<table>
<tr><th colspan="3">Question</th><th>Marking details</th><th>Marks Available</th></tr>
<tr><td>1</td><td>(a)</td><td></td><td>Rate of change [accept: increase] of velocity [not speed].
accept: $\frac{v-u}{t}$ or $\frac{\Delta v}{t}$ or $\frac{\Delta v}{\Delta t}$ (not $\frac{v}{t}$)</td><td>1</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>Both ΣF calculated correctly (20 N and 4 N) (1)
Use of $a = \frac{\Sigma F}{m}$ (1)
Accelerations = 10 m s^{-2} and 2 m s^{-2} (e.c.f.) (1)
[Accept answers based upon calculating resultant acceleration]</td><td>3</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Diagram with forces shown in opposition (1) and horizontal (1)
[B.o.d. on plan-view forces unless clearly incorrect]</td><td>2</td></tr>
<tr><td></td><td>(c)</td><td></td><td><table><tr><th>Statement</th><th>Must be true</th><th>Could be true</th><th>Cannot be true</th></tr><tr><td>xxxxxxxxxx</td><td></td><td></td><td>✓</td></tr><tr><td>xxxxxxxxx</td><td></td><td>✓</td><td></td></tr><tr><td>xxxxxxxx</td><td></td><td>✓</td><td></td></tr><tr><td>xxxxxxxxx</td><td></td><td></td><td>✓</td></tr></table></td><td>4</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[10]</td></tr>
<tr><td>2.</td><td>(a)</td><td>(i)</td><td>Δx / l – units cancel [ratio of extension to original length not enough – reference must be made to units]</td><td>1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Limit of proportionality labelled at (1.6, 1.1)</td><td>1</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>Strain is permanent / specimen no longer regains original shape (1)
Region of graph above limit of proportionality circled. (1)</td><td>2</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>E = gradient of linear portion of graph [or equiv. by impl.] (1)
Substitution, e.g. $\frac{1.0\times10^{8}}{1.4\times10^{-3}}$(l) = 7.1×10^{10} Pa [or N m^{-2}] (1)
[Accept 7.0×10^{10} Pa]</td><td>3</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>σ(from graph) = 0.7×10^{8} Pa (1)
[Or stress calculated from (b)(i) e.c.f.]
$F = \sigma A$(1) = $0.7 \times 10^{8} \times 5.0 \times 10^{-7}$ e.c.f. from σ.
F = 35 N (1) [range 35 – 36 N]
[Accept $E = \frac{\text{stress}}{\text{strain}}$ or $E = \frac{Fl}{\sigma x}$ for 1 mark]</td><td>3</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[10]</td></tr>
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Question			Marking details	Marks Available
5	*(a)*	(i)	Units of LHS = N = kg m s^{-2} Units of RHS = (kg m^{-3} . m^2) (+ manip.)(1) × (m^2 s^{-2}) (1)	3
		(ii)	$v^2 = \frac{2.8\times10^4}{1.2\times15\times4.2}$ (1) [or by impl.] v = 19.2 m s^{-1} (1)	2
	(b)	(i)	Centre of gravity	1
		(ii)	Bottom of near-side wheel labelled as 'pivot'	1
		(iii)	F_{wind} × 2.1 (1) = 1.0 × 10^5 × 1.4 (1) [or by impl.] ∴ F_{wind} = 67 kN (1) [accept 66 kN ✓b.o.d.]	3
				[10]

Question			Marking details	Marks Available
7.	*(a)*	(i)	Ball is seen to stay directly in front of the passenger [**or** clearly implied by 2nd statement]. (1) No [horizontal] forces on ball [so horizontal speed is constant, with the same value as the train] (1)	2
		(ii)	Observer sees the ball moving in the same direction as the train [with the same speed]. [Accept: "moving with the train."]	1
	(b)		Passenger sees the ball accelerating [or moving] 'backwards' [or towards the rear of the train]. Observer sees the ball moving in the same direction as the train with decreasing speed. (1) Net [horizontal] force on ball [due to air resistance] towards the back of the train. (1)	3
	(c)	(i)	The graph is symmetrical / up time = down time.	1
		(ii)	[Mean] velocity = $\frac{\text{[Total] displacement}}{\text{time}}$ - equation (1) ["rate of change of displacement" not enough] [Total] displacement = 0 (1) Use of "total" [or equiv.] appropriately once (1)	3
		(iii)	x = 11 m ; t = 1.5 s (1) $x = \frac{u+v}{2}t$, **or** $11 = \frac{u}{2} \times 1.5$ (1) **or** $v^2 = u^2 + 2ax$ **or** $0 = u^2 + 2 \times 9.81 \times 11$ (1) **or** $x = ut + \frac{1}{2}at^2$, **or** $11 = 1.5u + \frac{1}{2} 9.81 \times 1.5^2$ (1) $\therefore u$ = 14.7 m s^{-1} (1)	3
		(iv)	**Graph**: v axis – 20 to + 20 e.c.f. (1) Intercept on v axis 14.7 m s^{-1} e.c.f. (1) Straight line graph (1) to intercept time axis of 1.5 s (1) Graph continued straight beyond 1.5 s to negative values of v (1)	5
			Area under graph attempted [→ 1.5 s] (1) Height = 11 m (e.c.f.) (1)	2
				[20]

RADIATION AND STARS

a) Calculate the radius of a star whose 650nm light creates an intensity of 20W per square metre at a distance of 2 parsecs. [7]
   Ans: use I=P/A to find P=9.6x10^35W (2). Then use Wien's Law to find T = 4461.5K (2). Then plug these into Stefans Law (2) to find r = 5.83e13 (1)
b) Define a blackbody and give an example. [3]
   Something which absorbs (1) and radiates (1) at all wavelengths (1)
c) What is multi-wavelength astronomy and what can it tell us? [3]
   We can gain information at different wavelengths of em spectrum (1) cosmic microwave background - early universe (1), aspects of galaxies and supernovae, aspects of the sun etc (1)
d) What information can we gather from a spectrum from a distance star, and how do we accomplish this? [5]
   identify absorption/emission spectra to find which elements are present between star and ourselves (1) find peak wavelength and hence temperature of the star (2) comparing to lab measurements, starlight is either red or blueshifted (1) either moving towards or away (1)

PARTICLES & NUCLEAR STRUCTURE

a) What is a hadron? [2]
   A composite particle of quarks and/or antiquarks (1) can be baryons or mesons (1)
b) What is a baryon? [2]
   A composite particle of exactly 3 quarks (1) or 3 antiquarks (1)
c) How many generations of fundamental particles are there, and by what means did we discover them? [2]
   3 generations (1) discovered through the use of particle accelerators (1)
d) Define each of the known interactions: gravitational, weak, electromagnetic and strong. State what each is experienced by, their range any other information you can provide. [12]
   Gravitational range infinite and very weak
   Weak force, range very short, felt by all particles, leptons and quarks
   EM force, range infinite, felt by all charged particles
   Strong force, range short, felt by all quarks (all hadrons ie. All baryons and mesons)