys will be brought to rest **during** collision. By Newton's 2nd Law, net force on each trolley is the rate of change of linear momentum. i.e. $F = \dfrac{30}{0.20}$ = 150 N.	

Level 2 Solutions

2 (a)	A downward force of magnitude 4 N is exerted on the book by the Earth. {meaning of 'weight'}	
(b)	An upward force of magnitude 4 N is exerted on the book by the hand. {deduced fr 'equilibrium of book' }	
(c)	No, { (a) is 'Earth pulls book', its reaction force shd be 'book pulls Earth', NOT 'hand pushes book'}	
(d)	The reaction (force) to the force in part (a) is a force of magnitude 4 N, exerted on the Earth by the book. Its direction is upward. {Topic 7: Newton's Law of Gravitation}	
(e)	The reaction to the force in part (b) is a force of magnitude 4 N, exerted on the hand/palm by the book. Its direction is downward. **{a contact force}**	
(f)	(a) is the gravitational force that the Earth pulls on the book while (b) is the electromagnetic force that the hand pushes on the book. These 2 cannot be an action-reaction pair because (Any 1 reason): • the 2 forces are not of the same type/nature, or, • the 2 forces act on the same body (book). **{The 2 forces of an action-reaction pair always act on 2 different bodies- deduced fr 3rd Law}**	
4	Let v = velocity just before man's impact with the ground Using $v^2 = u^2 + 2as$ *{assume u = 0}* $v = \sqrt{2as} = \sqrt{2(9.81)(1.00)} = 4.43$ m s^{-1} $F_{net} = \frac{d(mv)}{dt} = \frac{70.0\,(0 - 4.43)}{0.1} = -3100$ N. ↑: $N - mg$ = 3100 where N is the force transmitted to his leg bones $N = 3100 + (70 \times 9.81) = 3800$ N Therefore, the force transmitted to his leg bones is 3800 N. Contrast Q5 (b)  	 [1] [1] [1]
5 (a)	$v^2 = u^2 + 2as$ $0 = 35^2 + 2a(0.60)$ $a = -1020$ m s^{-2} The deceleration of the dummy is 1020 m s^{-2}	[1] [1]
5(b)	F_{net} = m a = 55 (–1020) = – 56.1 kN Magnitude of the force on the dummy, X, due to the seat belt is 56.1 kN Why not X **– mg** = ma like Q4? Ans: the acceleration is in the horizontal direction. mg is a vertical force , hence has no component in the direction of the motion.	[1]

6



Consider a cylinder of length L and cross-sectional area A collides with the wall in time t.

Apply, $F_{net} = m\,a$ *in horiz dir,* *m: mass of water*

$= \rho\,(\text{volume})\,\dfrac{(0 - v)}{t}$ { 0 because …….. }

$= \rho\,A\,L\,\dfrac{(-v)}{t}$

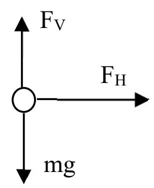
$= -\rho\,A\,\dfrac{L}{t}\,v$

$= -\rho\,A\,v^2$ { - ve sign is expected as …….. }

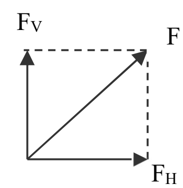
$\therefore$ The force exerted on the wall is $\rho\,A\,v^2$. Ans: B

7

External forces on Kimi:



Resolving the "total force by seat" on Kimi (F):



where F_V = Normal reaction force on Kimi by seat, (y-component of F)

F_H = Horizontal force on Kimi by seat (x-component of F)

Vertically, since Kimi is in vertical equilibrium,

$F_V = mg = 74g = 725.94$ N [1]

Horizontally however, there is acceleration, a_H

where a_H can be shown to be = 11.11 m s^{-2} {Use $v^2 = u^2 + 2as$, & convert km h^{-1} to m s^{-1}}

In the horizontal direction, $F_{net} = ma_H$

Hence $F_H = (74)(11.11) = 822.14$ N [1]

Total Force, F, exerted by car seat on Kimi

$= \sqrt{F_V^{\,2} + F_H^{\,2}}$

$= \sqrt{725.94^2 + 822.14^2}$ [1]

= <u>1100 N</u>

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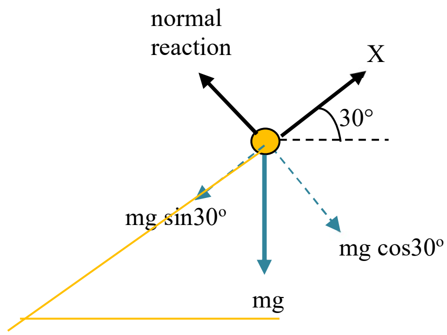

(a) Applying $F_{net} = ma$ (taking upslope as +ve),
↗ : **X – mg sin30°** = ma
X = mg sin30° + ma = <u>91.6 N</u>

(b) Applying $F_{net} = ma$ (taking downslope as +ve),
↙ : **mg sin30° – X** = ma
X = mg sin30° – ma = <u>55.6 N</u>

(b) Applying $F_{net} = ma$ (taking downslope as +ve),
↙ : mg sin30° = ma
a = g sin30° = <u>4.91 m s⁻²</u> (downslope)
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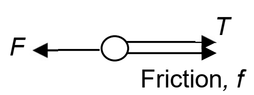
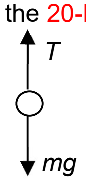
Two blocks are connected → Same acceleration experienced by both blocks.

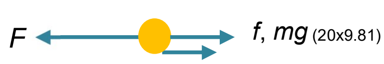
Consider the 25-kg mass alone,


$F_{net} = ma$
←: $F - T -$ friction $= ma$ {for 25 kg mass}
$F = 25a + T + 49$ --- (1)

Consider the 20-kg mass alone,


$F_{net} = ma$
↑: $T - mg = ma$ {for 20 kg mass}
$T = 20g + 20a$ --- (2)

Solving,
T = <u>208 N</u>, F = <u>272 N</u>

Alternatively, by considering both blocks as ONE system,


Note: ***Tension is now an internal force***

Applying $F_{net} = ma$ on this system,
←: $F - f - (20 \times 9.81) = (20 + 25)(0.6)$
Hence F = <u>272 N</u>
</td><td>[1]

[2]</td></tr>
<tr><td>10</td><td>Both blocks experience the same acceleration since they are "connected".</td><td></td></tr>
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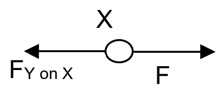
For the system of both blocks:

→:

$$F = m_{total}a$$
$$F = 3ma \quad \text{\{ Contact force between them: an internal force\}}$$
$$a = (\frac{F}{3m})$$

Considering just block X:



{Contact force between them, **$F_{Y\ on\ X}$ is now an external force}**

→ :

$$F - F_{YonX} = m_X a$$
$$F_{YonX} = F - m(\frac{F}{3m})$$
$$= \frac{2}{3}F$$

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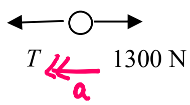
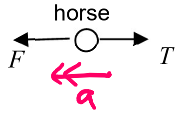


←: $T - 1300 = m_{wagon}\, a$ where $a = (v-u)/t = 6/5 = 1.2$ m s^{-2}

$T = 900\ (1.2) + 1300$

$= \underline{2380\ \text{N}}$



←: $F - T = m_{horse}\, a$,

where F is the (reaction force) that ground pushes on horse when horse pushes on ground.

$F = T + 350\ (1.2)$

$= 2380 + 420 = \underline{2800\ \text{N}}$

{Tension is an external force for wagon and horse considered separately}

Alt Method to det F:

Consider wagon + horse as the system:

F – friction = (m_{wagon} + m_{horse}) a {Here tension is an internal force}

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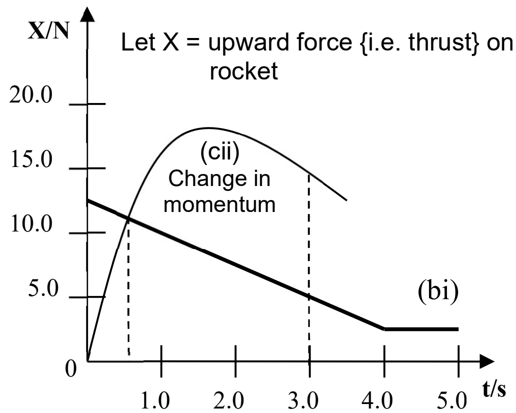
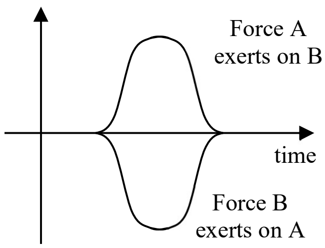
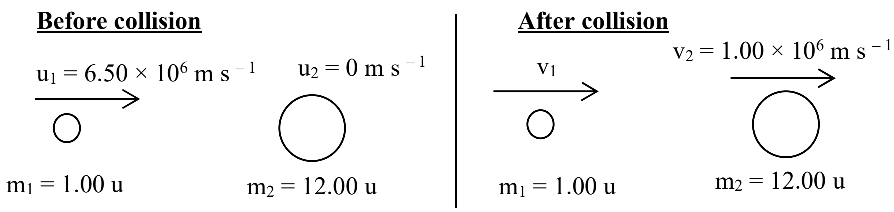
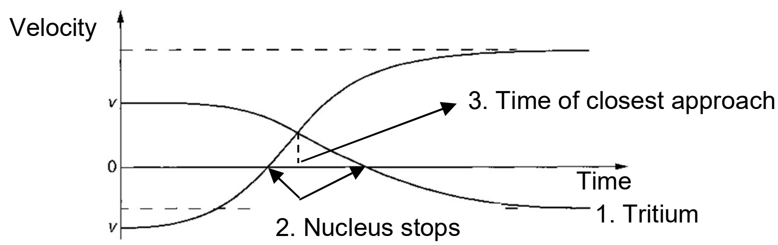
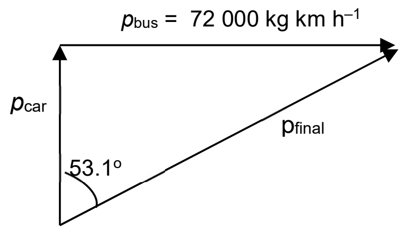
13 (a)	Given: $m_{initial}$ = 1.3 kg; m_{final} = 0.38 kg; $\frac{dm}{dt}$ = 0.23 kg s^{-1}; g = 9.8 N kg^{-1} (i) $W_{initial} = m_{initial} \times g$ = 12.74 N = <u>12.7N</u> (ii) $W_{final} = m_{final} \times g$ = 3.724 N = <u>3.72 N</u> (iii) $\Delta m = m_{final} - m_{initial}$ = 0.92 kg Time taken = $\frac{\Delta m}{\text{rate of change of mass}}$ = 4 s	[1] [1] [1]
(b)	 (i) At *t* = 0 , total wt *W* = 12.74 N. At *t* = 4 s, W = 3.72 N. From t = 0 to t = 4 s, graph is a <u>straight line</u> {since dm/dt = constant} with <u>negative slope</u>. For *t* > 4s, W = 3.72 N {constant, after all fuel burnt up } (ii) Lift-off occurs when upward force X > Tot weight. Hence from graph, time delay ≈ 0.5 s {where the 2 graphs intersect}	[1] [1] [1]
(c)	(i) F× t = Δp (ii) Area under net F-t graph, where net F = X – Total Wt = area between 2 graphs, lying between the pt of intersection & t = 3 s.	[1] [2]
(d)	Gravitational potential energy gained by the rocket, sound energy (noise), light energy. [any two]	[2]

14 (a)	(i) Linear momentum of a body : product of its mass and its (linear) velocity (ii) Change in momentum = force acting on object × time the force acts	[1] [1]
(b)	(i) One is the "mirror image" of the other {about the horiz axis}  This is typical variation of an "Impulsive Force" with time. The duration is typically very short. (ii) According to Newton's 3rd Law, the force which A exerts on B is at all times equal and opposite to the force which B exerts on A.{No time delay} Hence the 2 graphs must be symmetrical about the time axis. (iii) • When a variable force acts on an object, the change in momentum of the object is given by the area under the force-time graph. • Since the area under Force A – t graph is equal to the area under Force B – t graph, and opposite in sign, • any gain in momentum of one object is equal to the loss in momentum of the other. Hence total momentum of the 2 bodies – an isolated system- remains constant - which is the principle of conservation of momentum.	[1] [1] [1] [1] [1]
(c)	(i) Using $\Delta mv = F \times t$ Δv (car) = $\dfrac{F \times t}{m_c}$ = **15 m s^{-1}** , **an increase {since truck hits back of car}** (ii) Δv (truck) = $\dfrac{F \times t}{m_t}$ = **1.5 ms^{-1}** **a decrease**	[1] [2] [2]
(d)	It is unrealistic that the force during impact is constant.	[1]
(e)	Seat belts and air bags provide a backward force to bring person to a stop. In addition, air bags being compressible will <u>increase the time for which the change in momentum occurs</u>, thus <u>reducing the decelerating force acting on him</u>, Since $F \propto \dfrac{1}{time}$. {The air bag also helps to reduce the pressure on the driver as a result of having a larger area over which the force acts.}	[1] [1]
16	$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ $0 = (1.2)(5.0) + 70v_2$ { LHS is tot momentum before throw } $v_2 = -0.08571$ m s^{-1} {The negative sign indicates that velocity v_2 of the man is in opposite direction to that of the book's velocity of (+) 5.0 m s^{-1}} Time taken to reach the south shore = 5 / 0.08571 = <u>58.3 s</u>	[1] [1]

17 (a)	(i) $p = mv = 0.2 \times 8 = \underline{1.6 \text{ kg m s}^{-1}}$ (ii) Momentum of the plasticine is completely transferred to the ground (the Earth). K.E of the plasticine is dissipated as <u>internal, thermal and sound energies.</u>	[1] [2]
(b)	(i)  Using $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ & taking velocity to right as +ve: $v_1 = -5.5 \times 10^6$ m s^{-1} $= \underline{5.5 \times 10^6 \text{ m s}^{-1}}$ (to the left) (ii) Total KE before collision: $\frac{1}{2} m_1u_1^2 + \frac{1}{2} m_2u_2^2 = (21.125 \times 10^{12}$ u) Total KE after collision: $\frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2 = (21.125 \times 10^{12}$ u) Hence total <u>KE is conserved</u> during the collision.	[1] [1] [1] [1]
(c)	*Hint: "Explain how the law of conservation of momentum applies" implies that there should be no net external forces acting for PCM to be applicable.* Assume there is <u>no net force</u> acting on the system of two magnets . Total momentum before letting go is <u>zero.</u> On letting go, the 2 magnets will move off in <u>opposite directions with the same speed</u> {assume identical masses} because the total momentum after the interaction must still be zero. Hence the law of conservation of momentum applies.	[1] [1]
18 (a)	(i) Since the collision is elastic, the total KE of the 2 molecules is conserved, or relative velocity of approach equals to the relative velocity of separation. (ii) The velocities of both particles after the collision are collinear (occur along the same straight line), and also collinear with their velocities before their collision.	[1] [1]
(b)	(i) $v_2 - v_1 = u_1 - u_2$ $= 1.88 \times 10^3 - (-405)$ $= 2285$ m s^{-1} $= \underline{2290 \text{ m s}^{-1}}$ (ii) $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ (2.00 u) ($+1.88 \times 10^3$) + (32.0 u) (-405) = (2.00 u) v_1 + (32.0 u) v_2 $-9200 = 2.00\, v_1 + 32\, v_2$ ---- (1) $v_2 - v_1 = 2285$ ----- (2) { from (i) } Solving , $v_1 = -2421.2 = \underline{-2420 \text{ m s}^{-1}}$ $v_2 = -2421.2 + 2285 = \underline{-136 \text{ m s}^{-1}}$ Both molecules travel <u>to the left</u> after the collision	[1] [1] [1] [1]

19	There is no net external forces acting on the system of the stone and Earth (assuming there is no air resistance and external gravitational forces on them etc). Total momentum before letting go is zero. During the stone's fall, Earth moves towards stone with a momentum of equal magnitude (as that of the stone), but in opposite direction. Hence the total momentum must still be zero and the law of conservation of momentum applies. **Note:** Examiner's report did not specify if the type of external force(s) (as stated in brackets above) is necessary in the answer. **Common Mistake**: Many would tend to discuss the application of the PCM to the stone alone	[1] [1] [1]
20 (a)	Applying the principle of conservation of momentum, $3\,m\,v + (-2\,m\,v) = (3\,m + 2\,m)\,V$ $V = \mathbf{v / 5}$	[1] [1]
(bi)		[3]
(bii)	Applying the conservation of momentum, $3\,m\,v + 2\,m\,(-v) = 3\,m\,V_1 + 2\,m\,V_2$ Equating their relative speed of approach and separation, $v - (-v) = V_2 - V_1$ Solving the equations above simultaneously, Final speed of deuterium = **1.4 v** Final speed of tritium = **0.6 v**	[1] [1] [1] [1]
21	(i) Using F = ma = 750 x 4.8 = 3600 N (ii) Using $v^2 = u^2 + 2as$, $s = (v^2 - u^2)/ 2a$, (where a = [Ans in (i)]/m) = 65.1 m {Or, Work done by constant resistive force on car = Loss in KE i.e. 3600 N x distance = ½ mu^2 – zero } (iii) On the tyres: direction of horizontal force is opposite in direction to car's motion {since it's decelerating}. On the road: direction of force is the same as the direction of car since the forces are an action-reaction pair.	[1] [1] [1] [1] [1]
(b)	(i) Net decelerating force is reduced since component of weight acts in direction of motion. (ii) Net decelerating force = 3600 N – 750 g sin10° = 2322 N Thus deceleration = 2322 N ÷ 750 kg = 3.1 m s^{-2}	[1] [1] [1]

22 (a)	Momentum of bus = 2000 (36) = 72 000 kg km h^{-1} due East "Sliding freely on an oil patch implies that there is no net force and hence the vector sum of the momenta of the 2 vehicles before collision must equal to the final momentum of the entangled vehicles. Thus  tan 53.1 = 72000 / p_{car} p_{car} = 54059.13 kg km h^{-1} $p_{car} = m_{car}\ u_{car}$ u_{car} = 54059.13 / 750 = 72.1 km h^{-1} **Yes**, the car exceeded the speed limit of 70 km h^{-1}	[1] [1] [1]
(b)	sin 53.1° = 72000 / p_{final} p_{final} = 72000/ sin 53.1° $p_{final} = m_{total}\ v_f$ v_f = (72000/ sin 53.1°) / (2000 + 750) = **32.7 km h^{-1}**	[1] [1]

- End of tutorial solutions -